Ecology of Urban Bees: Preference for Native Plants in the Green Spaces of Quito

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Abstract

Across the Andes, bees are a heavily understudied group of insects, and despite it being seemingly counterintuitive, urban ecosystems are home to some of the least studied bees in the region. This, combined with the largely modified plant communities that characterize South American urban green spaces, where European and North American flora often rivals in abundance and richness with that of native plants, makes it so Andean cities like Quito, Ecuador, are perfect for studying both the ecology of bee pollinators, as well as the impact that exotic species have on native bees. We reviewed the reported diversity and interactions inside citizen science platform iNaturalist and in local entomological collections, and we also conducted direct observations on 5 native and 3 exotic plant species inside a city park during a four-month period, of which 6 species produced sufficient flowering for analysis, all in order to answer: 1) What is the diversity and spatial distribution of bee species and their plant associations across the urban green spaces of Quito? 2) Do native bee species show stronger preferences for native versus exotic flowering plants, and which plant species are most important for urban pollinators? We were able to identify 31 morphospecies belonging to five bee families, of which only one species was exotic. When excluding the exotic *Apis mellifera*, all four native bee families showed preference towards native flowering plants, although most bees were also shown to be polylectic, capable of visiting other flowers whenever their preferred food source was not available. We determined that abundance and richness of native plants held the highest correlation with native bee diversity, and we also identified *Dalea coerula, Bidens andicola* and *Lupinus pubescens* as the most important plants for urban pollinators inside the city of Quito. Overall, the implementation of native plant patches inside urban greenspaces is a decisive factor for bee conservancy in urban ecosystems of South America.

Introduction

Traditionally, urban ecosystems have been associated with low biodiversity. However, studies conducted over the last decade have demonstrated that, depending on habitat quality, cities can be home to a diverse array of insect pollinators such as bees and may even have higher native plant diversity than surrounding rural landscapes (Bates et al. 2011; Kowarik 2011). Moreover, although often overlooked, urban ecosystems provide their inhabitants with various ecosystem services dependent on their species' richness and abundance. These services include cooling effects, crop pollination and air quality improvement, all of which are in turn determined by the size of urban green spaces (Kremen et al. 2004; Aram et al. 2019; Islam et al. 2024).

Along with native plant coverage remnants, parks are the largest green spaces within cities. Their high accessibility allows city inhabitants to interact with nature without leaving the urban landscape. These experiences enrich the city-dwellers' lifestyle and fulfill important psychological needs (Chiesura 2004). In urban ecosystems, parks are where biodiversity often reaches its peak (Nielsen et al. 2014), although this depends on the park's size and landscape configuration. Even when comparing parks of similar size and proximity to forest remnants, other factors play a key role in understanding the composition of ground dwelling invertebrates such as the density of surrounding manmade structures and ground features (Peng et al. 2020). Therefore, its possible that these characteristics also determine the diversity of pollinators, such as ground-nesting bees. Additionally, vegetation composition within a park also affects the quality of services provided along with the diversity associated with said services. More homogenous parks tend to have lower species richness while heterogeneous green spaces, particularly mixed forests, host richer communities, providing higher quality ecosystem services (Nielsen et al. 2014; Mexia et al. 2018).

Flora and its pollinators are two key components of both natural and urban ecosystems. While both groups are often studied independently inside urban ecosystems, research that encompasses both flora and fauna in a multidisciplinary, multi-species approach is rare but necessary to better understand biodiversity patterns in parks and other urban green spaces (Nielsen et al. 2014). Among pollinators, bees (Anthophila) are exceptional, as they are responsible for approximately 80% of the insect-driven pollination as well as the pollination of more than 60% of the world's crops (Kremen et al. 2004; Thapa 2006). Consequently, a significant decline in bee diversity could cause the setting rates of various crops to drop (Klein et al. 2003). Even within cities, bees are often the most efficient pollinators available, though not necessarily the most abundant; this is especially true for native bees (Hausmann et al. 2016). A key unanswered question in plant-bee interactions is whether or not bees have a preference towards native plants. Current research suggests the answer is context-dependent, with studies supporting both hypotheses (Nicholls and Altieri 2013; Pardee and Philpott 2014; Philpott et al. 2023).

Increasing urbanization and other changes in land use are worldwide threats to bee populations. While urban green spaces may be suitable for bees to inhabit, the surrounding urban infrastructure also determines the number of bee species that could be able to live in these environments (Ahrné et al. 2009). Additionally, changes in the diversity and availability of floral resources also shape the pollinator communities of cities (Potts et al. 2010). In South America (SoAm), another threat to bee conservation is the expansion of the agricultural and livestock frontier (Freitas et al. 2009), as these areas often supply food to growing urban populations. Consequently, creating spaces that benefit the pollinators inside our cities has become both a need and a responsibility. Planting vegetation that benefits native bees can increase their abundance and richness, without sacrificing ornamental appeal (Frankie et al. 2005; Frankie et al. 2009). Different bee species can have preferences towards different plant families, such as Asteraceae or Lamiaceae, preferred by bees from the families Halictidae and Apidae respectively (Frankie et al. 2009). Because of this, understanding the preferences of the bee communities inside a city or wider biogeographic region is the first step toward achieving a successful habitat restoration.

Understanding the interactions between exotic and native species becomes more important in SoAm, where plant species' richness in urban parks appears to be higher for invasive plant species and lower for natives when compared to cities in North America, Europe or Asia (Nielsen et al. 2014; Figueroa et al. 2018). If bees in SoAm are shown to prefer native food sources, then urban parks should prioritize including a greater diversity of plant species that are preferred by local pollinators. The number of studies that describe the determinants of bee diversity and ensembles conducted in SoAm are about 4.5 times lower than those conducted in North America or Europe, with only a small number focused on high Andean cities (Prendergast et al. 2022).

In this study, we describe the relationship between bee pollinators and their native and exotic plant hosts in the green spaces within the urban parishes of the Metropolitan District of Quito (DMQ for its Spanish acronym), Ecuador. We assessed bee and plant abundance and richness using records from

scientific collections and the citizen science platform iNaturalist (https://ecuador.inaturalist.org/). We then carried out several field surveys in a city park, where we observed six species of plants and the pollinators that visited them, recording the number of flowers per plant, the ambient temperature and the overall richness of flowering plants at the time of each survey. We aimed to answer the following questions: 1) What is the diversity and spatial distribution of bee species and their plant associations across the urban green spaces of Quito? 2) Do native bee species show stronger preferences for native versus exotic flowering plants, and which plant species are most important for urban pollinators?

Materials and Methods

1. Study Design Overview

We combined two complementary approaches operating at different spatial scales: (1) a city-wide analysis of bee occurrence and bee–plant interaction data derived from museum collections and citizen science records across the DMQ, and (2) standardized field observations of bee visitation to selected native and exotic plant species within a single metropolitan park.

This dual-scale approach allowed us to evaluate general patterns of bee diversity and plant associations across the city while also directly quantifying visitation frequency, richness, and community composition under controlled field conditions.

2. City-Scale Patterns of Bee Diversity and Bee–Plant Interactions

2.1. Study Area

The DMQ is the canton that contains Ecuador's capital and its surrounding localities. It is located in the northern highlands of the country, as part of the Pichincha province, at a median altitude of 2 620 meters above sea level. The city is located across inter-volcanic valleys and is crossed by multiple small rivers that feed the Guayllabamba river basin. Quito has two seasons: a cold, wet season from October to May, and a warmer, dry season from June to September, with an average difference of only 0.9°C between the hottest and coldest months (15.3°C and 14.4°C respectively) (World Meteorological Organization 2013). The temperature is higher during the peak activity hours for bees, at around 17.5°C.

The DMQ is the second most populated city of Ecuador, with over 2 679 722 inhabitants and a high population density of approximately 4 735 residents per square kilometer (Instituto Nacional de Estadísticas y Censos 2022). Because of this, the DMQ is highly urbanized, and little of its original plant coverage remains, primarily as remnants surrounding rivers or within ravines. Despite this, the DMQ contains more than 1 355 parks and green areas, including 15 metropolitan parks that together cover approximately 1 960 ha. These parks form corridors that allow the movement of native flora and fauna across the city while also combining patches of exotic vegetation, such as eucalyptus forests, grasslands and lawns. The DMQ is administratively divided into urban, suburban and rural parishes. In this study, we focused on the 32 urban parishes (Fig. 1).

2.2. Data Collection

To explore the bee diversity and its interactions with the urban flora we downloaded bee occurrence records within the DMQ, directly from iNaturalist (https://ecuador.inaturalist.org/; only "research grade" records). We selected the observations to include only records from urban parishes, and then we curated them to either genus or species level by comparing the photographs with reference material from the Museum of Zoology of the Pontifical Catholic University of Ecuador (QCAZ) and using regional identification keys and historical species lists (Cockerell 1914; Mitchell 1930; Michener 2007; Moreno-Coellar et al. 2025) which we used to construct a species list (Table 1). All observations that featured bee-plant interactions were further curated to identify the associated plant species and family, with identifications validated in the PUCE QCA Herbarium. Additionally, we also downloaded data of occurrence via the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/; only museum records) database.

2.3. Selection of Focal Plant Families

To identify the plant groups most relevant to urban bee diversity within the DMQ, the interaction records from the city-scale dataset were aggregated at the plant family level. Plant families whose data accounted for more than 10% of the total number of recorded interactions were retained for further analysis.

For each of these families, we downloaded all plant observations, curated them, and assigned an origin value (native or exotic) to each species using the Plants of the World Online database and the new catalogue for continental Ecuador exotic flora to assign the origin status to each species (Ileana et al. 2025; Royal Botanical Gardens 2025).

2.4. Distribution of Quito's bees

We uploaded the data to ArcGIS (https://www.arcgis.com) where, using the coordinates available from some museum data and iNaturalist observations, we were able to determine the bee richness relative to area of each of the urban parishes; we also calculated the plant richness and abundance relative to area for all of the parishes.

Using this data, we determined which areas of the DMQ had the highest bee diversity relative to area and we also made four line graphs to visualize how the distribution of the bee species richness and the abundance and richness of plants correlated. Additionally, we created a visual heat map (Fig. 2) to identify the parishes that hosted the highest bee diversity.

3. Field Assessment of Bee–Plant Interactions

3.1. Selection of Focal Plant Species

To evaluate bee visitation to native and exotic plants under controlled field conditions, we selected flowering plant species based on their prominence in the city-scale bee–plant interaction dataset. Plant species were chosen to represent the most frequently visited taxa by native bees. In total, eight plant species were selected for monitoring: five natives and three exotics. Native species included *Dalea coerulea* (L.f.) Schinz & Thell., *Lupinus pubescens* Benth., *Bidens andicola* Kunth., and *Monnina salicifolia* Ruiz & Pav., which showed a high number of interactions with native bees in the city-wide dataset. Exotic species included *Hypochaeris radicata* L. and *Trifolium repens* L., selected as exotic counterparts to native species within the families Asteraceae and Fabaceae, respectively. In addition, *Salvia microphylla* Kunth. was selected due to its high number of recorded interactions, and *Salvia pauciserrata* Benth. was included as its native counterpart within Lamiaceae. In the event that any selected species failed to produce sufficient flowers during the sampling period, those species would be excluded from the interaction analysis but retained in the park survey effort.

3.2. Field Study Site

All field surveys were conducted within Bicentenario Metropolitan Park, a large urban green area selected because it contains a combination of exotic and native vegetation and because it was the only metropolitan park that already included all eight plant species selected for study. The park covers 103 ha and is located on the site of the city's former airport. Several ecological restoration efforts have been implemented within the park, resulting in large areas of native vegetation composed primarily of trees but also some bushes and herbaceous plants. The park also has grass lawns, where exotic Asteraceae and Fabaceae are the predominant flowering species, as well as various trails and a sports track adapted from the former airplane runway (Fig. 1) (EPMMOP 2024).

Each plant species was represented by two individual specimens within the park. All plants were located within approximately one hectare of one another, and a 1 m² observation quadrant was established for each individual plant (Fig. 1). We acknowledge that two individuals per species constitutes limited replication. This was constrained by the availability of naturally occurring specimens within the park, as Bicentenario was the only metropolitan park containing all selected species simultaneously, making it unfeasible to increase replication by sampling across multiple parks.

3.3. Observation and Collection Protocol

We relied on direct observation, paired with monthly hand nettings, to monitor the bees inside the park. We conducted observations twice a week, from May to August, in order to determine which bee species were feeding on each flower. To achieve this, we observed quadrants of one square meter for ten minutes at a time. We annotated every bee and other pollinators that were actively feeding on the flowers, nectar robbing was also considered, as in the case of carpenter bees that would often pierce the flower's corollas to access their food (Rojas-Nossa et al. 2016). We identified the bees to genus level, or in the case it was possible, to species level, while non-bee pollinators were identified only to family level (**Supplementary 1**). Since most insect pollinators are more active during warm, clear days, we only conducted our observations between 10 and 12:30 am, when the temperature was up to three degrees lower or higher than the average (17.5° ± 3° C); we also canceled the observations on rainy days. Before starting each observation, we annotated the date, temperature and the number of inflorescences of the selected plant species inside the quadrant, each day we carried out observations on every plant species selected, in a randomized order. In case some of the plant species didn't have any mature flowers, we annotated both the number of visits and the number of flowers as zero.

We used the hand netting to collect bee species that were difficult to identify by sight only, this included small halictids or colletids. We conducted the nettings once a month, on days where no direct observations were carried out, along with them, we also photographed bees and other pollinators to document their interactions. We compared the bees collected with the ones held at the invertebrate section of QCAZ and the National Institute of Biodiversity (INABIO) using taxonomic keys for each bee group (Friese 1899; Cockerell 1914; Moure 1964; Silveira et al. 2002; Gonzalez and Michener 2004; Roig Alsina 2009; Ferrari 2017; Packer 2021; Moreno-Coellar et al. 2025)

4. Bee–Plant Interactions

To characterize patterns of interaction between bees and flowering plants in Quito, we constructed two sets of bipartite bee–plant interaction networks. The first one used the citizen science dataset including plants from the eight most frequently visited plant families for the urban parishes of the DMQ, we built one network that showed the interactions between native bee morphospecies and plant species. Since the data we recovered can't be used to accurately portray the preference bee species may have towards different food sources, this network only explores the diversity of interactions within the city. Because of this, we converted the data into a binary dataset, where 1 meant the interaction between a bee and a plant species had been recorded and 0 meant it had not.

For the second set of networks we used the dataset containing data from the six plant species monitored at the Bicentenario metropolitan park. We created three distinct networks. The first one showed the links between the bee species and the six plant species, the second showed the links between the bee species and the plants classified by their origin (native or exotic), and the third showed the links between the four bee families found at the Bicentenario park and the plants classified by their origin. The monitoring allowed us to accurately portray the abundance each bee species had at each of the six plant hosts, thus, the networks of this set show the preference bee species have towards different taxa.

For both sets of networks, each plant species was classified according to its geographical origin (endemic, native, or exotic) following the catalogues of Jørgensen & León-Yánez (1999) and Herrera et al. (2025). We calculated the species degree (the number of interacting species from the opposite trophic

level) for each network. All networks were constructed in R version 4.3.1 (R Core Team, 2023) using the bipartite package v2.18 (Dormann et al., 2008).

The networks presented here are intended as qualitative visualizations of interaction structure. No additional network-level metrics were calculated, as the primary statistical comparisons between native and exotic plant use were addressed through the PERMANOVA analyses described below.

5. Statistical analysis

We analyzed the interactions observed at Bicentenario park to test whether variation in bee abundance at native and exotic plants was greater within groups or between groups to assess the significance of the differences between the communities of bees that visited each group. We applied a Permutational Multivariate Analysis of Variance (PERMANOVA) using the 'vegan' package in R, with 10 000 permutations, based on Bray-Curtis dissimilarity calculated from square-root transformed bee abundance data, grouping the two exotic plants' data as group one and the four native plants' data as group two. We then repeated this analysis to test if the variation in bee abundance was greater among different host plant species than among different sampling events of the same plant species. Finally, to evaluate the similarity between the bee communities associated with each plant species, and the similarity in host plant use between bee species, we generated two projections of the bipartite networks using the 'igraph' R package using the function bipartite_projection, creating two graphs labelled as proj1 for the similarities among plants and proj2 for the similarities among bees.

Results

1. City-Scale Patterns of Bee Diversity and Bee–Plant Interactions

We retrieved a total of 755 bee occurrence records between museum data from GBIF (130) and citizen science data from iNaturalist (625). All five bee families reported for Ecuador were also recorded within the city: Apidae, Megachilidae, Halictidae, Colletidae and Andrenidae. We registered a total of 31 morphospecies (Table 1), most of which belonged to Apidae (13) and Halictidae (7), Megachilidae (5) and Colletidae (5) tied for the second lowest species richness and Andrenidae had only one species. In terms of relative abundance, Apidae (72.58%) also had the highest number of collections and observations, followed by Megachilidae (11.52%), Halictidae (10.46%) and Colletidae (5.43%). The most frequently recorded species were *Thygater aethiops* (Smith, 1854) (17.09%), *Xylocopa viridigastra* Lepeletier, 1841 (14.97%) and *Bombus robustus* Smith, 1854 (13.38%).

Of the 625 iNaturalist observations, 333 showed native bees interacting with identifiable plant species. These interactions involved plants from 15 families of which the most frequently visited were Fabaceae (101), Lamiaceae (88) and Asteraceae (76). Fabaceae was important for Apidae and Megachilidae, 40.93% and 31.15% respectively of these bees' interactions were with this family. Lamiaceae was primarily visited by Apidae (40.41%). Asteraceae was most frequently visited by Halictidae (72.88%) and to a lesser extent Megachilidae (26.27%). Polygalaceae was the family Colletidae interacted with the most, with 75% of Colletidae interactions occurring with species of the genus *Monnina* (Table 2, Fig. 3).

The bipartite network of the citizen science data set showed 132 types of interactions between 43 plant species and 20 bee species within the DMQ (Fig. 3). *Dalea coerulea* was the plant that showed the highest number of links, interacting with 13 bee species, followed by *Hypochaeris radicata* (9) and *Bidens andicola* (7). On the other hand, the bee that showed the highest number of links was *Megachile* sp. as this bee interacted with 20 plant species, followed by *T. aethiops* (15), *Anthophora pillifrons* Packard, 1869 (12), *B. funebris* (11) and *X. viridigastra* (11). Family Andrenidae was not included in the network as the sole representative of this family, *Andinopanurgus amyae* (Gonzalez & Engel, 2011) had only one interaction record.

Eight plant families were involved in 80% of the interactions with bees: Asteraceae, Fabaceae, Solanaceae, Lamiaceae, Rosaceae, Onagraceae, Polygalaceae, and Rutaceae.

Most of the reported bee richness came from large urban parks, making the parishes of Iñaquito and Jipijapa the most rich in bee species (Fig. 2). Native plant richness was the best indicator for native bee richness as the line graphs showed that the native plant richness relative to area and native bee richness relative to area resembled each other the most (Fig. 4).

Additionally, we uploaded to iNaturalist all digital evidence of the interactions photographed while monitoring inside the Bicentenario Park, to provide evidence of the interactions occurring between plants and pollinators inside the city, these interactions include visits to plants that were not considered in the monitorings but were flowering between the quadrants (Fig. 5).

2. Field Assessment of Bee–Plant Interactions

During field surveys, we registered 16 bee species (Table 1) interacting with the eight selected flowers within Bicentenario metropolitan park. An additional bee species, *Thygater aethiops*, was recorded within the park; however, it only fed on *Solanum nigrescens*, a plant species not considered in this study. Of the 16 bee species recorded, only one was exotic, *Apis mellifera* Linnaeus, 1758, while all others were native to the area. Bees belonged to four families, with Apidae being the most diverse. We recorded 6 species from Apidae, 3 for Megachilidae, 4 for Halictidae, and 3 for Colletidae. Due to the difficulties in identifying free-flying bees, we decided to group both morphospecies of *Megachile* Latreille, 1802, as well as both morphospecies of *Colletes* Latreille, 1802 (Table 3).

3. Bee–Plant Interactions

Two of the initially selected species (*Monnina salicifolia* and *Salvia microphylla*) did not flower sufficiently during the sampling period and were excluded from the quantitative analysis, as established in the study design. All subsequent analyses are therefore based on the remaining six species. The network showed 554 interactions between 16 bee species and the six remaining plant species (Fig. 6, Table 3). Of these interactions, 420 (75.81%) were between bees and native plant species, the other 134 (24.19%) were between bees and exotic plants (Fig. 7).

The plant species with the highest number of links was *D. coerulea*, which received 283 visits from bee pollinators. The plant species with the lowest number of interactions were *S. pauciserrata* (Lamiaceae, native) and *L. pubescens* (Fabaceae, native) with 40 visits each. *D. coerulea* (Fabaceae, native) also had the highest bee species richness (10 species), followed by *B. andicola* (Asteraceae, native) with 8 species. (Table 4).

The bee species with the highest number of links was *A. mellifera* (Apidae), with a total of 139 recorded visits, mainly to exotic plant species (84.17%). *Megachile* sp. (Megachilidae, native) held the second highest number of interactions at 132, all of which were with native species (Fig. 6). The rarest bee species were *Caupolicana niveofasciata* Friese, 1898 (Colletidae, native), observed only once visiting the native *B. andicola*, and an unidentified species of *Exomalopsis* Spinola, 1853 (Apidae, native), which was recorded once visiting the exotic *T. repens*.

Most of the native bees recorded were ground-nesting solitary bees (gs) (60.48%), followed by ground-nesting eusocial bees (ge) (17.83%) and wood-nesting gregarious bees (wg) (15.42%). The abundant gs bees were mainly polylectic, visiting both native and exotic flowers of various families. ge bees, on the other hand, preferred native Fabaceae (*D. coerulea* and *L. pubescens*), but when these plants had a low floral availability, they would also rob nectar from *S. pauciserrata*. A similar pattern was observed for ws bees. Finally, cuckoo bees would feed on the same flowers as their hosts from the genus *Megachile* (Table 3). Four bee families interacted with the targeted plant species. Ranked from most to least abundant these were: Apidae (50.54%), Megachilidae (26.35%), Halictidae (21.29%) and Colletidae (1.81%). If we exclude *A. mellifera*, Apidae represented only 33.97% of recorded bees. When excluding the exotic *A. mellifera*, all four bee families showed preference for native flowers over exotic ones (**Supplementary 2**).

4. Statistical analysis

Analysis of the citizen science dataset showed that bees interacted more often with native plants (54.65%) rather than with exotic plants (45.35%). These interactions varied among bee families. Colletidae and Megachilidae were more frequently observed to interact with native plants (85% and 68.85% respectively). Apidae also interacted more with native plants (52.33%), whereas Halictidae interacted more frequently with exotic plants (62.71%). The plant species with the highest number of interactions were *Dalea coerulea* (17.12%), *Salvia microphylla* (12.31%), *Hypochaeris radicata* (11.11%), *Trifolium pratense* (6.91%), and *Bidens andicola* (5.11%). Overall, native plants interacted with a significantly higher abundance of bees than exotic plants did.

Analysis of the Bicentenario park monitoring showed that bees belonging to the family Apidae were largely polylectic, with only three species recorded visiting a single plant host, meanwhile, the other three families had considerably more oligolectic species. Megachilidae bees largely ($p = 1.67e\text{-}4$) preferred native Fabaceae, with only one species also visiting *B. andicola*. Contrary to what the network created with citizen science data (Fig. 3) suggested, Colletidae species were not strictly oligolectic and actually visited flowers from different families, such as Asteraceae and Fabaceae, although their strong preference towards native species was corroborated (Table 2, Table 3).

Bee interactions with native and exotic plants were significantly different (PERMANOVA, $p = 1e\text{-}5$), with most interactions occurring with native plant species. Bee interactions with each plant species were significantly different (PERMANOVA, $p = 1e\text{-}6$).

Discussion

Our research demonstrates that museological and citizen science data can be used to explore the bee richness inside urban ecosystems, like the urban parishes of Quito. It has been proven that photographic surveys can provide abundance estimates similar to the ones obtained by hand nettings and can also provide realistic diversity estimates especially when conducted by researchers, while photographic surveys conducted by citizen scientists show some biases towards larger bees but an overall similarity to the results obtained by researchers (Fogel et al. 2025); another study, conducted at Ecuador's coastal region, provided an assessment of the bee richness inside an organic farm using live photography of lethargic bees who were later released into the wild (Wilson et al. 2025).

We believe that ecological data can be obtained via well standardized field observations and photography, aided but not reliant on citizen science data as a tool to obtain a general understanding of a broader area. On the other hand, taxonomic data is still dependent on collections, our field monitoring, as well as the Wilson et al. (2025) assessment could not identify bees to species level due to the limitations of direct observation and photography. Additionally, the high number of cryptic species found in invertebrates, estimated to be on average 3.1 cryptic species per described insect species, highlights the importance of molecular data when describing or identifying species (Li and Wiens 2023).

Currently iNaturalist includes a feature, that allows users to tag plant-pollinator interactions, with observation fields such as "Nectar plant" and "Nectar/Pollen delivering plant", which have the potential to facilitate exploratory analysis like the one conducted in this study. We recommend that features like this should be made accessible from the iNaturalist mobile app, as right now observation fields can only be added from the computer version of this platform, which might be one of the reasons this valuable function is underused. Although we only used research grade observations for our research, observations classified as "Needs ID" can hold useful information that's often overlooked by researchers. In the case of the bees of the DMQ, insects belonging to the family Andrenidae have been observed inside the urban parishes, but because these bees were only curated to family level, we did not find them when filtering for research grade observations. Future studies should make the additional effort to review all observations available and not only those of research grade.

iNaturalist, where the taxonomic certainty of its observations is limited by the quality of the photographic evidence uploaded, might be more suited to monitoring and describing the ecology of larger bees, as it has been proven that citizen science data might be far more efficient than traditional methods at recording presence data from either invasive or endangered large-bodied bees (Wilson et al. 2020; Orr et al. 2023). In the context of SoAm, the quick identification of invasive species is key to protect the native pollinators and apps like iNaturalist might be the first to alert the scientific community of threats like the invasive *Bombus terrestris* (Linnaeus, 1758), whose range has been steadily increasing in the southern part of the continent (Geslin and Morales 2015; Aizen et al. 2019; Fontúrbel et al. 2021).

Overall, we believe that citizen science data can contribute with a wider lens to understanding the pollination ecology of urban ecosystems as it provides data from a broader area than most traditional monitorings could achieve, but its limitations to accurately portray the richness and abundance of native pollinators highlights the need for field monitoring conducted by researchers or by citizens under the supervision of trained staff.

We combined citizen science data with direct observations conducted inside a city park where we were able to describe the bee communities associated with six urban plant hosts that were part of a diverse floral neighborhood. We used a combination of direct observation, photography and nettings to document the bees present at metropolitan park Bicentenario, where we were able to identify 16 bee morphotypes. We conducted as few nettings as possible, trying to collect only a male and a female of each species for identification purposes only, as the local bee fauna remains largely undescribed or understudied. We believe that, in ecosystems with low bee abundance, it is best not to conduct large scale collections as they are likely to cause harm to the bee communities that are already threatened by habitat loss and their host plants' replacement with ornamental species. Tepedino and Portman (2021) also suggest that continuous, large-scale monitoring may worsen the status of bee communities, causing them to decline faster; they also suggest that non-lethal monitoring can provide valuable data in species that are identifiable on the field. We extend this assertion to bees that can't be identified to species level on the field but whose conservation status hasn't been assessed, we believe that it is better to keep ecological data up to genus level, rather than risking the safety of bee populations with intensive collections.

We were able to identify most bees present at Quito and inside the Bicentenario park to species level by examining the museological specimens at the QCAZ invertebrate collection and the ones we netted at Bicentenario park. Contrastingly, most identifications done in the field and obtained from iNaturalist data were left on genus level, as many bee species can only be accurately identified when examined under a stereoscope.

We registered 31 different bee species inside the urban parishes of Quito. This equates to around 10% of the reported bee richness of Ecuador (305 species) and around 5% of the country's estimated richness, which is situated at around 600 species (Freitas et al. 2009; Dorey et al. 2026). It should be noted that no bees belonging to the Andrenidae family are listed as part of the Ecuadorian bee diversity by Freitas et al. (2009) but at least three Andrenidae bee species collected in Ecuador can be found in the QCAZ collections, which suggests that both the reported and the estimated richness can be higher inside the region.

Bee richness inside the city of Quito is low when compared with other capitals and large cities of the Americas, across four studies from four different countries the lowest richness was found inside the capital of Colombia, Bogotá, with 40 species; the highest richness was that of the capital of Argentina, Buenos Aires, with 66 species (Nates-Parra et al. 2006; Mazzeo and Torretta 2015). Cities in North America are also home to a higher bee richness than that of Quito, with over 50 species in New York (United States of America) and Vancouver (Canada) (Tommasi et al. 2004; Matteson et al. 2008). The apparently low richness of Quito might be caused by a combination of poorly known bee diversity and the prevalence of exotic plants in urban green spaces.

It is possible that the high bee richness found inside of Quito, relative to the total richness of Ecuador, can be explained by the environment and ecosystem the city was built on top of. Globally, bee richness can be associated with low precipitation during the driest months as well as low seasonality, additionally, bees seem to be more diverse in non-forested ecosystems, such as deserts, bushlands or grasslands (Orr et al. 2021; Dorey et al. 2026), all of which are characteristics shared with the city of Quito.

Bee communities differed significantly among plant species, most bees visited several species (polylecty), while three bee species were recorded on a single plant family or tribe (oligolecty). No bee species were determined to visit a single plant species (monolecty). The low number of oligolectic and monolectic species might be explained by the highly fragmented nature of urban green spaces, which, together with the extent of the city, have been associated with reduced diversity of specialist bees (Ferrari and Polidori 2022). Bees belonging to families Colletidae and Halictidae were the only ones to consistently show a preference towards one or few plant families.

Bees belonging to the Colletidae family were shown to prefer plants from the families Polygalaceae and Fabaceae as their food sources. Plants belonging to the genus *Monnina* (Polygalaceae) and *Dalea* (Fabaceae) were frequently associated with colletids from the genus *Colletes* as well as *Caupolicana niveofasciata* Friese, 1898. Previous studies in the region have not described preferences between these genera, although *Monnina* has previously been reported to interact with *Colletes* and *Caupolicana*, albeit based on anecdotal observations only (Melo 2025). A bee from a related genus, *Mourecolletes brasiliensis* has been reported to have a strong preference towards Fabaceae and Polygalaceae, with these families summing up to 98.5% of the pollen grains found inside the nests of this species (Ferrari et al. 2022).

We found that bees belonging to the Halictidae family often exhibited a broad polylecty and interactions with several bee families were recorded. Despite this, our data also showed that halictids have a preference towards yellow flowers within the Asteraceae family, this preference was most noticeable amongst citizen science data. It's possible that this apparent preference is mainly motivated by floral availability and proximity to the nesting sites of these bees as it has been reported by other authors (Roberts 1969; Celis et al. 2023). In some cases, like with *Agapostemon nasutus* and *Lasioglossum* sp. this preference might go beyond floral availability, as these bees rarely or never foraged on other abundant species and instead frequented the Asteraceae *Bidens andicola* and *Hypochaeris radicata* even when this species had a low floral availability. Other authors have also documented the preference that some

halictids have towards rare plant species and have speculated that it might be explained by other factors like the fact that Asteraceae provides its pollinators with both pollen and nectar while other plant families only offer one of these two resources (Dalmazzo and Vossler 2015; Filho et al. 2023).

The cleptoparasite bees of the genus *Coelioxys* also exhibited a preference towards a specific plant family, Fabaceae. At Park Bicentenario their foraging behavior mirrored that of their possible hosts, *Megachile* antisanillae and *M. ecuadoria*, all three species visited almost exclusively two native legumes (*Dalea coerulea a*nd *Lupinus pubescens*). Literature describing the foraging preferences of *Coelioxys* adults is extremely scarce but the reproductive behavior and larval development of this genus have been reported to align closely with their host's (Scott et al. 2000; Rozen and Kamel 2008). Here, we propose that adult foraging behavior of *Coelioxys* might also mirror that of its host, possibly aiding these bees to identify nesting hosts.

Bee communities also differed significantly between native and exotic plant hosts. In addition to differences in species composition, where exotic bees were more common in exotic hosts and oligolectic and solitary polylectic bees were more common in native hosts, we also documented a higher species richness on some native plants, particularly *Dalea coerulea* and *Bidens andicola.* These data are consistent with previous, shorter studies conducted in the region and across the Ecuadorian Andes, which were based on citizen science databases (Padron 2025).

During our monitoring we noted that some bee species that were rare visitors of the plants we selected, were conspicuous around other plant species. These plants, like *Solanum nigrescens* M.Martens & Galeotti and *Monnina salicifolia* were part of the floral neighborhood of the Bicentenario park, and might explain the rare visits of bee species like *Exomalopsis bruesi* Cockerell, 1914. Future studies should expand the list of plant species monitored to include a broader representation of both native and non-native flora of the Andean cities, as well as other pollinator groups, like lepidopterans and hummingbirds.

Our results showed that native bees in Quito show preference towards native plants (Fig. 7) with both bee abundance and species richness being higher at native host plants. Similar patterns have been reported in other bioregions. Pardee and Philpott (2014), for example, compared paired native and exotic gardens and found that native bee abundance was higher at gardens with native plants. However, bee richness was only higher in native gardens for cavity-nesting species, while the richness of other bee groups depended on the gardens' spatial characteristics. Pawelek et al. (2017) reached the same conclusion by replacing the exotic ornamentals and crops from a local community garden with native, mostly unmanaged vegetation, this resulted in a significant increase in the local bee richness. Morandin and Kremen (2013) also noted how, in old, restored hedgerows, the richness and abundance of bee pollinators was greater on native plants. It should be noted how each of these studies had a different approach. Of these, Morandin and Kremen's is the most similar to ours, although in their study the observer walked across a transect with different plants, whereas we remained stationary in front of measured plots corresponding to individual species.

In contrast to this study, Seitz et al. (2020) found a higher abundance and bee richness on exotic pollinator crops during early flowering season. We believe that these results might be caused by the little time the plant communities have been established, as seeds were planted the same year the experiments were conducted for both 2016 and 2017 repetitions. Our study, as well as the studies cited in the previous paragraph, used plant communities that have been established for over three years, with the native parcels at the Bicentenario Park having been planted in 2015. It is also possible that, while bee communities of Maryland, USA, do visit exotic hosts more frequently, the same is not true for the bee communities of SoAm, or at least the high Andean region. We believe this to be the case as both studies included similar plant genera and families, including *T. repens*, which received high visitation rates in Seitz's study while in ours it did not.

Although both citizen science and direct observation data showed that bees preferred native host plants (Fig. 3, Fig. 6) the degree of these preferences varied significantly, we theorize that, while citizen science data showcases accurately the richness of interactions between bees and flowering plants, it currently doesn't reflect the frequency of each interaction with as much accuracy as observational or netting data obtained by field scientists. The possible limitations of citizen science efforts has been discussed previously by Turley et al. (2024) who found that these surveys documented only half the species richness as traditional collections, while they also often had a strong bias towards larger, more conspicuous bees, like *Bombus* or *Xylocopa*, while small bees are underrepresented. This might also be true for Quito, as both genera of large bees are better represented than the smaller-sized genera in the families Halictidae, Megachilidae and Colletidae, even though our observations conducted at park Bicentenario showed smaller bees to be much more abundant (Table 3).

We believe that this knowledge should be applied in future landscaping choices inside Quito, both in parks and in gardens. That does not mean that ornamental, exotic flowers should be completely avoided, as most oligolectic bees are capable of foraging from them, albeit, to a lesser extent than their preferred host plants. We have identified the most visited plants, both in terms of richness and abundance, and we think that these species should get special attention in local nurseries with the intent on providing local parks, sidewalks and gardens with plants that contribute to the maintenance of the local ecosystem services. These plants, *Dalea coerulea, Bidens andicola* and *Lupinus pubescens*, should be included in future pollinator gardens implemented throughout the city, including the corridors that are formed with the various metropolitan parks and that allow the larger native coverage remnants to connect between each other.

We suggest maintaining regular, observational and photographic monitoring at park Bicentenario, as a reference for bee communities' health in the northern part of the city, and to extend the scope of this study by conducting similar monitoring inside the metropolitan parks of both the central and southern parts of the city where fewer and smaller parks could cause differences in the behavior and diversity of the bees when compared to those on the northern parishes of the city. Furthermore, future studies should aim to take into account color preference and flower availability inside more diverse floral neighborhoods, as well as to elaborate a more comprehensive, molecular data driven, list of the bees of the DMQ and other understudied areas of the High Andes.

Declarations

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Ethics declarations

The authors declare no competing interests. No endangered species were collected, collections and monitoring were conducted according to the protocols of the Museo QCAZ's invertebrate section.

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Author Contribution

E.P and A.B proposed the mothodology and study site. E.P did the field work (monitoring), E.P and R.O reviewed the museum data and were in charge of bee indentification, E.P and R.O wrote the main manuscript. E.M created the interaction networks (figures 3 and 6-9), E.M and E.P conducted the statystical analysis. R.O prepared figures 1-2. All autors reviewed the manuscript.

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Data Availability

Data obtained from the field monitoring conducted at the Bicentenario park is included in the supplementary materials, photographs taken during the monitoring have bee uploaded to iNaturalist under CC licensing. Aditional data can be requested to the autors.

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Tables

Tables 1 to 4 are available in the Supplementary Files section.

Figures

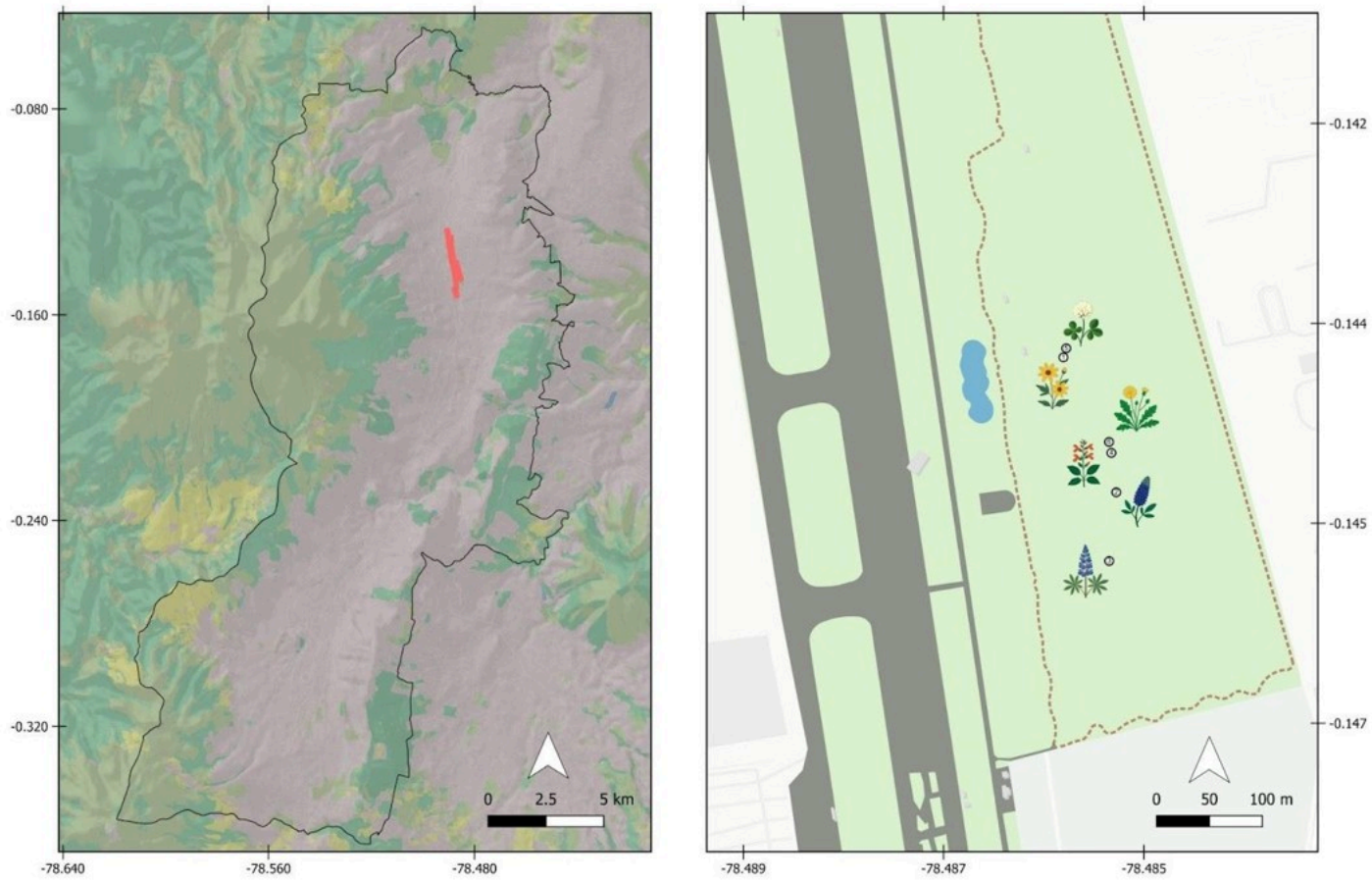

Figure 1

Study area. The left panel shows the location of Bicentenario Metropolitan Park (red) within the urban extent of Quito (gray), with urban parishes of the Metropolitan District of Quito (DMQ) delineated by dark boundaries. The right panel shows the sampling points within Bicentenario Metropolitan Park and the monitored plant species, ordered from top to bottom as follows: (5) *Trifolium repens* (exotic), (1) *Bidens andicola*(native), (6) *Hypochaeris radicata* (exotic), (4) *Salvia pauciserrata* (native), (2) *Dalea coerulea* (native), and (3) *Lupinus pubescens* (native).

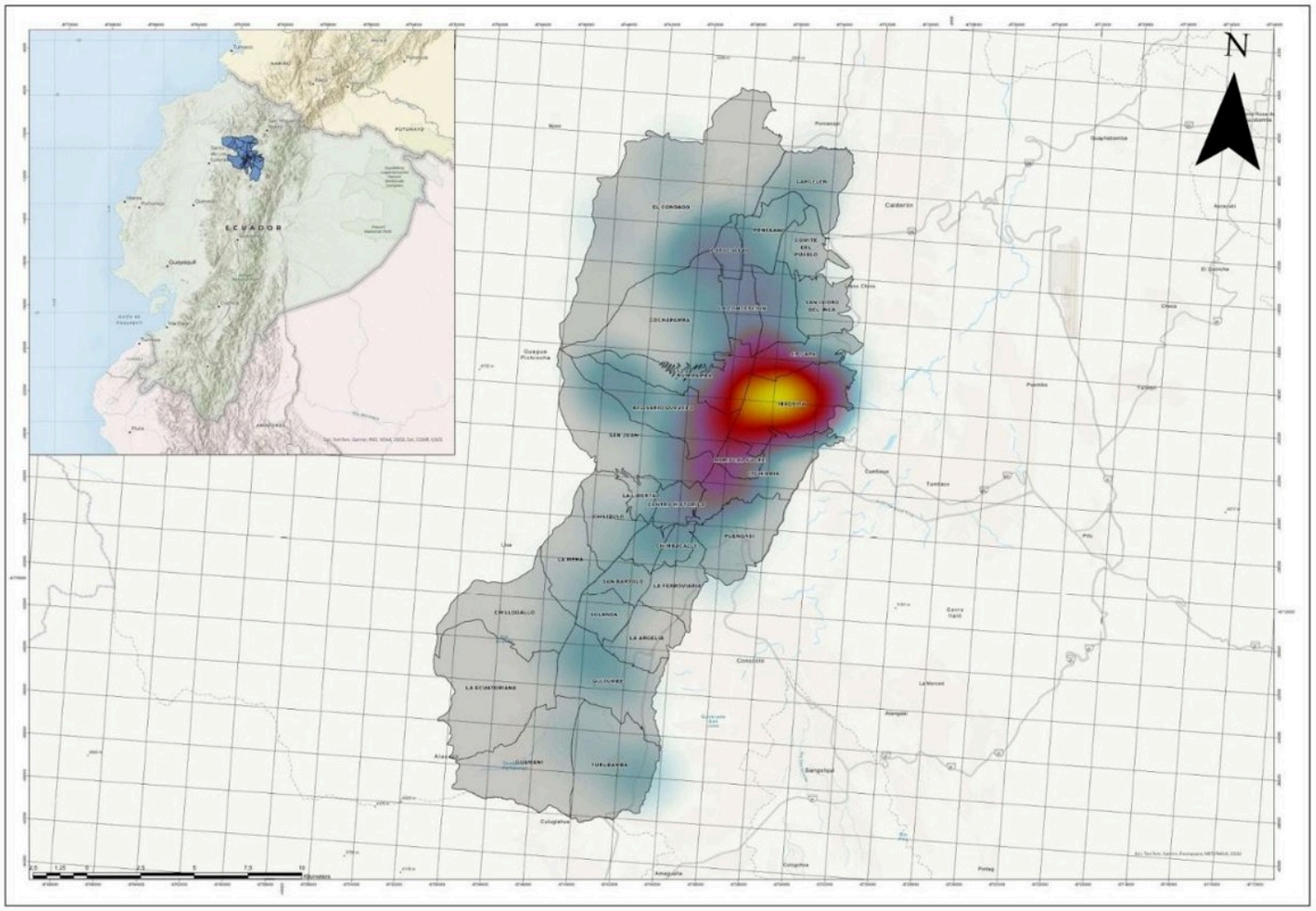

Figure 2

Heat map showing bee abundance inside the urban parishes inside the DMQ. The parishes of Iñaquito and Jipijapa (in yellow) host the highest bee abundance, whereas the parishes in blue show the least, grey areas on the map had no bee observations recorded on iNaturalist.

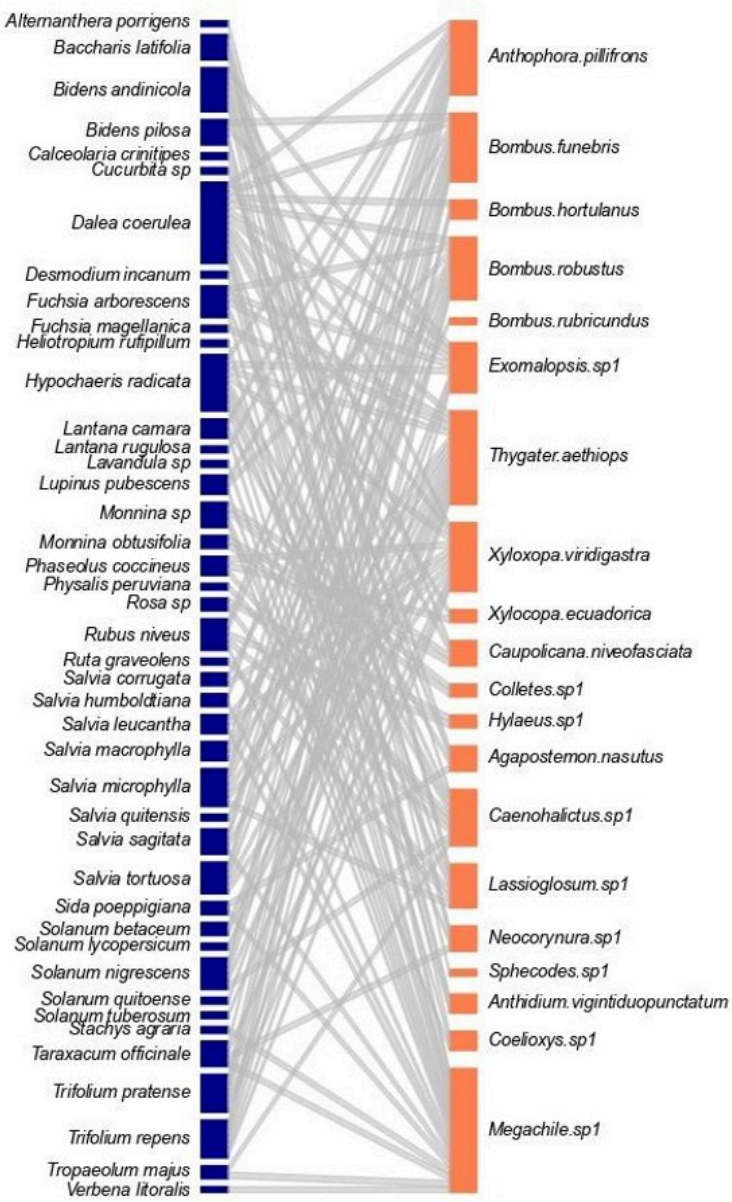

Figure 3

Network showing the interactions between native bee species and plant species found inside the urban parishes of the DMQ, obtained by curated iNaturalist data, created using the bipartite package (Dormann et al., 2014) in R (v.4.4). This network shows the number of links each species has but not the preference bee species may have as abundance data can not be inferred from iNaturalist observations in this area.

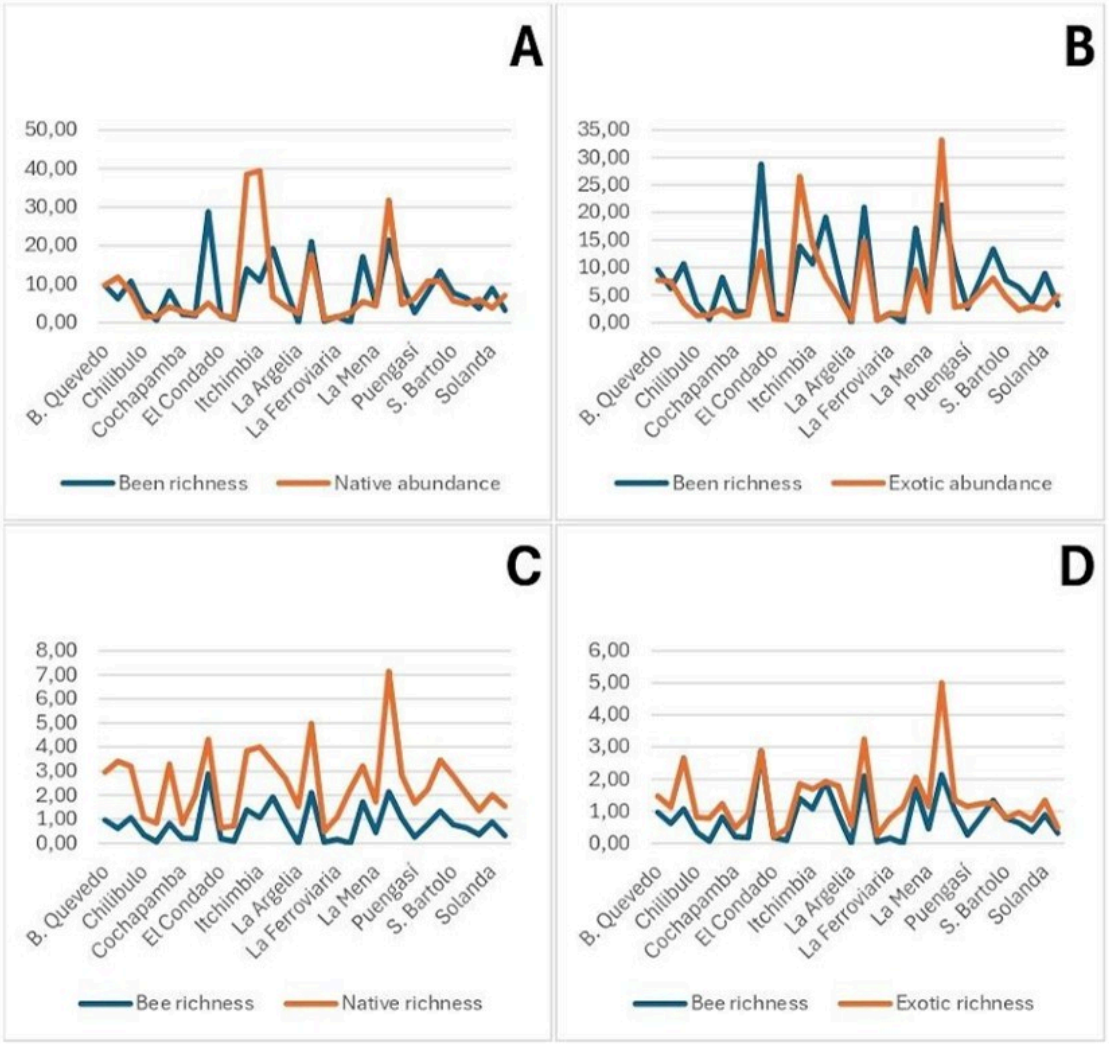

Figure 4

Line graphs showing the correlation between **A.** bee richness and native plant abundance, **B.** bee richness and exotic plant abundance, **C.** bee richness and native plant richness, and **D.** bee richness and exotic plant richness. All values are relative to parish area, in figures **A** and **B** bee richness is multiplied by ten for better visualization.

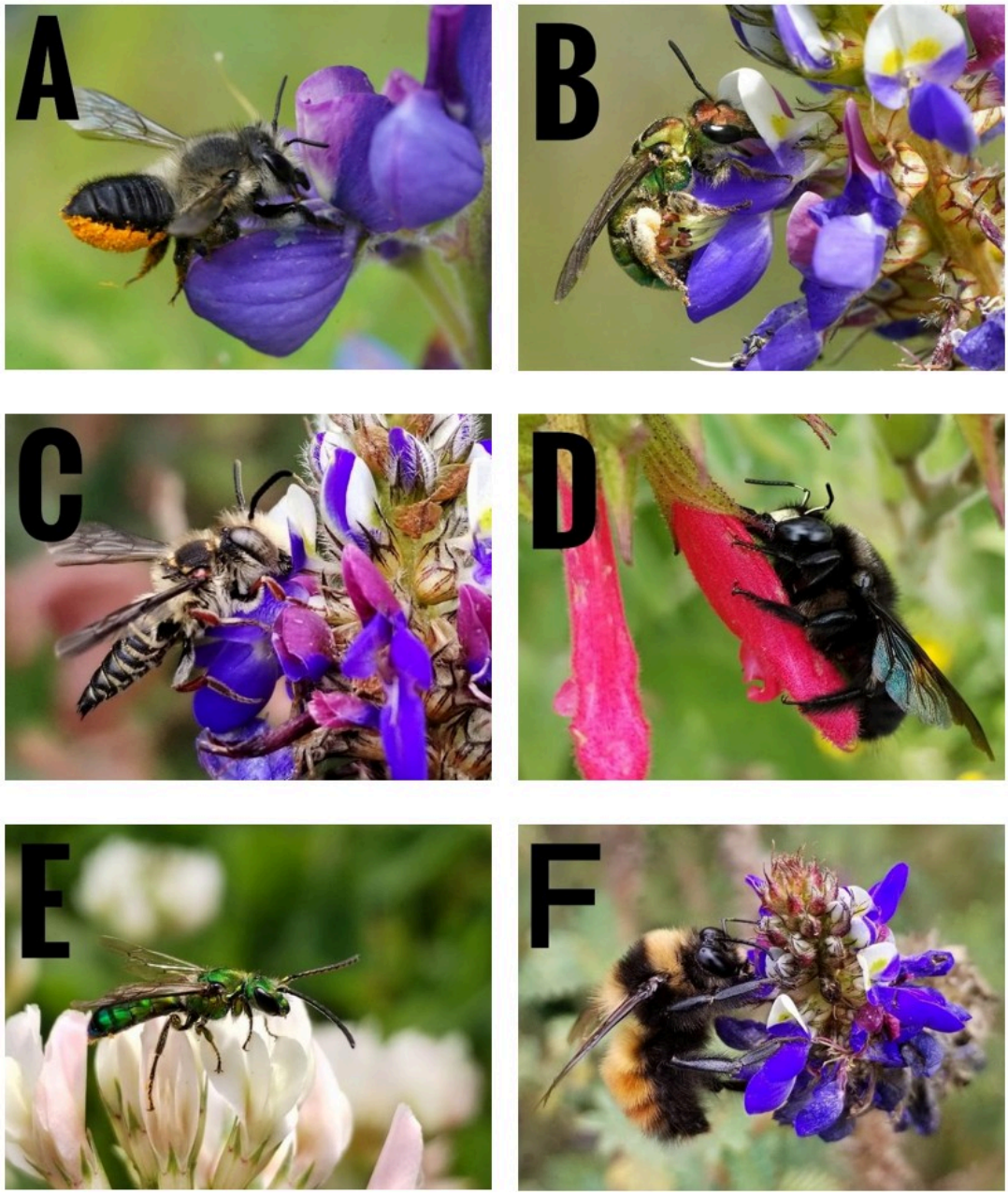

Figure 5

Photographs of the bee-plant interactions occurring inside the Bicentenario park. **A.** *Megachile antisanellae* (bee) and *Lupinus pubescens* (plant) **B.** *Neocorynura micheneri* (bee) and *Dalea coerulea* (plant) **C.** *Coelioxys* sp. (bee) and *Dalea coerulea* (plant) **D.** *Xylocopa viridigastra* (bee) and *Salvia pauciserrata* (plant) **E.** *Caenohalictus* sp. (bee) and *Trifolium repens* (plant) **F.** *Bombus robustus* (bee) and *Dalea coerulea.* Two additional species (*Monnina salicifolia* and *Salvia microphylla*) were monitored but excluded from the analysis due to insufficient flowering. (All interactions were photographed by Esteban Poveda and uploaded to the iNaturalist project https://www.inaturalist.org/projects/bee-plant-interaction-bicentenario-park-monitorings?).

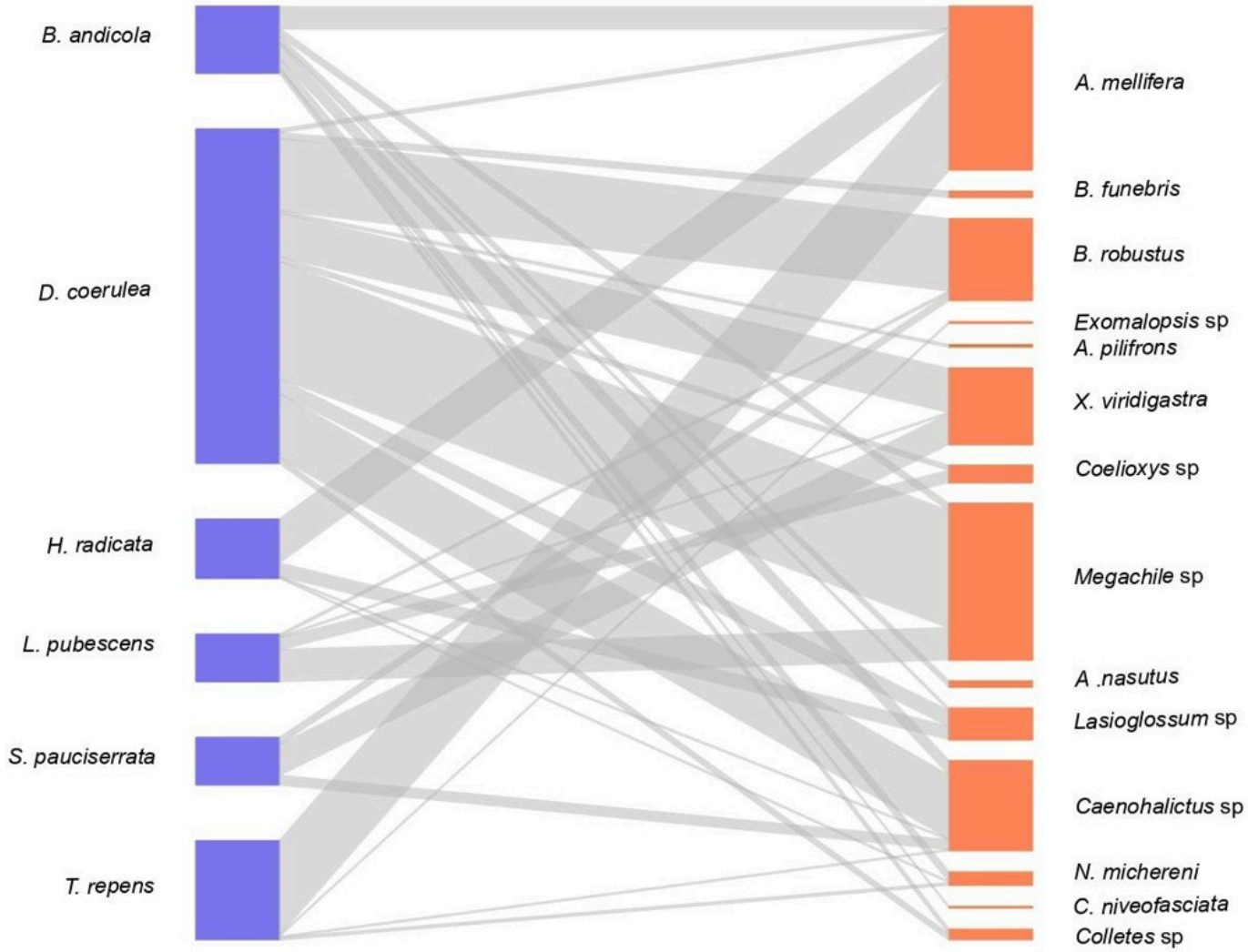

Figure 6

Interaction network between the six monitored plant species (native and exotic) inside the Bicentenario park and the bee species they interacted with, created using the bipartite package (Dormann et al., 2014) in R (v.4.4). This network shows the preference bee species have towards different food sources, width of the links indicates a higher recorded frequency of the interactions.

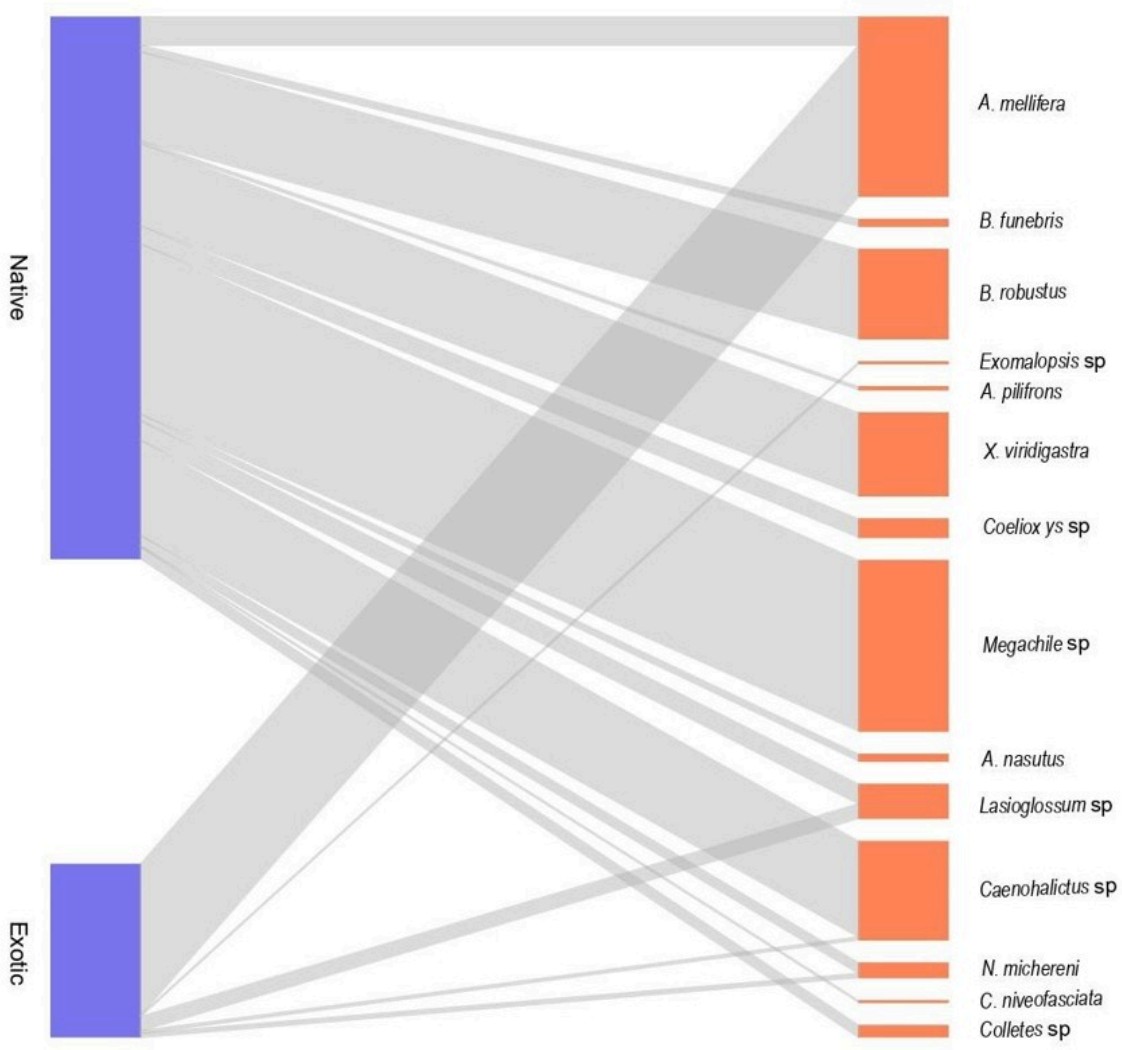

Figure 7

Interaction network between the monitored plant species inside the Bicentenario park, classified as native or exotic, and the bee species they interacted with, created using the bipartite package (Dormann et al., 2014) in R (v.4.4). This network shows the preference bee species have towards different food sources, width of the links indicates a higher recorded frequency of the interactions.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SUPPLEMENTARY1.xlsx
- Tables.docx