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PENSOFT

Survey of ants (Hymenoptera, Formicidae) in the city of Providence (Rhode Island, United States) and a new northern-most record for *Brachyponera chinensis* (Emery, 1895)

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Abstract. We surveyed ants in Providence, Rhode Island, from 2015 to 2019. Methods including repeated pitfall trap sampling and manual searching were used to collect ants at Providence College and a rapid biological assessment was conducted at Roger Williams Park. A total of 36 species were identified based on morphology, including the first observations of a colony of Needle Ants (*Brachyponera chinensis* Emery, 1895) in New England. Twenty-six species identified were new county records and seven species were new state records, representing a substantial update to the list of known ant species in Rhode Island, currently totaling 41 species in Providence and 69 species from six subfamilies across the state. These results are comparable with similarly scaled surveys conducted at parks and cities across the world, and they also offer a reminder that while urbanization can be associated with reductions in habitat availability for some fauna, cities can be accessible and ecologically important locations for exploring myrmecological biodiversity.

Keywords. BioBlitz, biodiversity, cities, Needle Ants, survey, urban ecology

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Introduction

Ants are among the most ecologically successful animals on the planet. Their social nature allows them to operate as complex adaptive systems, responding to and structuring ecological communities, providing critical ecosystem services, and with the potential to impact economic stability and agricultural productivity (Davidson 1997; Del Toro et al. 2012; Evans et al. 2011; King et al. 2013; McGlynn 1999; Ward 2006). Biodiversity data and the species distributions of many ant taxa have been widely studied, making them a key indicator species for identifying disturbed habitats and effects of climate change (Dunn et al. 2007; Jenkins et al. 2011). While the diversity of ants in many places has been relatively well sampled, this was not the case for Rhode Island, a state at the southern coastal boundary of New England where it may have a higher likelihood for biotic introductions and potential colonizations by introduced species.

Rhode Island's geological history was strongly influenced by glaciation events 14,000 years ago and its diverse habitats now include maritime coastal and wetland systems, freshwater wetlands, forests, peatlands, lakes and ponds, salt marshes, pine barrens, farmland, islands, and urban and suburban residential and industrial areas (RIDEM 2015). Although it is a small state, it has the highest ratio of coastline to land area of any state, and it is the second most densely populated state in the country. The capital city, Providence, is a gateway to Narragansett Bay, providing shipping access for the state's primary export (scrap metal) and it is also home to many universities and College campuses.

In 1906, William Morton Wheeler documented 84 species of ants across New England but only 12 species of ants in Rhode Island (Wheeler 1906). More than a century later, Aaron Ellison and colleagues exhaustively compiled 28,205 ant specimen records from across New England and published a guide to the 132 described species of ants in this region, including 47 in Rhode Island and 13 from Providence (Ellison et al. 2012). A recent targeted survey of a small parcel near the southern-most extremity of the state added nine new species to the list from Rhode Island (Ellison and Farnsworth 2014). Since the most under-surveyed part of the state remained Providence County, we focused on surveying two urban sites in the city of Providence (Fig. 1A) which were accessible to students engaged in this project on campus at Providence College (PC) and at Roger Williams Park (RWP).

Study Area

Providence College was founded in Providence in 1917 and the College community is made up of about 5,000 students who, together with faculty, administrative staff, and Dominican Friars, are engaged in study on a campus of 0.43 km^2 located adjacent to the Elmhurst, Smith Hill, and Wanskuck neighborhoods within the city (Fig. 1B). The campus consists of about 50 buildings (including academic, dining, residential, religious, and athletics facilities) on heavily maintained grounds. A recent campus inventory counted more than 1,000 trees from 65 species. The largest public park in Providence, Roger Williams Park (1.7 km^2) is located on the south side of the city approximately 11 km from Providence College (Fig. 1C). The park is located on land that was a gift from the Narragansett people to Roger Williams in 1638. It was, for a while, used as farmland, and then gifted to the people of Providence in 1872. Roger Williams Park is now home to a zoo, museum, ponds, a boathouse, the Providence Police Department's Mounted Command center, sporting fields, a botanical garden, a concert venue, and many walking paths and roads supporting vehicular traffic. Like Providence College, Roger Williams Park is surrounded by a densely inhabited residential neighborhood with nearby commercial and industrial districts.

Methods

At Providence College, the primary survey method involved a repeated sampling protocol using pitfall traps. The traps were made from 50 mL plastic centrifuge vials filled with approximately 15 mL of soapy water, and they were placed in the ground so that the top of the vial was level with the surface. A total of 39 traps were spread throughout campus (Fig. 1D). Twelve locations were chosen at random, avoiding athletic fields and locations with impenetrable surfaces. Three pitfall traps were placed in a 10 m radius at each of these locations and an additional pitfall trap was placed at each of the three bioswale locations on campus which were designed with specific native vegetation to receive excess rainwater runoff. For each of the 10 weeks of the survey, a student deployed the 39 traps on one day of the week, retrieved them two days later (aiming to select days with minimal expected rainfall), and closed empty vials were left as placeholders in the ground between capture periods. Each week, the numbers of ants and other invertebrates were counted; ants averaged more than 80% of the specimens captured but their abundance varied across locations on campus and over the duration of the 10-week period (Figs. 2, 3). Specimen sorting and identification of the 1,853 ants from the pitfall traps took approximately two years (Table 1). Additionally, baiting and manual collecting by students were conducted in subsequent years to expand on the results of the pitfall trap survey.

At Roger Williams Park, the Rhode Island Natural History Survey (https://rinhs.org) organized a BioBlitz rapid biological assessment event to catalog as many living things present over a 24-hour window, from 2 pm on May 31 to 2 pm on June 1, 2019. This event has been organized annually by the RINHS at different locations across Rhode Island for the last 20 years. Volunteer experts worked together with members of the general public, walking throughout the park, making observations, and returning collected specimens as necessary to an ad-hoc science center with resources for identification (including microscopes, reference books, insect pinning supplies, etc.). A total of 145 individuals actively engaged in the survey. Of these, 5–10 individuals were actively searching for ants, though many other participants donated ant specimens found among their samples.

Collected ants were preserved in ethanol, a subset of these were pinned, and specimens were identified using morphological characters and dichotomous keys (Ellison et al. 2012a). In the course of our work, specimens were examined under Motic and Wild stereomicroscopes (Martin Microscope Company, Easley, SC, USA) at 10–50×. Specimens were photographed using a Canon 6D, MP-E 65 mm 1–5× lens and with a commercially available focus-stacking system (Brecko et al. 2014). Specimen records were maintained in an online database and voucher specimens for each species we report new observations for were deposited with the

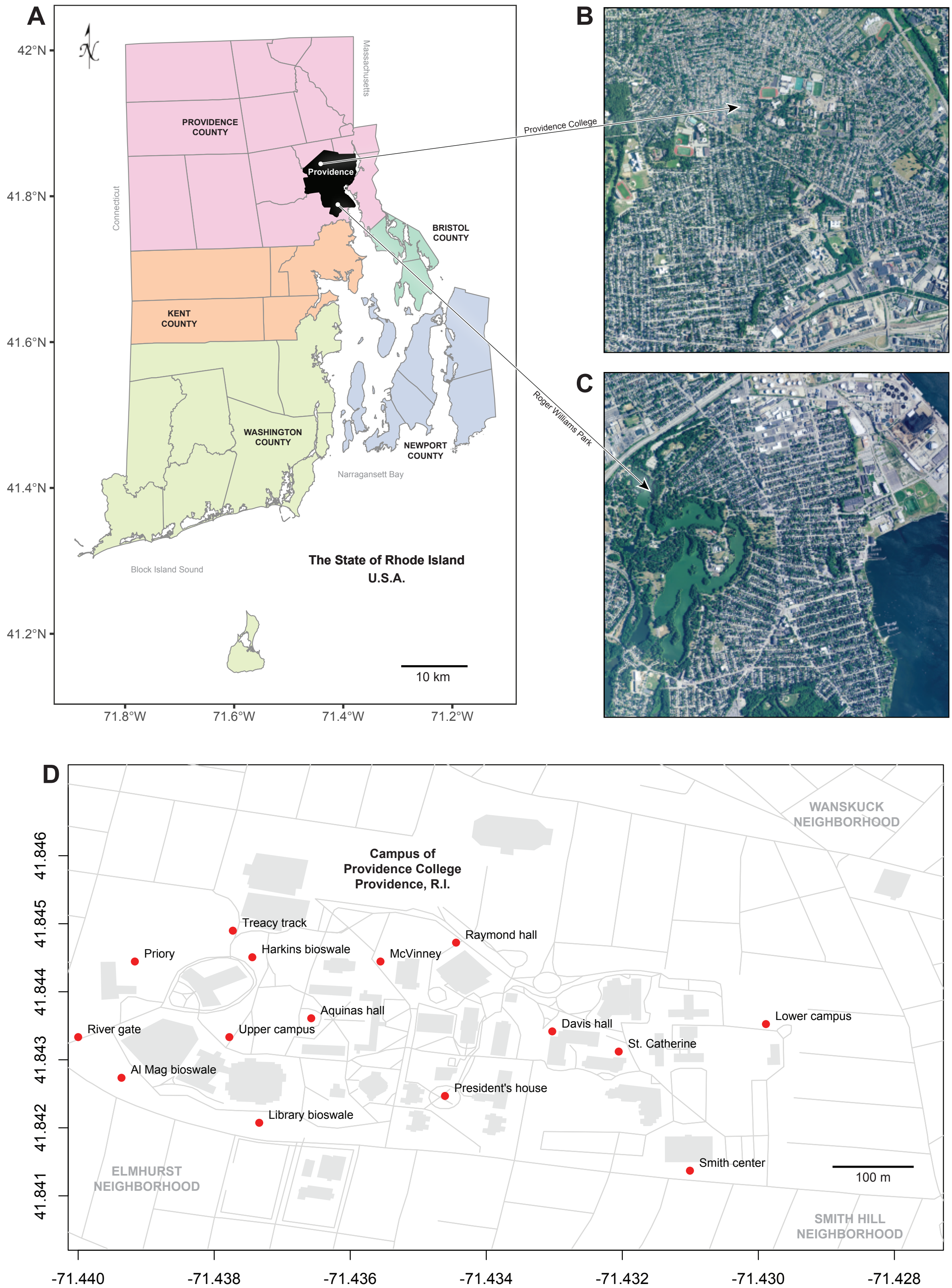

Figure 1. Survey sites. **A.** The state of Rhode Island with its municipal borders drawn and five counties labeled; the city of Providence is highlighted in black within the county of Providence. **B.** Aerial photograph of Providence College. **C.** Aerial photograph of Roger Williams Park. **D.** Map of Providence College showing the 15 pitfall trap locations.

Cornell University Insect Collection (Ithaca, NY, USA).

To confirm the morphological identification of *Brachyponera chinensis*, a species that was unexpected in the region, DNA barcoding was used for sequence-based identification (Hebert et al. 2003). Whole ants were extracted using a QIAGEN DNeasy Blood and Tissue extraction kit following the manufacturer's directions (QIAGEN Sciences, Germantown, MD, USA). Individual ants were pulverized in the digestion buffer (ATL + Proteinase K) using a dounce. DNA was eluted

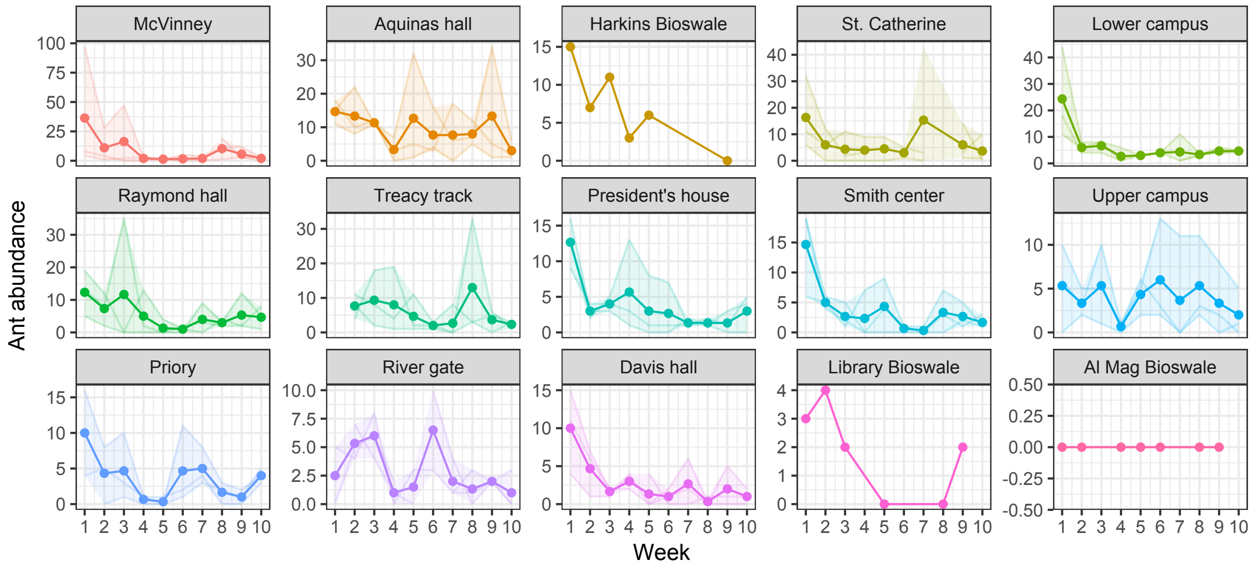

Figure 2. Time series of ant abundances across a 10-week repeated pitfall trap survey at the 15 locations on campus at Providence College. For 12 of 15 sites, data represent an average and range across the three pitfall traps at each of those sites; at the remaining three sites a single pitfall trap was used.

Figure 3. Summary of pitfall trap samples organized by species and date across all pitfall collection sites at Providence College in Summer 2015. The fill color of the vertical bars indicates abundance from low (grey) to high (red). Note that all facets share a common x-axis for date, but the y-axis scale is variable to show the relative specimen counts.

Table 1. Pitfall trap samples (*N* = 1,853) from Providence College during a 10-week survey in Summer 2015 were sorted and identified to 16 species. Manual collecting added an additional seven species to the list of ants found on campus.

Subfamily	Species	Count
Formicinae	*Formica subsericea*	463
	Camponotus pennsylvanicus	213
	Nylanderia flavipes	184
	Lasius neoniger	128
	Prenolepis imparis	36
	Formica subintegra	18
	Formica dolosa	2
	Lasius interjectus	2
	Formica incerta	1
Myrmicinae	*Tetramorium caespitum*	735
	Solenopsis molesta	58
	Aphaenogaster fulva	4
	Stenamma brevicorne	3
	Temnothorax schaumii	3
	Temnothorax longispinosus	2
Ponerinae	*Brachyponera chinensis*	1

in final volume of 200 μL of AE buffer. A section of the mitochondrial cytochrome c oxidase subunit 1 (COI) molecule was amplified in a PCR reaction using primers LCO1490 and HCO2198 (Folmer et al. 1994) at a final concentration of 5 μM for each primer. PCR amplification of the DNA began by heating the samples to 95 °C for 3 min followed by 35 cycles under the following conditions: 95 °C for 30 s, 50˚C for 30 s, and 72 °C for 45 s. PCR products were visualized and isolated using agarose gel electrophoresis (1.1% agarose in 1X TBE). Bands of appropriate size were excised from the gel and purified using a QIAGEN MinElute Gel Extraction Kit following the manufacturer's instructions. The concentration of the purified PCR products was measured using a nanospectrophotemeter. PCR product concentrations were standardized according to GeneWiz Sanger sequencing protocol, the sequencing reactions were then performed by GeneWiz (Azenta, Inc., Chelmsford, MA, USA). All four PCR products were sequenced in both directions. DNA sequences were aligned in MEGA v. 11 (Tamura et al. 2021). Similarity to known *Brachyponera chinensis* was tested using a GenBank BLAST search.

Results

Representatives of four subfamilies, 16 genera, and 36 species (Fig. 4; Table 2) have been collected and identified with taxonomy information referenced from the online catalog and bibliography of the world's ants, AntCat (Bolton 2019).

Family Formicidae Latreille, 1809
Subfamily Dolichoderinae Forel, 1878
Genus *Tapinoma* Foerster, 1850

***Tapinoma sessile* Say, 1836**
Figure 4, Appendix Figure A1, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8435, −071.4298; 32 m; 7.VII.2015; JSW leg.; PC015 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC121.

Identification. The petiole node appears to be missing a node, acidopore absent, characteristic odor of rotten coconuts or ripe bananas, horizontal slit at end of gaster.

Subfamily Ponerinae Lepeletier de Saint-Fargeau, 1835
Genus *Brachyponera* Emery, 1900

***Brachyponera chinensis* Emery, 1895**
Figure 4, Appendix Figure A2, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8436, −071.4365; 52 m; 7.VIII.2015; JSW leg.; GenBank ON666626, ON666627, ON666628, ON666629; PC014.

Identification. Large eyes, mesosoma step-like in lateral profile, waist 1-segmented, gaster constricted, subpetiolar lobe without circular impression, stinger present, shiny black, narrow in width with tapered and pointy gaster, appears larger and more active than *Ponera pennsylvanica*. DNA barcoding supported the morphological identification, with all four of the samples sequenced having a 100% match for the *Brachyponera chinensis* COI gene, GenBank accession number MT215089.1, and were a 99% match for *Brachyponera chinensis* voucher, specimen accession number OL663490.1.

Genus *Ponera* Latreille, 1804

***Ponera pennsylvanica* Buckley, 1866**
Figure 4, Appendix Figure A3, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8431, −071.4349; 52 m; 15.VII.2022; JSW leg. • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC029.

Identification. Small eyes (cf. *B. chinensis*), mesosoma smooth in lateral profile, waist 1-segmented, subpetiolar lobe with circular impression, gaster constricted, stinger present, brown to black color. This ant appears smaller than *B. chinensis*, lower tempo, and the continuous or leveled dorsal margin of the mesosoma of *Ponera* contrasts with the step-like mesosoma of *B. chinensis.*

Subfamily Formicinae Latreille, 1809
Genus *Brachymyrmex* Mayr, 1868

***Brachymyrmex depilis* Emery, 1893**
Figure 4, Appendix Figure A4, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; TH leg.; PC048.

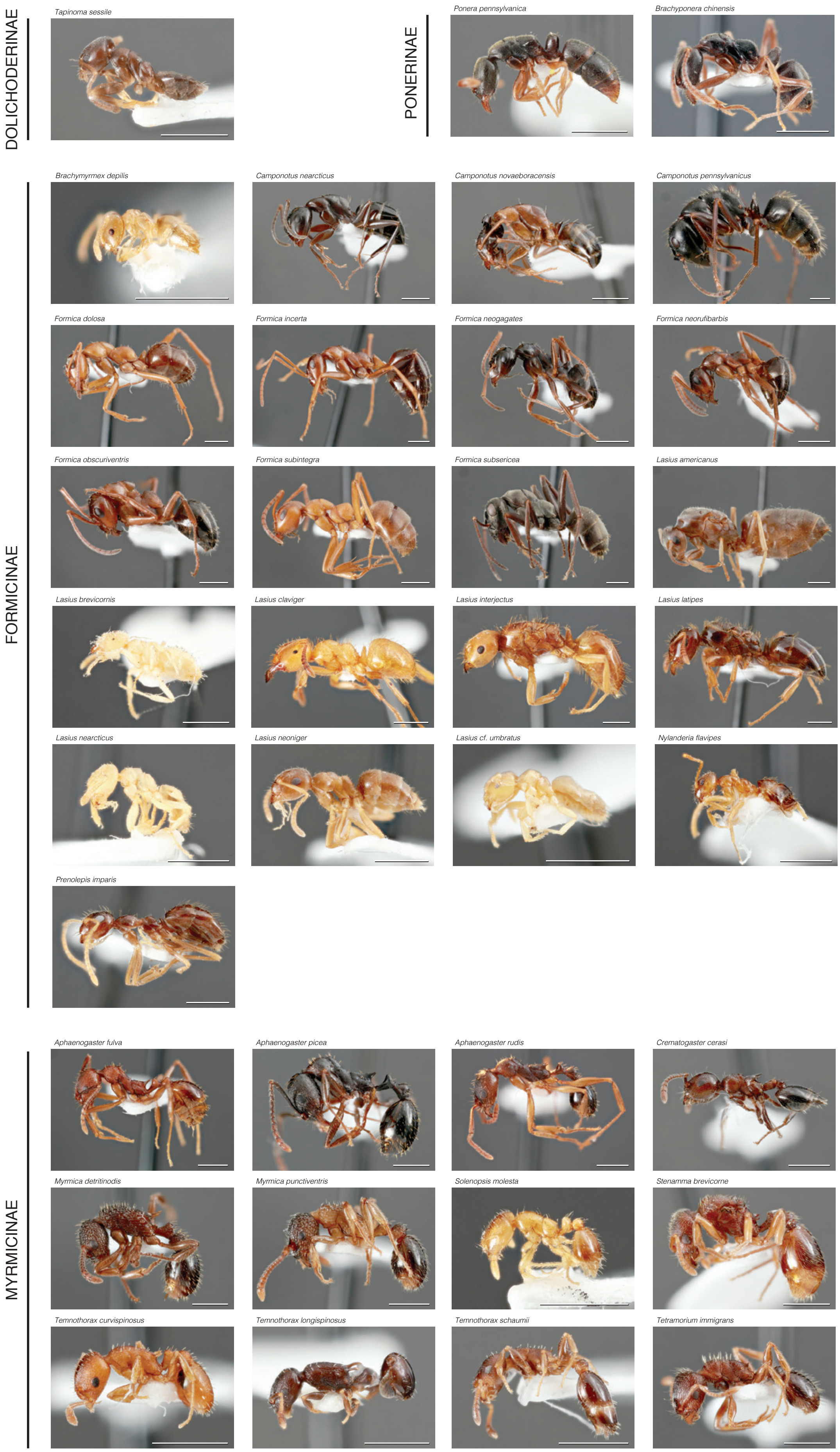

Figure 4. Photographs of the 36 species of ants identified in this study, organized by subfamily. The scale bar on the bottom right corner of each image is approximately 1 mm in length.

Identification. Minute size, 9-segmented antennae, 1-segmented petiole, acidopore present, yellow color.

Genus *Camponotus* Mayr, 1861

***Camponotus nearcticus* Emery, 1893**
Figure 4, Appendix Figure A5, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC038.

Identification. Notched clypeus, no erect hairs present on the cheeks, mesosoma smoothly convex, waist 1-segmented, red coloration on mesosoma, small for genus.

***Camponotus novaeboracensis* Fitch, 1855**
Figure 4, Appendix Figure A6, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC034.

Identification. Clypeus not notched, no erect hairs on the cheeks, mesosoma smoothly convex, red mesosoma, waist 1-segmented, shiny gaster.

***Camponotus pennsylvanicus* DeGreer 1773**
Figure 4, Appendix Figure A7, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.84333, −071.43778; 47 m; 10.VI.2015; JSW leg.; PC001 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC122.

Identification. Clypeus not notched, mesosoma smoothly convex, waist 1-segmented, microsculptured gaster with long, abundant golden hairs, both erect and appressed, black color.

Genus *Formica* Linnaeus, 1758

***Formica dolosa* Buren, 1944**
Figure 4, Appendix Figure A8, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8435, −071.4298; 32 m; 2.VII.2015; JSW leg.; PC006.

Identification. Clypeus not notched, mesosoma with bumps, many long hairs on the propodeum, waist 1-segmented, crest of petiole rounded, body long and slender, mostly concolorous and shiny.

***Formica incerta* Buren, 1944**
Figure 4, Appendix Figure A9, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8433, −071.4400; 40 m; 2.VII.2019; JSW leg.; PC005 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC047.

Identification. Clypeus not notched, mesosoma with bumps, few and short erect hairs on the propodeum, waist 1-segmented, body long and slender, mostly concolorous and shiny.

***Formica neogagates* Viereck, 1903**
Figure 4, Appendix Figure A10, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC045.

Identification. Clypeus not notched, scapes without erect hairs, mesosoma with bumps, waist 1-segmented, brown, smooth, shiny.

***Formica neorufibarbis* Emery, 1893**
Figure 4, Appendix Figure A11, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC046.

Identification. Clypeus not notched, hairy cheeks with elongate punctures, mesosoma with bumps, waist 1-segmented, bicolored.

***Formica obscuriventris* Mayr, 1870**
Figure 4, Appendix Figure A12, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC030.

Identification. Clypeus not notched, pinched at corners, head square shaped, mesosoma with bumps, waist 1-segmented, sharp erect hairs on gaster.

***Formica subintegra* Wheeler, 1908**
Figure 4, Appendix Figure A13, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8449, −071.4377; 48 m; 30.VII.2015; JSW leg.; PC004.

Identification. Clypeus notched, mesosoma with bumps, erect hairs present on dorsum of mesosoma, except on propodeum, waist 1-segmented.

***Formica subsericea* Say, 1836**
Figure 4, Appendix Figure A14, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8435, −071.4298; 32 m; 10.VII.2015; JSW leg.; PC003 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC044.

Identification. Clypeus not notched, antennal scape longer than the length of the head, mesosoma with bumps, waist 1-segmented, silvery pubescence on head, mesosoma, all legs, and gastral segments 1–3, many erect hairs on promesonotum and gaster.

Genus *Lasius* Fabricius, 1804

***Lasius americanus* Emery, 1893**
Figure 4, Appendix Figure A15, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8427, −071.4393; 43 m; 25.VIII.2014; JSW leg.; PC028 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC051.

Identification. Maxillary palps 6-segmented, no erect hairs on the antennal scape, large eyes, mesosoma with bumps, 1-segmented waist.

***Lasius brevicornis* Emery, 1893**
Figure 4, Appendix Figure A16, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8427, −071.4393; 30 m; 15.VI.2016; JSW leg.; PC024.

Identification. Maxillary palps 6-segmented, terminal segment of the maxillary palps shorter than penultimate segment, small eyes, mesosoma with bumps, 1-segmented waist, yellow coloration.

***Lasius claviger* Roger, 1862**
Figure 4, Appendix Figure A17, Table 2

New records. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC021.

Identification. Maxillary palps 3-segmented, mesosoma with bumps, long dense hairs, 1-segmented waist, citronella or lemon scent.

***Lasius interjectus* Mayr, 1866**
Figure 4, Appendix Figure A18, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8427, −071.4393; 50 m; 12.VI.2015; JSW leg.; PC016.

Identification. Maxillary palps 3-segmented, mesosoma with bumps, 1-segmented waist, on the second and third segments of the gaster erect hairs are only found on the edges of the tergites, citronella or lemon scent.

***Lasius latipes* Walsh, 1963**
Figure 4, Appendix Figure A19, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8427, −071.4393; 50 m; 5.IX.2014; JSW leg.; PC026.

Identification. Maxillary palps 3-segmented, cheeks and body with many erect hairs, 1-segmented waist, mesosoma with bumps, enlarged front legs.

***Lasius nearcticus* Wheeler, 1906**
Figure 4, Appendix Figure A20, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8445, −071.4374; 50 m; 17.VI.2015; JSW leg.; PC022.

Identification. Maxillary palps 6-segmented, yellow, small eyes, terminal segment of the maxillary palps longer than penultimate segment, 1-segmented waist, mesosoma with bumps.

***Lasius neoniger* Emery, 1893**
Figure 4, Appendix Figure A21, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8424, −071.4346; 53 m; 10.VI.2015; JSW leg.; PC013 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC123.

Identification. Maxillary palps 6-segmented, large eyes, many erect hairs on the antennal scape, mesosoma with bumps, 1-segmented waist.

Lasius* cf. *umbratus
Figure 4, Appendix Figure A22, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8424, −071.4346; 53 m; 7.VIII.2015; JSW leg.; PC023.

Identification. Maxillary palps 6-segmented, intermediate size eyes, erect hairs on antennae and hind tibiae, mesosoma with bumps, 1-segmented waist.

Genus *Nylanderia* Emery, 1906

***Nylanderia flavipes* Smith, 1874**
Figure 4, Appendix Figure A23, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8447, −071.4344; 50 m; 12.VII.2015; JSW leg.; PC007 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC040.

Identification. Scape with erect hairs, mesosoma with bumps, large black bristly hairs on the mesosoma, except on the propodeum, 1-segmented waist.

Genus *Prenolepis* Mayr, 1861

***Prenolepis imparis* Say, 1836**
Figure 4, Appendix Figure A24, Table 2

New record. USA – Rhode Island • Providence, Providence College; 41.8434, −071.4330; 43 m; 12.VIII.2015; JSW leg.; PC012.

Identification. Ocelli absent, 1-segmented waist, mesonotum distinctly curved and hourglass-shaped in dorsal view.

Subfamily Myrmicinae Lepeletier de Saint-Fargeau, 1835
Genus *Aphaenogaster* Mayr, 1853

***Aphaenogaster fulva* Roger, 1863**
Figure 4, Appendix Figure A25, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8435, −071.4298; 32 m; 12.VIII.2015; JSW leg.; PC017.

Identification. Last four segments of the antennae are lighter in color than the rest, prominently depressed propodeum, long legs, reddish-yellow color, ridge on top of mesonotum, propodeal spines short and point upward, 2-segmented waist.

***Aphaenogaster picea* Wheeler, 1908**
Figure 4, Appendix Figure A26, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8435, −071.4298; 32 m; 5.VI.2015; JSW leg.; PC018 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC036.

Identification. Last four segments of the antennae are lighter in color than the rest, prominently depressed propodeum, long legs, dark color, ridge on top of mesonotum, propodeal spines short and point rearward, 2-segmented waist.

Aphaenogaster rudis **Enzmann, 1947**
Figure 4, Appendix Figure A27, Table 2

New record. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC037.

Identification. Last four segments of the antennae are the same color as the rest prominently depressed propodeum, long legs, propodeal spines short and point upward, 2-segmented waist.

Genus *Crematogaster* Lund, 1831

Crematogaster cerasi **Fitch, 1855**
Figure 4, Appendix Figure A28, Table 2

New record. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC032.

Identification. Only one or two long erect hairs on each corner of the pronotum, 2-segmented waist, petiole attaches to top of heart-shaped gaster seen from a dorsal view.

Genus *Myrmica* Latreille, 1804

Myrmica detritinodis **Emery, 1921**
Figure 4, Appendix Figure A29, Table 2

New record. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC039.

Identification. Angular antennal scape bend, wavy mesosomal rugae, scape tapered basally, having a carina that crosses down the scape base, propodeum roughly level with promesonotum, long propodeal spines, 2-segmented waist.

Myrmica punctiventris **Roger, 1863**
Figure 4, Appendix Figure A30, Table 2

New record. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC035.

Identification. Curved antennal scape bend, propodeum lower than promesonotum, propodeal spines long with a narrow base, 2-segmented waist, pits at the base of erect hairs on the gaster.

Genus *Solenopsis* Westwood, 1840

Solenopsis molesta **Say, 1836**
Figure 4, Appendix Figure A31, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8413, −071.4310; 30 m; 10.VI.2015; JSW leg.; PC008 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC050.

Identification. Tiny yellow ant, very small eyes, propodeal spines absent, 2-segmented waist.

Genus *Stenamma* Westwood, 1839

Stenamma brevicorne **Mayr, 1886**
Figure 4, Appendix Figure A32, Table 2

New record. USA – Rhode Island • Providence, Providence College; 41.8424, −071.4346; 53 m; 12.VI.2015; JSW leg.; PC011.

Identification. Four-segmented antennal club, tiny eyes, short propodeal spines, 2-segmented waist, heavily sculptured rugae.

Genus *Temnothorax* Mayr, 1861

Temnothorax curvipspinosus **Mayr, 1866**
Figure 4, Appendix Figure A33, Table 2

New record. USA – Rhode Island • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC031.

Identification. Small yellow ant, five teeth on mandibles, long curved propodeal spines, 2-segmented waist.

Temnothorax longispinosus **Roger, 1863**
Figure 4, Appendix Figure A34, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8413, −071.4310; 48 m; 12.VII.2015; JSW leg.; PC009 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC041.

Identification. Small black ant, five teeth on mandibles, long propodeal spines point rearward, 2-segmented waist.

Temnothorax schaumii **Roger, 1863**
Figure 4, Appendix Figure A35, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8434, −071.4330; 43 m; 10.VI.2015; JSW leg.; PC010 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31.V.2019; JSW leg.; PC124.

Identification. Small red brown ant, five teeth on mandibles, finely striated head, fine sculpturing, short propodeal spines, 2-segmented waist.

Genus *Tetramorium* Mayr, 1855

Tetramorium immigrans **Santschi, 1927**
Figure 4, Appendix Figure A36, Table 2

New records. USA – Rhode Island • Providence, Providence College; 41.8447, −071.4344; 50 m; 12.VI.2015; JSW leg.; PC002 • Providence, Roger Williams Park; 41.7820, −071.4074; 12 m; 31 May 2019; JSW leg.; PC125.

Identification. Head with parallel rugae and antennae that insert into a crater-like cavity with a distinctly raised ridge at the anterior or distal margin, 2-segmented waist.

Discussion

In our survey of Providence, we identified 36 species of ants, 24 at Providence College, 25 at Roger Williams Park, and 13 species found at both sites (Fig. 4; Table 2). Of the 13 species of ants previously known to have been found in Providence, four species were not found in the current study, including *Formica integra* (Nylander, 1856), *Lasius umbratus* (Nylander, 1846), *Monomorium emarginatum* (DuBois, 1986), and *Myrmica americana* (Weber, 1939). If these species are still present in the city, and including an introduced population of *Pheidole megacephala* (Fabricius, 1793), we can count a total of 41 ant species in Providence.

We found three introduced species including *Tetramorium immigrans*, *Nylanderia flavipes*, and *Brachyponera chinensis*. The Pavement Ant (*T. immigrans*) is originally from Europe and is regionally pervasive. The yellow-footed ant (*N. flavipes*) is Asian in origin, but as of only a few years ago was only found from a few locations in New England (Ellison et al. 2012b); now it appears to have spread abundantly. The Needle Ant (*B. chinensis*) is having an ecological impact as a competitive invasive species in the mid-Atlantic states, but previously it had not been observed to have spread as far north as New England (Guénard and Dunn 2010; Guénard et al. 2018); the closest recent observation was in New York State (Ellison et al. 2012b). We note that while the common name often used for this species often includes a regional identifier, we generally omit this part of the name since it is not necessary for uniqueness and including it can unintentionally promote negative associations and stereotypes. In our study, *B. chinensis* was at first identified from only a single specimen among thousands in the pitfall trap collection and manual search at first turned up no additional observations. Students at Providence College, incentivized by extra credit, searched the campus and found a colony of *B. chinensis* nesting around the perimeter of a dormitory (Fig. 5). In the years since we learned of its presence there, we have removed workers and queens for study, nevertheless it persists. The occurrence of individuals has expanded slightly to the perimeters of adjacent buildings, but to the best of our knowledge, it has not yet been found anywhere else on campus or more broadly across the region.

How many different ant species should there be in Providence? We found existing records and supplemented those with our own collections, but the final tally we counted (N = 41 species) does not answer the question of how many ants we may have been expected to find. Whether for a region, a city, a park, or a backyard, there is not a general answer to this kind of question. However, the literature can offer some context. At the broadest spatial scales, there are published totals for locations including 1,884 ant species (2,485 including unresolved infraspecific taxa) in Africa (Fisher and Bolton, 2016), 951 in China (Liu et al., 2015), and 237 from the Solomon Islands (Sarnat et al., 2013). For North America, we count almost 1,000 species (Fisher and Cover, 2007), including 94 in the Florida Keys (Moreau et al. 2014) and 143 species in New England (Ellison et al. 2012). How do we compare the findings from a relatively small site such as a park or campus to these larger inventories? On a spatial scale more comparable to this study, surveys of college campuses, parks, cities, and islands have found between eight and 164 species with a median count of 40 species and an average of 43 (Table 3). There is a lot of variation in species counts in different studies and using multiple methods can significantly increase species yield (Ellison and Farnsworth 2014; Ellison et al. 2007; Guénard et al. 2014), but without standardized survey methods or experimental approaches it is hard to attribute differences in diversity to ecologically meaningful factors. Even without standardized methods, however, studies such as this one, together with community science initiatives, can help raise awareness about local biodiversity and inform more ecologically oriented studies.

We reviewed the ant species records on the popular BugGuide and iNaturalist platforms for comparison with our data and previously curated species records. BugGuide (https://bugguide.net) has been operational as a website since 2003 and iNaturalist (https://www.inaturalist.org) has been available as a website and mobile application since 2008. As of July 2019, the BugGuide website contained records for 119 ant observations in Rhode Island, the vast majority of which were from Block Island. State-wide, there were 21 species identified and just three from Providence. Two

Table 2. Results of this survey combined with an updated checklist of Rhode Island ants. This table lists the species found at Providence College (PC) and Roger Williams Park (RWP) in Providence as well as the other ant species found in Rhode Island. The source for each species' inclusion is indicated by superscript: (1) Ellison et al. 2012; (2) Ellison and Farnsworth 2014; (3) research grade iNaturalist observations, and (4) new records reported here. For each new species record, we indicate its voucher specimen ID and whether it represents a new county or state record.

Subfamily	Species	Voucher	PC	RWP	County	State
Amblyoponinae	*Stigmatomma pallipes*[1]	—				
Ponerinae	*Brachyponera chinensis*[4]	pc014	■		⁕	⁕
	Ponera pennsylvanica[1]	pc029	■	■	⁕	
Proceratiinae	*Proceratium crassicorne*[3]	—			⁕	⁕
Dolichoderinae	*Dolichoderus plagiatus*[1]	—				
	Dolichoderus pustulatus[1]	—				
	Tapinoma sessile[1]	pc015	■	■		
Formicinae	*Brachymyrmex depilis*[4]	pc048		■	⁕	⁕

Table 2. Continued.

Subfamily	Species	Voucher	PC	RWP	County	State
Formicinae	*Camponotus americanus*[1]	—				
	Camponotus castaneus[1]	—				
	Camponotus chromaiodes[1]	—				
	Camponotus nearcticus[1]	pc038		■		
	Camponotus novaeboracensis[1]	pc034		■		
	Camponotus pennsylvanicus[1]	pc001	■	■		
	Formica argentea[1]	—				
	Formica dolosa[1]	pc006	■			
	Formica exsectoides[1]	—				
	Formica impexa[1]	—				
	Formica incerta[1]	pc005	■	■	⁕	
	Formica integra[1]	—				
	Formica neogagates[2]	pc045		■	⁕	
	Formica neorufibarbis[4]	pc046		■	⁕	⁕
	Formica obscuriventris[1]	pc030		■	⁕	
	Formica pallidefulva[1]	—				
	Formica pergandei[1]	—				
	Formica querquetulana[1]	—				
	Formica subaenescens[1]	—				
	Formica subintegra[1]	pc004	■			
	Formica subsericea[1]	pc003	■	■		
	Lasius americanus[1]	pc028	■	■		
	Lasius brevicornis[1]	pc025	■		⁕	
	Lasius cf umbratus[4]	pc023	■		⁕	⁕
	Lasius claviger[1]	pc021		■		
	Lasius interjectus[1]	pc016	■		⁕	
	Lasius latipes[1]	pc027	■			
	Lasius nearcticus[2]	pc022	■		⁕	
	Lasius neoniger[1]	pc013	■	■	⁕	
	Lasius pallitarsis[2]	—				
	Lasius speculiventris[1]	—				
	Lasius umbratus[1]	—				
	Nylanderia flavipes[4]	pc07	■	■	⁕	⁕
	Nylanderia parvula[1]	—				
	Prenolepis imparis[1]	pc012	■		⁕	
Myrmicinae	*Aphaenogaster fulva*[2]	pc017	■		⁕	
	Aphaenogaster picea[2]	pc018	■	■	⁕	
	Aphaenogaster rudis[1]	pc037		■	⁕	
	Aphaenogaster treatae[1]	—				
	Crematogaster cerasi[1]	pc032		■	⁕	
	Crematogaster lineolata[1]	—				
	Monomorium emarginatum[1]	—				
	Monomorium viridum[1]	—				
	Myrmecina americana[3]	—				
	Myrmica americana[1]	—				
	Myrmica incompleta[2]	—				
	Myrmica detritinodis[4]	pc039		■	⁕	⁕
	Myrmica punctiventris[2]	pc035		■	⁕	
	Myrmica rubra[1]	—				
	Myrmica sp. AF-scu[2]	—				
	Myrmica sp. AF-smi[1]	—				
	Pheidole megacephala[3]	—			⁕	⁕
	Solenopsis molesta[2]	pc008	■	■	⁕	
	Stenamma brevicorne[4]	pc011	■		⁕	⁕
	Stenamma impar[2]	—				
	Strumigenys pulchella[3]	—				
	Temnothorax americanus[3]	—				
	Temnothorax curvipspinosus[1]	pc031		■	⁕	
	Temnothorax longispinosus[1]	pc009	■	■	⁕	
	Temnothorax schaumii[1]	pc010	■	■	⁕	
	Tetramorium immigrans[1]	pc002	■	■	⁕	

Figure 5. Photographs of the Needle Ant colony on campus. **A.** Students digging into a nest entrance on campus adjacent to McDermott Hall at Providence College. **B.** Queen and three workers of the Needle Ant, *Brachyponera chinensis*. **C.** Two ponerine ants from Providence photographed in the same frame for scale comparison, the smaller one on the left is *Ponera pennsylvanica* and the larger one on the right is *B. chinensis*.

species that had not previously been published as found in Rhode Island, *Brachymyrmex depilis* and *Stenamma brevicorne*, both of which we also found in Providence, were observed by users on BugGuide in East Greenwich and Block Island, respectively. On iNaturalist, there were 208 observations (35 species) of ants distributed from across Rhode Island, and of these, 65 observations (26 species) are classified as research grade quality by the community. Of the species with research grade observations, most were already known to be in Rhode Island, but six new candidate state records first published on this platform included *Brachyponera chinensis*, *Brachymyrmex depilis* (Emery, 1893), *and Pheidole megacephala* in Providence, *Strumigenys pulchella* (Emery, 1895) and *Temnothorax americanus* (Emery, 1895) in Lincoln, *Myrmecina americana* (Emery, 1895) in Hopkinton, and *Proceratium crassicorne* (Emery, 1895) from West Greenwich. Although *P. megacephala*

Table 3. Ant species counts for local surveys. The studies listed were selected based on surveys that were conducted in parks, cities, and small islands, though the spatial scale is varied and some are more broadly regional or habitat-specific. Other varying factors include survey intensity and duration, methods applied, and the degree of urbanization as this list includes habitats ranging from conservation wilderness to one of the most densely populated urban areas on the planet (Macau).

Location	Species count	Methods	Source
Salvador, Brazil	164	Winkler, diurnal manual, and umbrella	Melo et al. 2014
Macau, China	105	Manual and winkler	Leong et al. 2017
Archbold Biological Station, Florida, USA	102	Manual, baiting, malaise, ultraviolet light, Tullgren extraction	Deyrup and Trager 1986
Duke Forest, North Carolina, USA	95	Repeated pitfall, winkler, and artificial nests	Pelini et al. 2011
North Carolina State University, USA	89	Repeated manual, baiting, pitfall, and winkler	Guénard et al. 2014
E.S. George Reserve, Michigan, USA	87	26-year study	Talbot 2012
Chicago, IL, USA	70	Comprehensive search	Talbot 1934
Jaragua National Park, Dominican Republic	64	Manual, beating, Davis sifter	Lubertazzi and Alpert 2014
Barbados, Lesser Antilles islands	62	Manual, beating, litter,	Wetterer et al. 2016
Buenos Aires, Argentina	60	Manual, baits, leaf litter, soil, and pitfall	Josens et al. 2016
Kiev, Ukraine	59	Manual and pitfall	Radchenko et al. 2018
Nantucket island, MA, USA	58	Manual, pitfall, barrier, baiting, litter sifting	Ellison 2012
Yaoundé, Cameroon	53	Manual and baiting	Masse et al. 2019
Pitch Pine barrens, New York, USA	53	Pitfall transects, timed quadrat searches, litter sifting	Barber 2015
Sofia, Bulgaria	52	Manual search	Antonova and Penev 2008
Boston Harbor Islands, Massachusetts, USA	51	Manual, pitfall, malaise, blacklight, beating, litter sifting, and BioBlitz	Clark et al. 2011
Longleaf pine savannas, Florida, USA	51	Pitfall array	Tschinkel et al. 2012
Block Island, Rhode Island, USA	51	Timed hand-sampling, litter sifting, and by-catch from a deer tick drag-sheet survey	Ellison and Farnsworth 2014
Taichung City, Taiwan	50	Pitfall	Liu et al. 2019
Harvard Forest, Massachusetts, USA	48	Repeated manual, baiting, pitfall, and winkler	Pelini et al. 2011
Wichita Mountains Wildlife Refuge, Oklahoma, USA	47	Manual, pitfall, and winkler	Roeder and Roeder 2016
Cordoba and Seville, Spain	46	Pitfall traps	Carpintero and Reyes-López 2014
Urban parks in São Paulo, Brazil	46	Pitfall transects	Souza-Campana et al. 2016
Garden City, Georgia, USA	45	Pitfall transects, litter, debris dissection, baiting	Gochnour et al. 2019
Households in São Paulo, Brazil	44	Manual and baiting	Piva and Campos 2012
Prince of Songkla University, Thailand	44	Manual and leaf litter	Watanasit et al. 2005
Acadia National Park, Maine, USA	42	Transects, manual, baiting, leaf litter, and pitfall	Ouellette et al. 2010
Fort Barton and Barton Woods, Rhode Island, USA	42	Timed hand-sampling and litter sifting	Ellison and Farnsworth 2014
Manhattan, New York, USA	42	Manual and winkler	Savage et al. 2014
Providence, Rhode Island, USA	41	Manual, pitfall, and BioBlitz	This study
Coatepec, Veracruz, Mexico	40	Random sampling	Lopez-Moreno et al. 2002
Cities in New Zealand	38	Surface trapping (adhesive)	Stringer et al. 2009
A single oak tree in Mississippi, USA	36	Serendipitous checking, litter and soil sifting, and baiting	Macgown and Brown 2006
Thimble Islands, Connecticut, USA	35	Manual, leaf litter, beating, transect inspection	Goldstein 1975
Amravati city, India	34	Manual search	Chavhan and Pawar 2011
Santa Cruz Island, California, USA	34	Manual, tuna and cookie baiting, litter sifting	Wetterer et al. 2000
Black Rock Forest, New York, USA	33	Manual, pitfall, and sieved litter	Ellison et al. 2007
Marília, Brazil	33	Pitfall and baits	Dáttilo et al. 2011
Sites across Denmark	31	Baiting	Sheard et al. 2020
Helsinki, Finland	30	Manual, nest searching	Vepsäläinen et al. 2008
Toledo, Ohio, USA	30	Tuna baiting	Uno et al. 2010
Tokyo, Japan	28	Manual search	Yamaguchi 2004
Tvärminne archipelago, Baltic Sea, Finland	28	Manual search	Vepsäläinen and Pisarski 1982
Detroit, Michigan, USA	27	Tuna baiting	Uno et al. 2010
Madeiran archipelago, Portugal	27	Manual, soil and litter sifting	Wetterer et al. 2007
Warsaw, Poland	27	Manual search	Slipinski et al. 2012
Cities in Côte d'Ivoire	25	Transects using tuna	Kouakou et al. 2018
Karnatak University campus, Dharwad, India	24	Manual search and digging	Yashavantakumar et al. 2016
Gauhati University campus, Assam, India	21	Manual, baiting, beating, and litter sifting	Hazarika et al. 2019
Households in Manaus, Brazil	21	Molasses baits	Marques et al. 2002
Maharani Science College, India	20	Manual search	Mahalaskshmi and Channaveerappa 2016
Jahangir Nagar University campus, Bangladesh	19	Manual and sifting	Hannan 2007
Moscow, Russia	16	Manual and quadrat search	Putyatina et al. 2017

Table 3. Continued.

Location	Species count	Methods	Source
Six small mangrove islands, Florida, USA	16	Fumigation/re-colonization island experiment	Simberloff and Wilson 1969
Cádiz, Spain	15	Manual search	Reyes-López and Taheri 2018
San Francisco, California, USA	15	Pitfall traps and manual search	Clarke et al. 2008
Azores, Portugal	14	Manual, soil and litter sifting	Wetterer et al. 2004
South County Museum, Rhode Island, USA	13	Manual, BioBlitz, pitfall trap samples were washed out by Tropical Storm Andrea	Ellison and Farnsworth 2014
Street medians in NYC, New York, USA	13	Manual and pitfall	Pećarević et al. 2010
University of the Pacific, Stockton, CA, USA	9	Bait stations	Stahlschmidt and Johnson 2018
Kogi State University Campus, Anyigba Nigeria	8	Manual, pitfall, and Berlese funnel	Okpanachi and Yaro 2019

was not found using the described methods of our study which focused on collecting outdoors, after being alerted about an unknown ant inside a rainforest exhibit at the zoo, we collected individuals, verified their identification, and have shared pinned specimens.

One major question raised in interpreting our results is whether or not the urbanization of areas contributes to the loss or gain of myrmecological biodiversity. Some studies have shown a general trend of urbanization associated with a decrease in overall diversity, although perhaps mitigated among arthropods by an increase in abundance (Faeth et al. 2011). The results of our survey cast doubt on the assumption that cities are not diverse places and others have concluded similarly based on surveys for ants in Raleigh (Menke et al. 2010) or Macau (Leong et al. 2017) and for bee diversity in New York City (Matteson et al. 2008) and Vancouver (Tommasi et al. 2004). Cities may have more asphalt and concrete than rural areas, but they also have a high flux of potential resources mediated by human activity ranging from invasive plant transport to food waste (Penick et al. 2015). The urban heat island effect offers a refuge against lower critical thermal limits (Stringer et al. 2009). Especially at the small scale of an individual ant, cities offer highly heterogeneous, spatially compartmentalized, and highly variable thermal micro-habitats (Pincebourde et al. 2016). Cities may also be less likely to be sprayed with large amounts of pesticides as might be the case in more agriculturally developed regions.

Our study only focused on two sites, and both were on institutionally maintained grounds. It is possible that the number of species we identified might not be found in the residential and commercial districts throughout the city—that the ant diversity is relatively concentrated in the urban parks—but this remains to be determined. If a diversity of ant species may be found at a number of parks scattered across and within the city, would they not also be found under stones, on trees, and within houses more generally throughout the city? In Taichung City (Taiwan), there was not a significant change in ant species diversity across the city with respect to the distance from urban parks, though there were associations with park size, soil moisture, and the number of trash bins (Liu et al. 2019). Gradients for urban insect diversity have been mapped out in other cities including Phoenix and Los Angeles, but while a combination of microhabitat temperatures, humidity, surface permeability, and plant drought-tolerance have been identified as important factors, they can have variable impacts in the different cities and for different taxa sampled (Adams et al. 2020; McGlynn et al. 2019).

As E.O. Wilson and others have implored (Pimm et al. 2014; Saunders 2019; Tschinkel and Wilson 2014; Wilson 2017), we have only scratched the surface of identifying the biodiversity on the planet, the smallest habitats are likely the most threatened, and there is an imminent need to identify and conserve the wildlife all around us before it disappears. There is also value to highlighting the biodiversity found within urban ecosystems, as this is the nature many people will encounter most frequently and can inspire future conservation efforts more broadly (Dunn et al. 2006). There is a great opportunity for community science initiatives such as the successful School of Ants project (Lucky et al. 2014) and local BioBlitz events to continue to address these questions across a broader range of localities and spatial scales.

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Author Contributions

Conceptualization: JB, JSW, DG, HA. Data curation: JSW. Formal analysis: JSW. Funding acquisition: JSW, HA, JM, DG. Investigation: MR, JM, HA, JSW, NWK, JB, JDE, TH, JE. Methodology: JSW, JB, DG. Project administration: JSW, DG. Resources: JSW. Supervision: JM, JSW. Validation: JSW. Visualization: JSW. Writing – original draft: JSW. Writing – review and editing: HA, DG, JSW, NWK, JB, JDE, MR, JM.

References

Adams BJ, Li E, Bahlai CA, Meineke EK, McGlynn TP, Brown BV (2020) Local-and landscape-scale variables shape insect diversity in an urban biodiversity hot spot. Ecological Applications 30: e02089. https://doi.org/10.1002/eap.2089

Antonova V, Penev L (2008) Classification of ant assemblages (Hymenoptera: Formicidae) in Green Areas of Sofia. Acta Zoologica Bulgarica 60: 103–110.

Barber GW (2015) Ant assemblages of New York State inland pine barrens. Northeastern Naturalist 22: 551–572. https://doi.org/10.1656/045.022.0310

Bolton B (2019) An online catalog of the ants of the world. http://antcat.org. Accessed on: 2019-8-5.

Brecko J, Mathys A, Dekoninck W, Leponce M, Vanden-Spiegel D, Semal P (2014) Focus stacking: comparing commercial top-end set-ups with a semi-automatic low budget approach. A possible solution for mass digitization of type specimens. ZooKeys 464:1–23. https://doi.org/10.3897/zookeys.464.8615

Carpintero S, Reyes-López J (2014) Effect of park age, size, shape and isolation on ant assemblages in two cities of southern Spain. Entomological Science 17: 41–51. https://doi.org/10.1111/ens.12027

Clark AT, Rykken JJ, Farrell BD (2011) The effects of biogeography on ant diversity and activity on the Boston Harbor Islands, Massachusetts, U.S.A. PLoS ONE 6 (11): e28045. https://doi.org/10.1371/journal.pone.0028045

Clarke KM, Fisher BL, LeBuhn G (2008) The influence of urban park characteristics on ant (Hymenoptera, Formicidae) communities. Urban Ecosystems 11: 317–334. https://doi.org/10.1007/s11252-008-0065-8

Chavhan A, Pawar SS (2011) Distribution and diversity of ant species (Hymenoptera: Formicidae) in and around Amravati City of Maharashtra, India. World Journal of Zoology 6: 395–400.

Davidson DW (1997) The role of resource imbalances in the evolutionary ecology of tropical arboreal ants. Biological Journal of the Linnean Society 61: 153–181. https://doi.org/10.1111/j.1095-8312.1997.tb01785.x

Dáttilo W, Sibinel N, Falcão JCF, Nunes RV (2011) Mirmecofauna em um fragmento de Floresta Atlântica urbana no Município de Marília, SP, Brasil. Bioscience Journal 27: 494–504.

Del Toro I, Ribbons RR, Pelini SL (2012) The little things that run the world revisited: a review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae). Myrmecological News 17: 133–146.

Deyrup M, Trager J (1986) Ants of the Archbold Biological Station, Highlands County, Florida (Hymenoptera: Formicidae). Florida Entomologist 69: 206–228. https://doi.org/10.2307/3494763

Dunn RR, Gavin MC, Sanchez MC, Solomon JN (2006) The pigeon paradox: dependence of global conservation on urban nature. Conservation Biology 20: 1814–1816.

Dunn RR, Sanders NJ, Fitzpatrick MC, Laurent E, Lessard J-P, Agosti D, Andersen AN, Bruhl C, Cerda X, Ellison AM, Fisher BL, Gibb H, Gotelli NJ, Gove A, Guenard B, Janda M, Kaspari M, Longino JT, Majer J, McGlynn TP, Menke SB, Parr CL, Philpott SM, Pfeiffer M, Retana J, Suarez AV, Vasconcelos HL (2007) Global ant (Hymenoptera: Formicidae) biodiversity and biogeography—a new database and its possibilities. Myrmecological News 10: 77–83.

Ellison AM (2012) The ants of Nantucket: unexpectedly high biodiversity in an anthropogenic landscape. Northeastern Naturalist 19: 43–66. https://doi.org/10.1656/045.019.s604

Ellison AM, Farnsworth EJ (2014) Targeted sampling increases knowledge and improves estimates of ant species richness in Rhode Island. Northeastern Naturalist 21: 13–24. https://doi.org/10.1656/045.021.0118

Ellison AM, Gotelli NJ, Farnsworth EJ, Alpert GD (2012) A field guide to the ants of New England. Yale University Press, New Haven, USA, 416 pp.

Ellison AM, Record S, Arguello A, Gotelli NJ (2007) Rapid inventory of the ant assemblage in a temperate hardwood forest: species composition and assessment of sampling methods. Environmental Entomology 36: 766–775. https://doi.org/10.1093/ee/36.4.766

Evans TA, Dawes TZ, Ward PR, Lo N (2011) Ants and termites increase crop yield in a dry climate. Nature Communications 2 (262). https://doi.org/10.1038/ncomms1257

Faeth SH, Bang C, Saari S (2011) Urban biodiversity: patterns and mechanisms. Annals of the New York Academy of Sciences 1223: 69–81. https://doi.org/10.1111/j.1749-6632.2010.05925.x

Fisher BL, Bolton B (2016) Ants of Africa and Madagascar: a guide to the genera. University of California Press, Oakland, USA, 512 pp.

Fisher BL, Cover SP (2007) Ants of North America. University of California Press, Berkeley, USA, 216 pp.

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–299.

Gochnour BM, Suiter DR, Booher D (2019) Ant (Hymenoptera: Formicidae) Fauna of the Marine Port of Savannah, Garden City, Georgia (USA). Journal of Entomological Science 54: 417–429. https://doi.org/10.18474/jes18-132

Goldstein EL (1975) Island biogeography of Ants. Evolution 29: 750–762. https://doi.org/10.2307/2407082

Guénard B, Dunn RR (2010) A new (old), invasive ant in the hardwood forests of eastern North America and its potentially widespread impacts. PLoS ONE 5: e11614. https://doi.org/10.1371/journal.pone.0011614

Guénard B, Cardinal-De Casas A, Dunn RR (2014) High diversity in an urban habitat: are some animal assemblages resilient to long-term anthropogenic change? Urban Ecosystems 18: 449–463. https://doi.org/10.1007/s11252-014-0406-8

Guénard B, Wetterer JK, Macgown JA (2018) global and temporal spread of a taxonomically challenging invasive ant, *Brachyponera chinensis* (Hymenoptera: Formicidae). Florida Entomologist 101: 649–656. https://doi.org/10.1653/024.101.0402

Hannan H (2007) Ant records from Savar, Dhaka, Bangladesh. Asian Myrmecology 1: 101–104. https://doi.org/10.20362/am.001009

Hazarika HN, Adhikari K, Khanikor B (2019) Diversity and distribution of ants (Hymenoptera: Formicidae) in Gauhati University Campus, Assam. International Journal for Research in Engineering Application & Management 4: 448–453.

Hebert P, Cywinska A, Ball S, deWaard JR (2003) Biological identifications through DNA barcodes. Proceedings of the Royal Society B: Biological Sciences 270:313–321. http://doi.org/10.1098/rspb.2002.2218

Jenkins CN, Sanders NJ, Andersen AN, Arnan X, Brühl CA, Cerda X, Ellison AM, Fisher BL, Fitzpatrick MC, Gotelli NJ, Gove AD, Guénard B, Lattke JE, Lessard J-P, McGlynn TP, Menke SB, Parr CL, Philpott SM, Vasconcelos HL, Weiser MD, Dunn RR (2011) Global diversity in light of climate change: the case of ants. Diversity and Distributions 17: 652–662. https://doi.org/10.1111/j.1472-4642.2011.00770.x

Josens R, Sola F, Lois-Milevicich J, Mackay W (2016) Urban ants of the city of Buenos Aires, Argentina: species survey and practical control. International Journal of Pest Management 63: 213–223. https://doi.org/10.1080/09670874.2016.1239035

King JR, Warren RJ, Bradford MA (2013) Social insects dominate eastern US temperate hardwood forest macroinvertebrate communities in warmer regions. PLoS ONE 8:e75843. https://doi.org/10.1371/journal.pone.0075843

Kouakou LMM, Yeo K, Ouattara K, Dekoninck W, Delsinne T, Konate S (2018) Investigating urban ant community (Hymenoptera: Formicidae) in port cities and in major towns along the border in Côte d'Ivoire: a rapid assessment to detect potential introduced invasive ant species. Journal of Animal & Plant Sciences 36: 5793–5811.

Leong CM, Shiao SF, Guénard B (2017) Ants in the city, a preliminary checklist of Formicidae (Hymenoptera) in Macau, one of the most heavily urbanized regions of the world. Asian Myrmecology 9: 1–20. http://doi.org/10.20362/am.009014

Liu C, Guénard B, Garcia FH, Yamane S, Blanchard B, Yang D-R, Economo E (2015) New records of ant species from Yunnan, China. ZooKeys 477: 17–78. https://doi.org/10.3897/zookeys.477.8775

Liu KL, Peng MH, Hung YC, Neoh KB (2019) Effects of park size, peri-urban forest spillover, and environmental filtering on diversity, structure, and morphology of ant assemblages in urban park. Urban Ecosystems 22: 643–656. https://doi.org/10.1007/s11252-019-00851-z

Lopez-Moreno IR, Diaz-Betancourt ME, Landa TS (2002) Social insects in human environments—ants in the city of Coatepec (Veracruz, Mexico). Sociobiology 42: 605–621.

Lubertazzi D, Alpert GD (2014) The ants (Hymenoptera: Formicidae) of Jaragua National Park, Dominican Republic. Journal of Insects 2014: 1–6. https://doi.org/10.1155/2014/104157

Lucky A, Savage AM, Nichols LM, Castracani C, Shell L, Grasso DA, Mori A, Dunn RR (2014) Ecologists, educators, and writers collaborate with the public to assess backyard diversity in The School of Ants Project. Ecosphere 5 (7):78. https://doi.org/10.1890/es13-00364.1

Macgown JA, Brown RL (2006) Observations on the high diversity of native ant species coexisting with imported fire ants at a microspatial scale in Mississippi. Southeastern Naturalist 5: 573–586. https://doi.org/10.1656/1528-7092(2006)5[573:oothdo]2.0.co;2

Mahalaskshmi BR, Channaveerappa H (2016) Diversity of Ant Species (Hymenoptera: Formicidae) in the campus of Maharani's Science College for Women: a mini model of habitat persistence. International Journal of Pure and Applied Zoology 4: 277–281.

Marques APC, Ale-Rocha R, Rafael JA (2002) Levantamento de Formigas (Hymenoptera: Formicidae) em residências de Manaus, estado do Amazonas, Brasil. Acta Amazonica 32: 133–140. https://doi.org/10.1590/1809-43922002321140

Masse PSM, Giovani ET, Mony R (2019) Household and home garden infesting arthropods (Ants and Myriapods) in the city of Yaoundé, Cameroon. Journal of Entomology and Zoology Studies 7: 1030–1037.

Matteson KC, Ascher JS, Langellotto GA (2008) Bee richness and abundance in New York City urban gardens. Annals of the Entomological Society of America 101: 140–150. https://doi.org/10.1603/0013-8746(2008)101[140:braain]2.0.co;2

McGlynn TP (1999) The worldwide transfer of ants: geographical distribution and ecological invasions. Journal of Biogeography 26: 535–548. https://doi.org/10.1046/j.1365-2699.1999.00310.x

McGlynn TP, Meineke EK, Bahlai CA, Li E, Hartop EA, Adams BJ, Brown BV (2019) Temperature accounts for the biodiversity of a hyperdiverse group of insects in urban Los Angeles. Proceedings of the Royal Society B: Biological Sciences 286: 20191818. https://doi.org/10.1098/rspb.2019.1818

Melo TS, Peres MCL, Chavari JL, Brescovit AD, Delabie JHC (2014) Ants (Formicidae) and spiders (Araneae) listed from the metropolitan region of Salvador, Brazil. Check List 10: 355–365. https://doi.org/10.15560/10.2.355

Menke SB, Guénard B, Sexton JO, Weiser MD, Dunn RR, Silverman J (2010) Urban areas may serve as habitat and corridors for dry-adapted, heat tolerant species; an example from ants. Urban Ecosystems 14: 135–163. https://doi.org/10.1007/s11252-010-0150-7

Moreau CS, Deyrup MA, Davis LR (2014) Ants of the Florida Keys: species accounts, biogeography, and Cconservation (Hymenoptera: Formicidae). Journal of Insect Science 14:295. https://doi.org/10.1093/jisesa/ieu157

Ouellette GD, Drummond FA, Choate B, Groden E (2010) Ant diversity and distribution in Acadia National Park, Maine. Environmental Entomology 39: 1447–1456. https://doi.org/10.1603/en09306

Okpanachi MA, Yaro CA (2019) Ants (Hymenoptera: Formicidae) from Kogi State University Campus, Anyigba, Nigeria. East African Scholars Journal of Agriculture and Life Sciences 2: 221–226.

Pećarević M, Danoff-Burg J, Dunn RR (2010) Biodiversity on Broadway—enigmatic diversity of the societies of ants (Formicidae) on the streets of New York City. PLoS ONE 5 (10): e13222. https://doi.org/10.1371/journal.pone.0013222

Pelini SL, Bowles FP, Ellison AM, Gotelli NJ, Sanders NJ, Dunn RR (2011) Heating up the forest: open-top chamber warming manipulation of arthropod communities at Harvard and Duke Forests. Methods in Ecology and Evolution 2: 534–540. https://doi.org/10.1111/j.2041-210x.2011.00100.x

Penick CA, Savage AM, Dunn RR (2015) Stable isotopes reveal links between human food inputs and urban ant diets. Proceedings of the Royal Society B: Biological Sciences 282: 20142608. https://doi.org/10.1098/rspb.2014.2608

Pimm SL, Jenkins CN, Abell R, Brooks TM, Gittleman JL, Joppa LN, Raven PH, Roberts CM, Sexton JO (2014) The biodiversity of species and their rates of extinction, distribution, and protection. Science 344 (6187): 1246752. https://doi.org/10.1126/science.1246752

Pincebourde S, Murdock CC, Vickers M, Sears MW (2016) Fine-scale microclimatic variation can shape the responses of organisms to global change in both natural and urban environments. Integrative and Comparative Biology 56: 45–61. https://doi.org/10.1093/icb/icw016

Piva A, Campos AEC (2012) Ant community structure (Hymenoptera: Formicidae) in two neighborhoods with different urban profiles in the city of São Paulo, Brazil. Psyche 2012: 390748. https://doi.org/10.1155/2012/390748

Putyatina TS, Perfilieva KS, Zakalyukina YV (2017) Typification of urban habitats, with ant assemblages of Moscow city taken as an example. Entomological Review 97: 1053–1062. https://doi.org/10.1134/S0013873817080048

Radchenko AG, Stukalyuk SV, Netsvetov MV (2019) Ants (Hymenoptera, Formicidae) of Kyiv. Entomological Review 99: 753–773. https://doi.org/10.1134/S0013873819060058

Reyes-López J, Taheri A (2018) First checklist of ants (Hymenoptera, Formicidae) of urban green areas in Cádiz (Andalusia, Spain). Boletín de la Asociación Española de Entomología 42: 217–223.

RIDEM (2015) Rhode Island's fish and wildlife habitat. In: Rhode Island Wildlife Action Plan. The Rhode Island Department of Environmental Management, Providence, USA, 1–66.

Roeder KA, Roeder DV (2016) A checklist and assemblage comparison of ants (Hymenoptera: Formicidae) from the Wichita Mountains Wildlife Refuge in Oklahoma. Check List 12: 1935. https://doi.org/10.15560/12.4.1935

Sarnat E, Blanchard B, Guénard B, Fasi J, Economo E (2013) Checklist of the ants (Hymenoptera, Formicidae) of the Solomon Islands and a new survey of Makira Island. ZooKeys 257: 47–88. https://doi.org/10.3897/zookeys.257.4156

Saunders ME (2019) No simple answers for insect conservation: media hype has missed the biggest concern that ecologists and entomologists have about six-legged life: how little we know about it. American Scientist 107: 148. https://doi.org/10.1511/2019.107.3.148

Savage AM, Hackett B, Guénard B, Youngsteadt EK, Dunn RR (2014) Fine-scale heterogeneity across Manhattan's urban habitat mosaic is associated with variation in ant composition and richness. Insect Conservation and Diversity: 8: 216–228. https://doi.org/10.1111/icad.12098

Sheard JK, Sanders NJ, Gundlach C, Schär S, Larsen RS (2020) Monitoring the influx of new species through citizen science: the first introduced ant in Denmark. PeerJ 8: e8850 https://doi.org/10.7717/peerj.8850

Simberloff DS, Wilson EO (1969) Experimental zoogeography of islands: the colonization of empty islands. Ecology 50: 278–296. https://doi.org/10.2307/1934856

Slipinski P, Zmihorski M, Czechowski W (2012) Species diversity and nestedness of ant assemblages in an urban environment. European Journal of Entomology 109: 197–206. https://doi.org/10.14411/eje.2012.026

Souza-Campana DR de, Silva OGMD, Menino L, Morini MS de C (2016) Epigaeic ant (Hymenoptera: Formicidae) communities in urban parks located in Atlantic Forest biome. Check List 12: 1967. https://doi.org/10.15560/12.5.1967

Stahlschmidt ZR, Johnson D (2018) Moving targets: determinants of nutritional preferences and habitat use in an urban ant community. Urban Ecosystems 21: 1151–1158. https://doi.org/10.1007/s11252-018-0796-0

Stringer LD, Stephens AEA, Suckling DM, Charles JG (2009) Ant dominance in urban areas. Urban Ecosystems 12: 503–514. https://doi.org/10.1007/s11252-009-0100-4

Talbot M (1934) Distribution of ant species in the Chicago region with reference to ecological factors and physiological toleration. Ecology 15: 416–439. https://doi.org/10.2307/1932358

Talbot M (2012) The natural history of the ants of Michigan's E.S. George Reserve: a 26-year Study. Museum of Zoology, University of Michigan, Ann Arbor, USA, 228 pp.

Tamura K, Stecher G, Kumar S (2021) MEGA 11: Molecular Evolutionary Genetics Analysis version 11. Molecular Biology and Evolution 38: 3022–3027. https://doi.org/10.1093/molbev/msab120

Tommasi D, Miro A, Higo HA, Winston ML (2004) Bee diversity and abundance in an urban setting. The Canadian Entomologist 136: 851–869. https://doi.org/10.4039/n04-010

Tschinkel WR, Wilson EO (2014) Scientific natural history: telling the epics of nature. BioScience 64 (5): 438–443. https://doi.org/10.1093/biosci/biu033

Tschinkel WR, Murdock T, King JR, Kwapich C (2012) Ant distribution in relation to ground water in north Florida pine flatwoods. Journal of Insect Science 12 (1): 114. https://doi.org/10.1673/031.012.11401

Uno S, Cotton J, Philpott SM (2010) Diversity, abundance, and species composition of ants in urban green spaces. Urban Ecosystems 13: 425–441. https://doi.org/10.1007/s11252-010-0136-5

Vepsäläinen K, Ikonen H, Koivula MJ (2008) The structure of ant assemblages in an urban area of Helsinki, southern Finland. Annales Zoologici Fennici 45: 109–127. https://doi.org/10.5735/086.045.0203

Vepsäläinen K, Pisarski B (1982) Assembly of island ant communities. Annales Zoological Fennici 19: 327–335.

Ward PS (2006) Ants. Current Biology 16: R152–R155. https://doi.org/10.1016/j.cub.2006.02.054

Watanasit S, Noon-anant N, Binnima N (2005) Preliminary survey of ants at a reserve area of Prince of Songkla University, Songkhla Province, southern Thailand. Songklanakarin Journal of Science and Technology 33: 151–161.

Wetterer JK, Espadaler X, Wetterer AL, Cabral SGM (2004) Native and exotic ants of the Azores (Hymenoptera: Formicidae). Sociobiology 44: 1–20.

Wetterer JK, Espadaler X, Wetterer AL, Aguin-Pombo D, Franquinho-Aguiar AM (2007) Ants (Hymenoptera: Formicidae) of the Madeiran Archipelago. Sociobiology 49: 1–33.

Wetterer JK, Lubertazzi D, Rana JD, Wilson EO (2016) Ants of Barbados (Hymenoptera, Formicidae). Breviora 548: 1–34.

Wetterer JK, Ward PS, Wetterer AL, Longino JT, Trager JC, Miller SE (2000) Ants (Hymenoptera: Formicidae) of Santa Cruz Island, California. Bulletin of Southern California Academy of Sciences 99: 25–31.

Wheeler WM (1906) Fauna of New England. 7. List of the Formicidae. Occasional Papers of the Boston Natural History Society 7: 1–24.

Wilson EO (2017) Biodiversity research requires more boots on the ground. Nature Ecology & Evolution 1: 1590–1591. https://doi.org/10.1038/s41559-017-0360-y

Yamaguchi T (2004) Influence of urbanization on ant distribution in parks of Tokyo and Chiba City, Japan. I. Analysis of ant species richness. Ecological Research 19: 209–216. https://doi.org/10.1111/j.1440-1703.2003.00625.x
Yashavantakumar GS, Vidya VN, Vidya RS, Veeranagoudar DK, Biradar PM (2016) Diversity of ant species in Karnatak University campus, Dharwad. International Journal of Advanced Scientific Research and Management 1: 64–69.

Appendix

Photos and identification of the 36 species collected in Providence, Rhode Island, USA.

Figure A1. *Tapinoma sessile*

Figure A2. *Brachyponera chinensis*

Figure A3. *Ponera pennsylvanica*

Figure A4. *Brachymyrmex depilis*

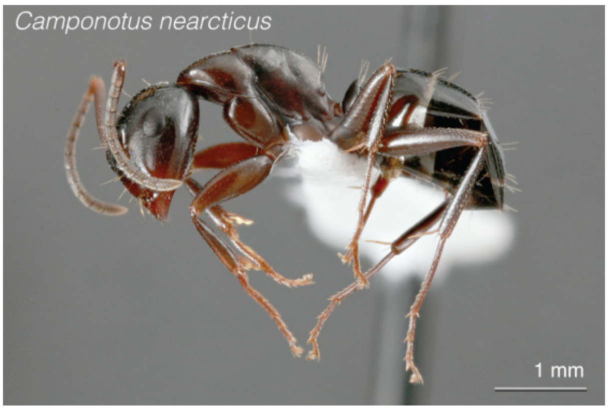

Figure A5. *Camponotus nearcticus*

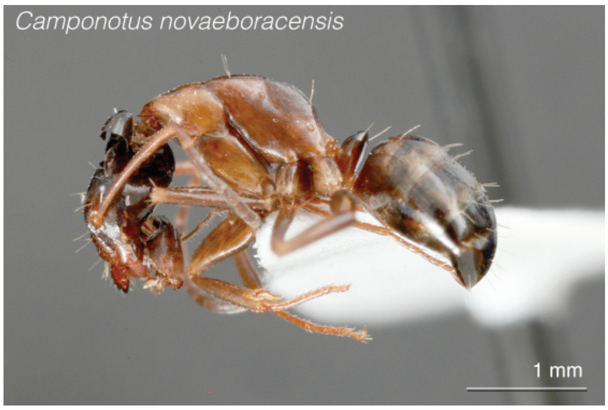

Figure A6. *Camponotus novaeboracensis*

Figure A7. *Camponotus pennsylvanicus*

Figure A8. *Formica dolosa*

Figure A9. *Formica incerta*

Figure A10. *Formica neogagates*

Figure A11. *Formica neorufibarbis*

Figure A12. *Formica obscuriventris*

Figure A13. *Formica subintegra*

Figure A14. *Formica subsericea*

Figure A15. *Lasius americanus* (formerly, *L. alienus*)

Figure A16. *Lasius brevicornis*

Figure A17. *Lasius claviger*

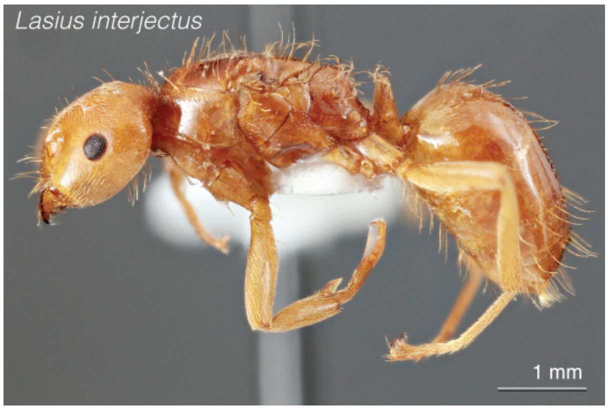

Figure A18. *Lasius interjectus*

Figure A19. *Lasius latipes*

Figure A20. *Lasius nearcticus*

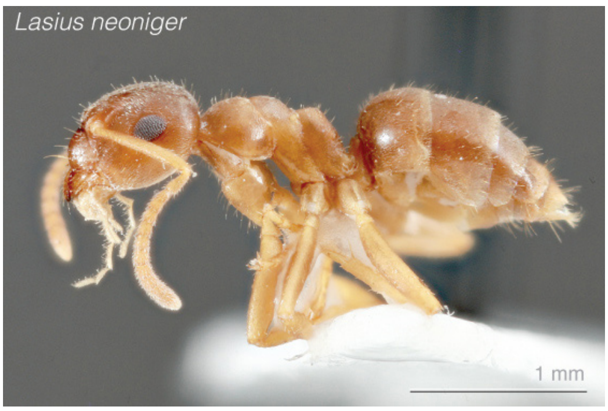

Figure A21. *Lasius neoniger*

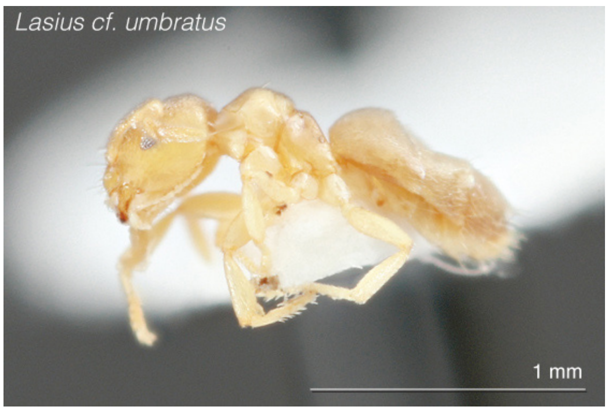

Figure A22. *Lasius* cf. *umbratus*

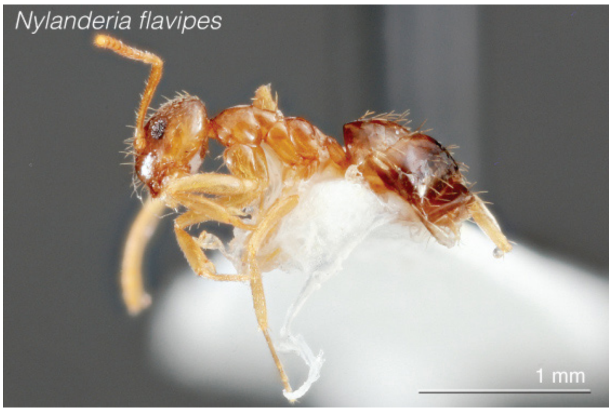

Figure A23. *Nylanderia flavipes*

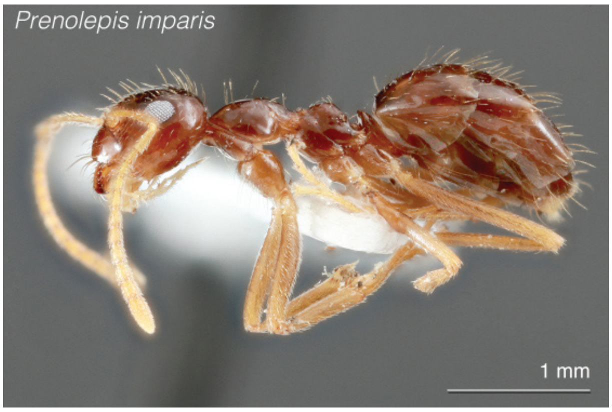

Figure A24. *Prenolepis imparis*

Figure A25. *Aphaenogaster fulva*

Figure A26. *Aphaenogaster picea*

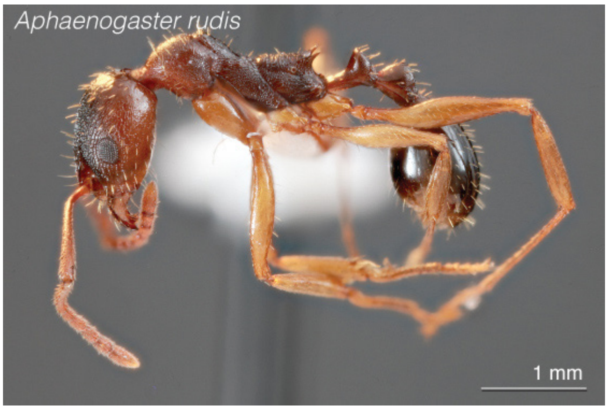

Figure A27. *Aphaenogaster rudis*

Figure A28. *Crematogaster cerasi*

Figure A29. *Myrmica detritinodis*

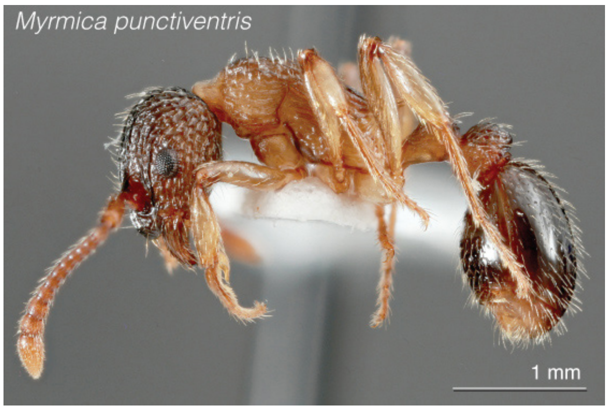

Figure A30. *Myrmica punctiventris*

Figure A31. *Solenopsis molesta*

Figure A32. *Stenamma brevicorne*

Figure A33. *Temnothorax curvipspinosus*

Figure A34. *Temnothorax longispinosus*

Figure A35. *Temnothorax schaumii*

Figure A36. *Tetramorium immigrans*