



## The bee fauna (Hymenoptera: Apoidea: Anthophila) of allotments in downtown Lisbon

MIGUEL AZEVEDO<sup>1,2</sup> , ELISABETE FIGUEIREDO<sup>2</sup>  and MARIA TERESA REBELO<sup>1</sup> 

<sup>1</sup> CESAM – Centre for Environmental and Marine Studies, Departamento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal; e-mails: azevedo.mfs@gmail.com, mtrebelo@fc.ul.pt

<sup>2</sup> LEAF - Linking Landscape, Environment, Agriculture and Food, Associated Laboratory TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal; e-mail: elisalacerda@isa.ulisboa.pt

**Key words.** Biodiversity, life history traits, Mediterranean, pollinators, urban ecology, wild bees

**Abstract.** In the last ten years, a growing number of studies have focused on urban green areas as potential refuges for biodiversity, where private gardens, urban parks and green roofs have relatively high diversities of wild bees. However, the western Mediterranean is still poorly studied and is a biodiversity hotspot that is already suffering the consequences of climate change. It is essential to rectify this and understand how urban settings can support biodiversity. In this context, this study provides an assessment of the taxonomic and functional composition of bee assemblages in three allotments in downtown Lisbon, Portugal. Using only an entomological net, we collected 202 specimens from April to July 2018, belonging to five families, 20 genera and 58 species, of which six are rare species in Portugal and nine first records for the Lisbon district. Megachilidae was the most diverse family, comprising 15 species, while Apidae was the most abundant family. Most of the species identified were solitary and had a generalist pollen diet, with a low incidence of social and parasitic species.

### INTRODUCTION

It is widely recognized that pollinators and the ecosystem services they provide are under increasing pressure, with both climate change and land-use conversion considered to be the drivers globally (Goulson et al., 2015; Mazarin et al., 2018). In Europe, livestock breeding, pesticides and habitat loss and fragmentation are the primary reasons for the decline in wild bees (Rundlöf et al., 2015; Bongaarts, 2019; Sirami et al., 2019; Senapathi et al., 2021).

Pollination is an essential ecosystem service, with bees considered one of the most important pollinators (Bates et al., 2011; Winfree et al., 2011). They are responsible for supporting the production of a wide variety of foods, mainly vegetable and fruit crops, and keystone species in both human managed and natural ecosystems (Kleijn et al., 2015). It is known that pollinators have a significant economic contribution to crop production (Gallai et al., 2009; Kleijn et al., 2015). Unfortunately, of the 2,000 species in Europe, 9% are threatened with extinction and for 57% there is not enough data to assess their risk of extinction (Nieto et al., 2014).

Bees are functionally described based on their life-history traits (food, sociality and nesting requirements). Some taxa display floral specificity (oligolectic), while others are pollen generalists (polylectic) (Dötterl & Vereecken, 2010). The 20,000 species described globally are either so-

cial, solitary or parasitic, and most are solitary. Regarding their nesting requirements, they can nest either in cavities in the soil or above-ground (Nieto et al., 2014).

Despite urban settings usually being associated with habitat loss and fragmentation, attention has been drawn to the positive effect that these areas have on wild bees (Ahrné et al., 2009; Newbold et al., 2016; Banaszak-Cibicka et al., 2018; Buchholz et al., 2020; Lanner et al., 2020; Theodorou et al., 2020). Urban green areas, like urban parks and allotments, can be a vital component of bee conservation once managed to produce a continuous source of flowers throughout the year, due to the presence of many native and exotic species of plants (Loram et al., 2008; Roulston & Goodell, 2011; Pardee & Philpott, 2014; Threlfall et al., 2015; Banaszak-Cibicka et al., 2018; Zhao et al., 2019). However, the positive effect of urban areas on bee communities is poorly understood (Ayers & Rehan, 2021). Some studies report a negative effect of anthropogenic disturbances on diversity (Birdshire et al., 2020), while others a neutral/positive effect (Matteson et al., 2008; Buchholz & Egerer, 2020; Buchholz et al., 2020; Lanner et al., 2020; Theodorou et al., 2020). In recent years, the potential that cities have for the development of bee communities have been studied. Most of this research was carried out in Northern and Central Europe (Matteson & Langellotto, 2010; Banaszak-Cibicka & Żmihorski, 2012; Geslin et

al., 2015; Hofmann & Renner, 2020; Lanner et al., 2020), whereas for the Mediterranean region there is a clear lack of such studies. It is crucial to address this as the same conservation measures cannot be applied in every region due to differences in their environments, land and geographical history (Aguirre-Gutiérrez et al., 2015, 2016; Connelly et al., 2015; Mallinger et al., 2016; Durant & Otto, 2019; Grab et al., 2019; Bogusch et al., 2020).

The Mediterranean area provided perfect conditions for bee speciation, which resulted in a high diversity of bees (Michener, 1979; Nielsen et al., 2011; Tscheulin et al., 2011; Baños-Picón et al., 2013; Pisanty & Mandelik, 2015; Sanchez et al., 2020). In Europe, bee species richness increases from north to south with the highest species richness in the Mediterranean region. Besides having a higher species richness, the Iberian, Italian and Balkan peninsulas also have the highest concentrations of endemism (Nieto et al., 2014), which is similarly associated with a general north-south positive gradient. Two main factors can explain these patterns: (i) a more favourable energy and water balance in the Mediterranean areas, which has resulted in an extremely high floral diversity (Petanidou & Ellis, 1997; Potts et al., 2003; Sébastien et al., 2009); (ii) the likely role these areas had as refuges during the Quaternary glaciations (Felinier, 2011).

This study aims to improve our understanding of the diversity of wild bees in urban areas in a species-rich, but poorly studied, Mediterranean biodiversity hotspot. It is crucial to understand bee communities and how green areas in cities can promote wild bee conservation. The possibility of declines in bees due to changes in floral availability associated with climate change makes it especially important to determine how cities can help in conserving bees. Therefore, this study aimed to answer the following questions: (1) Which wild bee communities are attracted to allotments in downtown Lisbon, a highly urbanized Mediterranean city? and (2) What are the ecological requirements of these species?

## MATERIALS AND METHODS

### Study location

In recent years, Lisbon has increased the number of managed green areas, such as allotments, mainly associated with urban parks. This study was conducted at three different allotments in downtown Lisbon (38°44'N, 9°8'W) (Fig. 1): Quinta da Granja (8400 m<sup>2</sup>), Quinta das Flores (5200 m<sup>2</sup>) and Quinta Conde D'Arcos (4500 m<sup>2</sup>), from April to July 2018. These sites are in similarly highly urbanized environments and the surrounding flora is managed by Lisbon city hall. These allotments are mainly used for urban agriculture and organically farmed for growing similar species of flowering plants. The three gardens are at least 2 km from each other (beyond the foraging distances of bees).

### Species sampled

Wild bees were collected using an entomological net. Sampling took place between 10 am and 4 pm to maximize captures, on warm and sunny days (15–30°C), with low wind speed and no rain. In each allotment, 15 transects (20 m × 3 m) were each scanned for 20 min, capturing any bees on vegetation, ground, structures such as fences or in flight. Plant species in flower were

recorded for each transect, focusing only on species richness. After collection, bees were individually stored in tubes filled with ethanol 70% and kept in a freezer (–20°C) before being processed, mounted and identified to species level using several identification keys (Amiet et al., 2001, 2002, 2007, 2010, 2014; Michener, 2007; BWARS, 2016; Michez et al., 2019; Asher & Pickering, 2020) and the reference collection of ISA (Instituto Superior de Agronomia, Universidade de Lisboa). The identification of specimens was carried out with the aid of a binocular magnifying glass (NexiusZoom) in the laboratory. Of the 215 specimens collected, it was not possible to identify 13 individuals to species level due to damage. When it was impossible to identify to species level, we sent the specimens to taxonomists specializing in European bees. The identification of the flowering plants was done using the Flora-On platform (Portuguese Botanic Society, 2014). At all three allotments there were no honeybee hives or commercial bumblebee colonies.

### Compilation of the ecological traits of bees

Information in the literature on their ecological traits was compiled (Michener, 2007; Matteson et al., 2008; Baldock et al., 2015, 2018; Kratschmer et al., 2019; Michez et al., 2019; Lanner et al., 2020) and when no information was available we contacted the bee specialists. Species were described based on their life-history traits (LHTs), dividing each trait into two categories: nesting (below-ground or above ground), sociality (solitary or eusocial) and pollen preference (polylectic or oligolectic) (Westrich, 2019). Parasitic species were placed in a third category as they do not build nests or collect pollen for their brood and lay their eggs in nests of their hosts (Bogusch et al., 2006; Bogusch & Straka, 2012).

### Statistical analysis

The number of genera, families and relative frequency of the species captured were determined. The relative frequency of LHTs was also measured. The same analysis was performed for the flowering plants. To address diversity, Hill numbers with three different exponents were calculated: (q) of diversity with a q value of 0 for species richness with all species having the same weight; q = 1 for the exponential of Shannon's index with species being weighted according to their abundance in the community and q = 2 for the inverse of the Simpson's index, which favours abundant species (Jost, 2006; Tuomisto, 2010). The differences between the values of the Hill numbers gives the degree of unevenness or dominance in each community (Jost, 2006). The higher the dominance in a community, the bigger the differences between these three values.

As this study included many species for which only one or two individuals (singletons and doubletons) were recorded, the sampling effort was determined using a species accumulation curve of the number of species by randomly selecting the order of each transect. To determine total species richness (sampling on all dates pooled) in the allotments sampled, non-parametric estimators Chao1 and Jackknife1 (both abundance based) were used (Picanço et al., 2017). These reduce the under-sampling effect that influences the number of species recorded (Sobs) (Walther & Moore, 2005; Fetridge et al., 2008; Russo et al., 2015).

## RESULTS

### Bee fauna

In total, 202 specimens were included in the analysis, made up of five families, 20 genera and 58 species (Table 1). The species *Xylocopa violacea* (Linnaeus, 1758) and *Bombus terrestris* (Linnaeus, 1758) were recorded in the



**Fig. 1.** Map of the sites sampled in downtown Lisbon.

three allotments, identified in the field and then released. Therefore, they were excluded from the abundance analysis. The European honeybee, *Apis mellifera* Linnaeus, 1758, was also recorded at all sites but not captured.

The family Megachilidae was the most diverse family, with a total of 15 species, followed by Apidae, Andrenidae, Halictidae and Collectidae. Regarding the number of species in each genus, *Andrena* had the highest species richness, comprising 11 species, followed by *Hylaeus* with eight species. For the genera *Amegilla*, *Ammobates*, *Bombus*, *Colletes*, *Xylocopa* and *Sphecodes* only one species was recorded, whereas the highest number of specimens (35 specimens) was recorded for *Eucera*. The data collected included some rare species (one or two records). In total, of the 58 species captured, 17 (29%) were based on only one (singletons) and 14 (24%) on two individuals (doubletons). The species, *Lasioglossum malachurum* (Kirby, 1802) and *Eucera elongatula* Vachal, 1907, were

the most abundant, with 17 and 14 individuals respectively, making up around 15% of the total assemblage.

The species accumulation curve based on sampling effort indicates a non-stabilization of bee species richness across sites (Fig. 2). Based on Hill numbers significantly fewer species (degree of unevenness or dominance in the community) are associated with the last than the first number [ $q = 0$  (58.0);  $q = 1$  (38.9);  $q = 2$  (28.8)], indicating around 50% fewer species of bees. Depending on the estimators used (Chao 1 and Jackknife 1) and for all three locations combined the potential specific richness is between 66 and 77 species, which is greater than that recorded in the present study (58) (Fig. 2, Table S1).

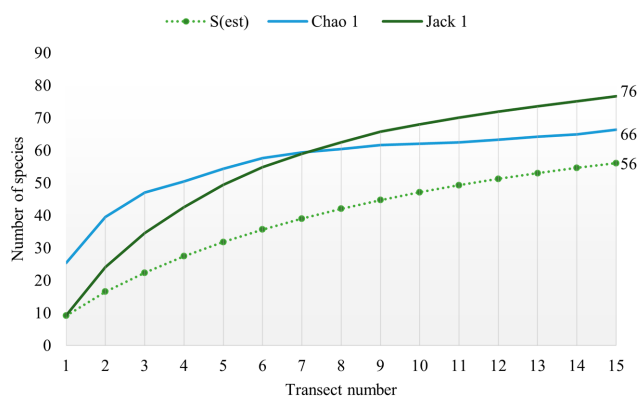
#### Bee ecological traits and flowering plants

In terms of sociality, most species and individuals were solitary (85% of species, 79% of individuals), polylectic (84% of species, 85% of individuals) and either nest below-ground (48% of species, 55% of individuals) or in

**Table 1.** Taxonomic and functional composition of the bee fauna in three allotments in downtown Lisbon.

Taxonomic group	N	Nesting behaviour	Pollen preference	Sociality
<b>Andrenidae</b>				
<i>Andrena agilissima</i> (Scopoli, 1770)	1	Below-ground	Oligolectic (Brassicaceae)	Solitary
<i>Andrena flavipes</i> Panzer, 1799	1	Below-ground	Polylectic	Solitary
<i>Andrena florentina</i> Magretti, 1883**	1	Below-ground	Oligolectic (Brassicaceae)	Solitary
<i>Andrena livens</i> Pérez, 1895	1	Below-ground	Polylectic	Solitary
<i>Andrena minutula</i> (Kirby, 1802) <sup>a</sup>	4	Below-ground	Polylectic	Solitary
<i>Andrena nigroaenea</i> (Kirby, 1802)	2	Below-ground	Polylectic	Solitary
<i>Andrena orbitalis</i> Morawitz, 1871	6	Below-ground	Polylectic	Solitary
<i>Andrena ovatula</i> (Kirby, 1802)	2	Below-ground	Polylectic	Solitary
<i>Andrena pillipes</i> Fabricius, 1781 <sup>a</sup>	1	Below-ground	Polylectic	Solitary
<i>Andrena suerinensis</i> Friese, 1884*	1	Below-ground	Oligolectic (Brassicaceae)	Solitary
<b>Apidae</b>				
<i>Amegilla albigena</i> (Lepelletier, 1841)	4	Below-ground	Polylectic	Solitary
<i>Ammobates muticus</i> Spinola, 1843	2	Parasitic	Polylectic	Parasitic
<i>Anthophora fulvitaris</i> Brullé, 1832	1	Below-ground	Polylectic	Solitary
<i>Anthophora plumipes</i> (Pallas, 1772)	3	Below-ground	Polylectic	Solitary
<i>Ceratina cucurbitina</i> (Rossi, 1792)	9	Above-ground	Polylectic	Solitary
<i>Ceratina nigrolabiata</i> Friese, 1896**	5	Above-ground	Polylectic	Solitary
<i>Eucera codinai</i> Dusmet y Alonso, 1926	4	Below-ground	Oligolectic (Fabaceae)	Solitary
<i>Eucera elongatula</i> Vachal, 1907	14	Below-ground	Polylectic	Solitary
<i>Eucera nigrilabris</i> Lepelletier, 1841	12	Below-ground	Polylectic	Solitary
<i>Eucera notata</i> Lepelletier, 1841	5	Below-ground	Oligolectic (Asteraceae)	Solitary
<i>Nomada agrestis</i> Fabricius, 1787	1	Parasitic	Polylectic	Parasitic
<i>Nomada basalis</i> Herrich-Schäffer, 1839	3	Parasitic	Polylectic	Parasitic
<i>Xylocopa violacea</i> Linnaeus, 1758	N/A	Above-ground	Polylectic	Solitary
<i>Bombus terrestris</i> Linnaeus, 1758	N/A	Below-ground	Polylectic	Eusocial
<b>Colletidae</b>				
<i>Colletes succinctus</i> (Linnaeus, 1758)	2	Below-ground	Oligolectic (Ericaceae)	Solitary
<i>Hylaeus brevicornis</i> Nylander, 1852 <sup>a</sup>	1	Above-ground	Polylectic	Solitary
<i>Hylaeus communis</i> Nylander, 1852*** <sup>a</sup>	2	Above-ground	Polylectic	Solitary
<i>Hylaeus dilatatus</i> (Kirby, 1802)	3	Above-ground	Polylectic	Solitary
<i>Hylaeus hyalinatus</i> Smith, 1842*** <sup>a</sup>	1	Above-ground	Polylectic	Solitary
<i>Hylaeus incongruus</i> Forster, 1871*** <sup>a</sup>	5	Above-ground	Polylectic	Solitary
<i>Hylaeus pictipes</i> Nylander, 1852	2	Above-ground	Polylectic	Solitary
<i>Hylaeus pictus</i> (Smith, 1853)	4	Above-ground	Polylectic	Solitary
<i>Hylaeus punctulatus</i> Smith, 1842* <sup>a</sup>	3	Above-ground	Polylectic	Solitary
<b>Halictidae</b>				
<i>Halictus fulvipes</i> (Klug, 1817)	2	Below-ground	Polylectic	Solitary
<i>Halictus quadricinctus</i> (Fabricius, 1776)	4	Below-ground	Polylectic	Solitary
<i>Seladonia gemmea</i> Dours, 1872	3	Below-ground	Polylectic	Solitary
<i>Seladonia subaurata</i> (Rossi, 1792)	9	Below-ground	Polylectic	Eusocial
<i>Lasioglossum angusticeps</i> (Perkins, 1895)*	1	Below-ground	Polylectic	Solitary
<i>Lasioglossum interruptum</i> (Panzer, 1798)	8	Below-ground	Polylectic	Eusocial
<i>Lasioglossum leucozonium</i> (Schränk, 1781)	1	Below-ground	Polylectic	Solitary
<i>Lasioglossum malachurum</i> (Kirby, 1802)	17	Below-ground	Polylectic	Eusocial
<i>Lasioglossum pauperatum</i> (Brullé, 1832)	1	Below-ground	Polylectic	Eusocial
<i>Sphecodes alternatus</i> Smith, 1853 <sup>a</sup>	1	Parasitic	Polylectic	Parasitic
<b>Megachilidae</b>				
<i>Anthidium florentinum</i> Fabricius, 1775	2	Above-ground	Polylectic	Solitary
<i>Anthidium manicatum</i> Linnaeus, 1758	8	Above-ground	Polylectic	Solitary
<i>Anthidium oblongatum</i> Illiger, 1806	2	Above-ground	Polylectic	Solitary
<i>Heriades crenulatus</i> Nylander, 1856	2	Above-ground	Oligolectic (Asteraceae)	Solitary
<i>Heriades rubicola</i> Pérez, 1890	2	Above-ground	Oligolectic (Asteraceae)	Solitary
<i>Hoplitis adunca</i> Panzer, 1798	3	Above-ground	Oligolectic (Boraginaceae)	Solitary
<i>Hoplitis annulata</i> Latreille, 1811 <sup>a</sup>	2	Above-ground	Polylectic	Solitary
<i>Hoplitis benoisti</i> Alfken, 1935	11	Above-ground	Polylectic	Solitary
<i>Megachile ericetorum</i> Lepelletier, 1841**	2	Above-ground	Oligolectic (Fabaceae)	Solitary
<i>Megachile pilidens</i> Alfken, 1924	1	Above-ground	Polylectic	Solitary
<i>Megachile willughbiella</i> Kirby, 1802	1	Above-ground	Polylectic	Solitary
<i>Osmia bicornis</i> Linnaeus, 1758	2	Above-ground	Polylectic	Solitary
<i>Osmia caerulescens</i> Linnaeus, 1758	3	Above-ground	Polylectic	Solitary
<i>Osmia niveata</i> Fabricius, 1804	7	Above-ground	Oligolectic (Asteraceae)	Solitary
<i>Osmia submicans</i> Morawitz, 1870	1	Above-ground	Polylectic	Solitary

N – total number of specimens; Nesting behaviour – nesting type (below-ground, above-ground and parasitic); Pollen preference – food requirements/preferences (oligolectic, polylectic); Sociability – bee social behaviour (solitary, eusocial and parasitic); N/A – abundance data is not available for *B. terrestris* and *X. violacea* as they were released immediately after capture; <sup>a</sup>First record of this species in the Lisbon district (Baldock et al., 2018); \*Scarce species on Portugal mainland (6–10 records) (Baldock et al.; 2018); \*\*Rare species on Portugal mainland (≤ 5 records) (Baldock et al., 2018).



**Fig. 2.** Species accumulation curve for the allotments, which reflects the specific richness of bees as a function of presence-absence data (Sest). Richness estimates obtained using Chao 1 and Jackknife 1.

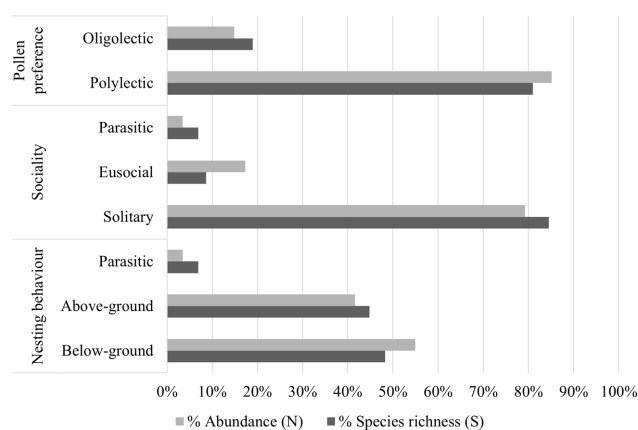
above-ground cavities (45% of species, 42% of individuals) (Fig. 3). There were only four parasitic species: *Ammobates muticus* Spinola, 1843; *Nomada agrestis* Fabricius, 1781; *Nomada basalis* Herrich-Schäffer, 1839; and *Sphecodes alternatus* Smith, 1853, which made up 3.5% of the specimens collected. Among the 58 species, 11 were oligolectic, 4 specialists on Asteraceae, 3 on Brassicaceae, 2 on Fabaceae and 1 each on Boraginaceae, Lamiaceae and Ericaceae. Oligolectic species accounted for 15% of the specimens collected (Fig. 3).

Across all sample dates, 66 species of flowering plants belonging to 25 different families were recorded (Table S2). The family Asteraceae was the most abundant family at all three sites, with a total of 47 records, followed by Lamiaceae (36), Apiaceae (22), Fabaceae (20), Brassicaceae (18), Convolvulaceae (15), Papaveraceae (15) and Boraginaceae (13).

**DISCUSSION**

The Mediterranean area lacks studies on wild bees in urban settings, although this group has attracted attention in recent years. For Portugal, a study focused on the diversity of pollinating insects in small-scale farming landscapes in the Oeste region (2012–2013) reported about 70 species of bees belonging to 16 genera (Catarina Reis, pers. commun.). A two-year study (2014–2015) in the north of the country in which the abundance and diversity of bees at sites at different stages of land abandonment were compared, reports 157 species of bees, with several the first confirmed records for Portugal, based on capturing 2721 specimens (Penado et al., 2022). In Lisbon, a study carried out at Tapada da Ajuda in Lisbon’s biggest green area, recorded 32 species in allotments in 2016 (Carvajal et al., 2017).

As referred to above, there are studies on small-scale farming landscapes and semi-natural/natural landscapes, which are two of the most extensive land-use classes in Portugal. To our knowledge, this is the first study to focus on the diversity of wild bees in the Mediterranean area in urban areas, the third main land-use class in this country (CLMS, 2018).



**Fig. 3.** Percentage of the different life history traits (LTHs) and abundance of the species of wild bees sampled (N = 202 specimens).

In the present study, 58 species were recorded in three allotments in Lisbon city centre, which is approximately 8% of the 712 species listed as occurring on the Portuguese mainland (Baldock et al., 2018; Wood et al., 2020). This assemblage includes 35% of the species recorded in the Lisbon district (Baldock et al., 2018). Among specimens there were six rare species (i.e., with five or fewer published records): *Andrena florentina* Magretti, 1883, *Hylaeus communis* Nylander, 1852, *Hylaeus hyalinatus* Smith, 1842, *Hylaeus incongruus* Forster, 1871, *Ceratina nigrolabiata* Friese, 1896 and *Megachile ericetorum* Lepeletier, 1841, and nine that were first records for the Lisbon area (Table 1). It is worth stressing that 37 species recorded in this study are not reported by Carvajal et al. (2017). Hereafter, a total of 69 species are now reported as occurring in allotments in downtown Lisbon.

The highest species richness was recorded for the Megachilidae, which may be linked to their flexibility in nest selection as they are known to use several types of above-ground cavities in human-made structures (Matteson et al., 2008; MacIvor & Packer, 2015; Egerer et al., 2020). On the other hand, although *Andrena* was the most diverse genus (11 species), the Andrenidae were the least abundant (10% of total records). The abundance of these bees differs from that reported in other studies in central Europe (Banaszak-Cibicka & Źmihorski, 2012; Geslin et al., 2015; Sirohi et al., 2015), where the Andrenidae are the most abundant. The low incidence of these bees might be due to the fact that this family primarily consists of ground-nesting species that forage in spring, which in 2018 was late and it rained in the early months (IPMA, 2018). In urban areas, in the Mediterranean region, they are usually associated with grassland and ruderal habitats, where the soil is rarely cultivated and there are more native species of plants (Banaszak-Cibicka & Źmihorski, 2012). The Apidae were the most abundant (31% of total records), probably because it is the most diverse family in terms of morphology and behaviour (Michener, 2007) and as a consequence resilient and adaptable in their response to changes in their habitat. The most dominant species, *Lasioglossum malachurum* (8% of total records), is a eusocial species present in spring

and summer, which possibly accounts for the high number of specimens collected. The genus *Lasioglossum* is also referred to as one of the most resilient to land-use change mostly due to its life histories traits (Grab et al., 2019).

There are several European based studies showing the potential of urban areas for supporting a high species richness of wild bees (Banaszak-Cibicka & Żmihorski, 2012; Geslin et al., 2015; Sirohi et al., 2015; Langellotto, 2017; Banaszak-Cibicka et al., 2018; Buchholz et al., 2020; Lanner et al., 2020; Theodorou et al., 2020). In the present study, a high species richness was recorded for a very small assemblage, indicating that the number of species should be higher than that recorded. The accumulation curve also showed that the number of species did not stabilize throughout each season. It is expected that the species richness would increase between seasons once there is a natural succession of spring and summer species (Michez et al., 2019). However, in cities like Lisbon, with hot summers and green areas subject to high maintenance (removal of wildflowers), the succession could be negatively affected as fewer flowers are available (Hamblin et al., 2018). Regarding the diversity indexes ( $q = 0, 1, 2$ ), the community has a high degree of unevenness (two dominant species, *Lasioglossum malachurum* and *Eucera elongatula*), which is explained by the loss of almost 50% of species richness from the first to the last Hill numbers. This loss is probably due to a high number of singletons and doubletons, indicating an under-sampled assemblage. Our estimators (Chao 1 & Jackknife 1) corroborate this as they predict between 66 and 77 species at the sites sampled. Although there are several studies on wild bee richness in urban areas (Geslin et al., 2015; Sirohi et al., 2015; Buchholz et al., 2020; Lanner et al., 2020), they differ in the percentage of species reported in terms of each country's total bee fauna. Comparing our results with those of the above studies pose problems due to different sampling methods and their primary focus. In addition, each city has a different spatial planning and geographic setting leading to different bee assemblages (Sirohi et al., 2015). Similarly, studies focusing on bee LHTs instead of taxonomic diversity have a better potential for making comparisons and drawing better hypotheses/conclusions (Sheffield et al., 2013). On the other hand, compared with studies in the Mediterranean countryside (Pisanty et al., 2015; Hevia et al., 2016; Rodrigo Gómez et al., 2021; Penado et al., 2022), the number of species in urban settings should be lower, as was recorded here.

In this study most of the wild bees were solitary (85%), pollen generalists (81%) and had similar percentages in both nesting requirements (48% below-ground or 44% above-ground). These findings are comparable to those of studies in Poland and Austria, the first in urban public gardens (Banaszak-Cibicka & Żmihorski, 2012) and second in communal gardens (Lanner et al., 2020), although a lower number of social species were recorded in this study. Mediterranean regions generally have a low percentage of social species in their faunas because of radically different hot summers (Hamblin et al., 2018). Also, in allotments

there are few areas of bare soil in such small patches used for the intensive production of crops, making it almost impossible for the right conditions to exist for large colonies of eusocial species to persist. Most of the bees collected were polylectic. As in previous studies, urban areas tend to have a low incidence of oligolectic species (Matteson et al., 2008; Banaszak-Cibicka & Żmihorski, 2012; Geslin et al., 2015). Although there were few oligolectic species they do occur in allotments. Of the 11 oligolectic species recorded, their preferences ranged from Asteraceae, Brassicaceae, Fabaceae, Boraginaceae to Ericaceae (Table S2), which matched the incidence of these flower taxa in the transects. It is common to have similar plants in gardens as many exotic flowers are planted by local gardeners. This could potentially mean that by planting specific flowers from different taxa, other specialist bees could thrive in allotments (Langellotto, 2017; Egerer et al., 2020). Almost half of the species captured nest in cavities above-ground. Cavity nesters do not rely on patches of sparsely vegetated ground. They use many different cavities from cracks in walls, cavities dug by other insects or themselves, hollow stems or tree trunks (Matteson et al., 2008; Fortel et al., 2014). It is also widespread to use reeds or bamboo for garden fences and to grow plants, which bees use for nesting and feeding (MacIvor & Packer, 2015). Therefore, the sites sampled hosted a high richness of megachilids (15 species). Parasitic wild bees made up 6.9% (four species) of the species of bees collected, but only 3.5% of the specimens. These bees are indicators of the stability of wild bee communities (Sheffield et al., 2013), as they tend to respond very quickly to habitat disturbances (Fortel et al., 2014). In the present study, the low number of parasitic species could be due to the absence of specific bee hosts and/or low number of samples.

In conclusion, this study showed that allotments can potentially host a diverse wild bee fauna in a highly urbanized Mediterranean city. These green islands provide food and nesting places for bee communities, favouring solitary species and pollen generalists. On the other hand, a few eusocial, parasitic and pollen specialist species were also recorded. The actual richness is likely to be higher than that recorded, due to the very low number of samples. Nevertheless, it is worthy of mention that in the small assemblage (202 specimens) recorded there were 58 species of wild bees. In addition, some bees like the megachilids occur more frequently than other bees in allotments. So, specific conservation measures like increasing the availability of nests (bee hotels) and planting a variety of endemic plants could enhance the “refuge potential” of these areas since they are watered all year and as a consequence remain favourable habitats during hot and dry summers. It is also essential to study non-urbanized areas in order to better understand the importance of these habitats as a baseline for direct comparison with urban settings.

In the future the use of different sampling methods should increase the number of species and individuals captured and enable more different types of locations to be sampled so that an accurate plan of action can be devel-

oped for Lisbon allotments. Although this study included only three allotments, nevertheless, it shows they are important in urban areas in the Mediterranean area. In addition, the effect of different types of urban planning should be investigated, since the level of land heterogeneity and geographical history influence the wild bee fauna. Given the lack of studies on wild bee diversity in the Western area of the Mediterranean, coupled with the growing threats to these insects, the results presented increase our level of understanding, but a great deal more research is needed.

**ACKNOWLEDGMENTS.** We are very thankful to the late D. Baldock and T. Wood for many of the species identifications. We acknowledge financial support from CESAM (UIDP/50017/2020+UIDB/50017/2020+ LA/P/0094/2020) and LEAF (UIDB/AGR/04129/2020), FCT/MCTES from national funds and co-funding from FEDER, within the PT2020 Partnership Agreement and Compete 2020. MA has a PhD grant from FCT: 2020.08908. BD.

**AUTHORS' CONTRIBUTIONS:** MA did the experiments, analysed the data, prepared figures and tables; EF and MTR conceived and designed the experiments; All authors were involved in the writing, reviewed drafts and approved the final draft of this paper.

**CONFLICTS OF INTEREST:** The authors declare that they have no conflict of interest.

## REFERENCES

- AGUIRRE-GUTIÉRREZ J., BIESMEIJER J.C., VAN LOON E.E., REEMER M., WALLISDEVRIES M.F. & CARVALHEIRO L.G. 2015: Susceptibility of pollinators to ongoing landscape changes depends on landscape history. — *Divers. Distrib.* **21**: 1129–1140.
- AGUIRRE-GUTIÉRREZ J., KISSLING W.D., CARVALHEIRO L.G., WALLISDEVRIES M.F., FRANZÉN M. & BIESMEIJER J.C. 2016: Functional traits help to explain half-century long shifts in pollinator distributions. — *Sci. Rep.* **6**: 24451, 13 pp.
- AHRNÉ K., BENGTTSSON J. & ELMQVIST T. 2009: Bumble bees (*Bombus* spp.) along a gradient of increasing urbanization. — *PLoS ONE* **4**: e5574, 9 pp.
- AMIET F., HERRMANN M., MÜLLER A. & NEUMEYER R. 2001: *Fauna Helvetica 6. Apidae 3: Halictus, Lasioglossum*. Centre Suisse de Cartographie de la Faune (CSCF), Neuchâtel, 208 pp.
- AMIET F., HERRMANN M., MÜLLER A. & NEUMEYER R. 2002: *Fauna Helvetica 9. Apidae 4: Anthidium, Chelostoma, Coelioxys, Dioxys, Heriades, Lithurgus, Megachile, Osmia, Stelis*. Centre Suisse de Cartographie de la Faune (CSCF), Neuchâtel, 273 pp.
- AMIET F., HERRMANN M., MÜLLER A. & NEUMEYER R. 2007: *Fauna Helvetica 20. Apidae 5: Ammobates, Ammobatooides, Anthophora, Biastes, Ceratina, Dasypoda, Epeoloides, Epeolus, Eucera, Macropis, Melecta, Melitta, Nomada, Pasites, Tetralonia, Thyreus, Xylocopa*. Centre Suisse de Cartographie de la Faune (CSCF), Neuchâtel, 356 pp.
- AMIET F., HERRMANN M., MÜLLER A. & NEUMEYER R. 2010: *Fauna Helvetica 26. Apidae 6: Andrena, Melitturga, Panurginus, Panurgus*. Centre Suisse de Cartographie de la Faune (CSCF), Neuchâtel, 318 pp.
- AMIET F., HERRMANN M., MÜLLER A. & NEUMEYER R. 2014: *Fauna Helvetica 4. Apidae 2: Colletes, Dufourea, Hylaeus, Nomia, Nomioides, Rophitoides, Rophites, Sphecodes, Systropha*. Centre Suisse de Cartographie de la Faune (CSCF), Neuchâtel, 239 pp.
- ASHER J.S. & PICKERING J. 2020: *Discover Life Bee Species Guide and World Checklist (Hymenoptera: Apoidea: Anthophila)*. URL: [https://www.discoverlife.org/mp/20q?guide=Apoidea\\_species](https://www.discoverlife.org/mp/20q?guide=Apoidea_species) (last accessed 17 Aug. 2021).
- AYERS A.C. & REHAN S.M. 2021: Supporting bees in cities: how bees are influenced by local and landscape features. — *Insects* **12**(2): 128, 18 pp.
- BALDOCK K.C.R., GODDARD M.A., HICKS D.M., KUNIN W.E., MITSCHUNAS N., OSGATHORPE L.M., POTTS S.G., ROBERTSON K.M., SCOTT A. V., STONE G.N. ET AL. 2015: Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. — *Proc. Royal Soc. (B)* **282**(1803): 20142849, 10 pp.
- BALDOCK D.W., WOOD T.J., CROSS I. & SMIT J. 2018: *The Bees of Portugal (Hymenoptera: Apoidea: Anthophila)*. Entomofauna, Munich, 164 pp.
- BANASZAK-CIBICKA W. & ŽMIHORSKI M. 2012: Wild bees along an urban gradient: Winners and losers. — *J. Insect Conserv.* **16**: 331–343.
- BANASZAK-CIBICKA W., TWERD L., FLISZKIEWICZ M., GIEJDASZ K. & LANGOWSKA A. 2018: City parks vs. natural areas – is it possible to preserve a natural level of bee richness and abundance in a city park? — *Urban Ecosyst.* **21**: 599–613.
- BAÑOS-PICÓN L., TORRES F., TORMOS J., GAYUBO S.F. & ASÍS J.D. 2013: Comparison of two Mediterranean crop systems: Polycrop favours trap-nesting solitary bees over monocrop. — *Basic Appl. Ecol.* **14**: 255–262.
- BATES A.J., SADLER J.P., FAIRBRASS A.J., FALK S.J., HALE J.D. & MATTHEWS T.J. 2011: Changing bee and hoverfly pollinator assemblages along an urban-rural gradient. — *PLoS ONE* **6**(8): e23459, 11 pp.
- BIRDSHIRE K.R., CARPER A.L. & BRILES C.E. 2020: Bee community response to local and landscape factors along an urban-rural gradient. — *Urban Ecosyst.* **23**: 689–702.
- BOGUSCH P. & STRAKA J. 2012: Review and identification of the cuckoo bees of central Europe (Hymenoptera: Halictidae: Sphecodes). — *Zootaxa* **41**: 1–41.
- BOGUSCH P., KRATOCHVÍL L. & STRAKA J. 2006: Generalist cuckoo bees (Hymenoptera: Apoidea: Sphecodes) are species-specialist at the individual level. — *Behav. Ecol.* **60**: 422–429.
- BOGUSCH P., HLAVÁČKOVÁ L., GASOL N.R. & HENEBERG P. 2020: Near-natural habitats near almond orchards with presence of empty gastropod shells are important for solitary shell-nesting bees and wasps. — *Agric. Ecosyst. Environ.* **299**: e106949, 9 pp.
- BONGAARTS J. 2019: IPBES, 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. — *Popul. Dev. Rev.* **45**: 680–681.
- BUCHHOLZ S. & EGERER M.H. 2020: Functional ecology of wild bees in cities: towards a better understanding of trait-urbanization relationships. — *Biodiv. Conserv.* **29**: 2779–2801.
- BUCHHOLZ S., GATHOF A.K., GROSSMANN A.J., KOWARIK I. & FISCHER L.K. 2020: Wild bees in urban grasslands: Urbanisation, functional diversity and species traits. — *Landsc. Urban Plan.* **196**: 103731, 10 pp.
- BWARS 2021: *Bees, Wasps & Ants Recording Society*. URL: [https://www.bwars.com/species\\_list](https://www.bwars.com/species_list). (last accessed 4 Aug. 2021).
- CARVAJAL M., FIGUEIREDO E. & REBELO M.T. 2017: Diversidade de abelhas (Hymenoptera: Apoidea) em espaço urbanizado: o caso da Tapada da Ajuda, Lisboa. — *O Apicultor, Revista Apicultura* **26**(98): 25–28 [in Portuguese].

- CLMS 2018: *Copernicus Land Monitoring Service. European Environment Agency (EEA)*. URL: <https://land.copernicus.eu/user-corner/technical-library> (last accessed 17 Jun. 2021).
- CONNELLY H., POVEDA K. & LOEB G. 2015: Landscape simplification decreases wild bee pollination services to strawberry. — *Agric. Ecosyst. Environ.* **211**: 51–56.
- DÖTTERL S. & VEREECKEN N.J. 2010: The chemical ecology and evolution of bee-flower interactions: A review and perspectives. — *Can. J. Zool.* **88**: 668–697.
- DURANT J.L. & OTTO C.R.V. 2019: Feeling the sting? Addressing land-use changes can mitigate bee declines. — *Land Use Policy* **87**: 104005, 8 pp.
- EGERER M., CECALA J.M. & COHEN H. 2020: Wild bee conservation within urban gardens and nurseries: Effects of local and landscape management. — *Sustainability* **12**: 1–19.
- FELINER G.N. 2011: Southern European glacial refugia: A tale of tales. — *Taxon* **60**: 365–372.
- FETRIDGE E.D., ASCHER J.S. & LANGELLOTTA G.A. 2008: The bee fauna of residential gardens in a suburb of New York City (Hymenoptera: Apoidea). — *Ann. Entomol. Soc. Am.* **101**: 1067–1077.
- FORTEL L., HENRY M., GUILBAUD L., GUIRAO A.L., KUHLMANN M., MOURET H., ROLLIN O. & VAISSIÈRE B.E. 2014: Decreasing abundance, increasing diversity and changing structure of the wild bee community (Hymenoptera: Anthophila) along an urbanization gradient. — *PLoS ONE* **9**(8): e104679, 12 pp.
- GALLAI N., SALLES J.M., SETTELE J. & VAISSIÈRE B.E. 2009: Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. — *Ecol. Econ.* **68**: 810–821.
- GESLIN B., LE FÉON V., KUHLMANN M., VAISSIÈRE B.E. & DAJOZ I. 2015: The bee fauna of large parks in downtown Paris, France. — *Ann. Soc. Entomol. Fr.* **51**: 487–493.
- GOULSON D., NICHOLLS E., BOTÍAS C. & ROTHERAY E.L. 2015: Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. — *Science* **347**: 1255957, 9 pp.
- GRAB H., BRANSTETTER M.G., AMON N., URBAN-MEAD K.R., PARK M.G., GIBBS J., BLITZER E.J., POVEDA K., LOEB G. & DANFORTH B.N. 2019: Agriculturally dominated landscapes reduce bee phylogenetic diversity and pollination services. — *Science* **363**: 282–284.
- HAMBLIN A.L., YOUNGSTEADT E. & FRANK S.D. 2018: Wild bee abundance declines with urban warming, regardless of floral density. — *Urban Ecosyst.* **21**: 419–428.
- HEVIA V., BOSCH J., AZCÁRATE F.M., FERNANDEZ E., RODRIGO A., BARRIL-GRAELLS H. & GONZÁLEZ J.A. 2016: Bee diversity and abundance in a livestock drove road and its impact on pollination and seed set in adjacent sunflower fields. — *Agric. Ecosyst. Environ.* **232**: 336–344.
- HOFMANN M.M. & RENNER S.S. 2020: Bee species decrease and increase between the 1990s and 2018 in large urban protected sites. — *J. Insect Conserv.* **24**: 637–642.
- IPMA 2018: *Portuguese Institute of the Ocean and Atmosphere*. URL: <http://www.ipma.pt/pt/index.html> [in Portuguese] (last accessed 10 Aug. 2021).
- JOST L. 2006: Entropy and diversity. — *Oikos* **113**: 363–375.
- KLEIN D., WINFREE R., BARTOMEUS I., CARVALHEIRO L.G., HENRY M., ISAACS R., KLEIN A.M., KREMEN C., M'GONIGLE L.K., RADER R. ET AL. 2015: Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. — *Nat. Commun.* **6**: 1–9.
- KRATSCHEMER S., PACHINGER B., SCHWANTZER M., PAREDES D., GUZMÁN G., GOMÉZ J.A., ENTRENAS J.A., GUERNION M., BUREL F., NICOLAI A. ET AL. 2019: Response of wild bee diversity, abundance, and functional traits to vineyard inter-row management intensity and landscape diversity across Europe. — *Ecol. Evol.* **9**: 4103–4115.
- LANGELLOTTA G.A. 2017: An analysis of bee communities in home and community gardens. — *Acta Hort.* **1189**: 491–496.
- LANNER J., KRATSCHEMER S., PETROVIĆ B., GAULHOFER F., MEIMBERG H. & PACHINGER B. 2020: City dwelling wild bees: how communal gardens promote species richness. — *Urban Ecosyst.* **23**: 271–288.
- LORAM A., THOMPSON K., WARREN P.H. & GASTON K.J. 2008: Urban domestic gardens (XII): The richness and composition of the flora in five UK cities. — *Appl. Veg. Sci.* **19**: 321–330.
- MACIVOR J.S. & PACKER L. 2015: 'Bee Hotels' as tools for native pollinator conservation: A premature verdict? — *PLoS ONE* **10**: e0122126, 13 pp.
- MALLINGER R.E., GIBBS J. & GRATTON C. 2016: Diverse landscapes have a higher abundance and species richness of spring wild bees by providing complementary floral resources over bees' foraging periods. — *Landsc. Ecol.* **31**: 1523–1535.
- MATTESON K.C. & LANGELLOTTA G.A. 2010: Determinates of inner-city butterfly and bee species richness. — *Urban Ecosyst.* **13**: 333–347.
- MATTESON K.C., ASCHER J.S. & LANGELLOTTA G.A. 2008: Bee richness and abundance in New York City urban gardens. — *Ann. Entomol. Soc. Am.* **101**: 140–150.
- MAZOR T., DOROPOULOS C., SCHWARZMUELLER F., GLADISH D.W., KUMARAN N., MERKEL K., MARCO M. DI & GAGIC V. 2018: Global mismatch of policy and research on drivers of biodiversity loss. — *Nat. Ecol. Evol.* **2**: 1071–1074.
- MICHENER C.D. 1979: Biogeography of the bees. — *Ann. Missouri Bot. Gard.* **66**: 277–347.
- MICHENER C.D. 2007: *The Bees of the World*. The Johns Hopkins Uni Press, Baltimore, 953 pp.
- MICHEZ D., RASMONT P., TERZO M. & VEREECKEN N.J. 2019: *Bees of Europe*. NAP Editions, Verrières-le-Buisson, 548 pp.
- NEWBOLD T., HUDSON L.N., ARNELL A.P., CONTU S., DE PALMA A., FERRIER S., HILL S.L.L., HOSKINS A.J., LYSENKO I., PHILLIPS H.R.P. ET AL. 2016: Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. — *Science* **353**: 288–291.
- NIELSEN A., STEFFAN-DEWENTER I., WESTPHAL C., MESSINGER O., POTTS S.G., ROBERTS S.P.M., SETTELE J., SZENTGYÖRGYI H., VAISSIÈRE B.E., VAITIS M. ET AL. 2011: Assessing bee species richness in two Mediterranean communities: Importance of habitat type and sampling techniques. — *Ecol. Res.* **26**: 969–983.
- NIETO A., ROBERTS S.P.M., KEMP J., RASMONT P., KUHLMANN M., CRIADO M.G., BIESMEIJER J.C., BOGUSCH P., DATHE H.H., DE LA RÚA P. ET AL. 2014: *European Red List of Bees*. Office of the European Union, Luxembourg, 96 pp.
- PARDEE G.L. & PHILPOTT S.M. 2014: Native plants are the bee's knees: local and landscape predictors of bee richness and abundance in backyard gardens. — *Urban Ecosyst.* **17**: 641–659.
- PATINY S., RASMONT P. & MICHEZ D. 2009: A survey and review of the status of wild bees in the West-Palaearctic region. — *Apidologie* **40**: 313–331.
- PENADO A., REBELO H., GOULSON D., WOOD T.J., PORTO M., ROTHERAY E.L. & BEJA P. 2022: From pastures to forests: Changes in Mediterranean wild bee communities after rural land abandonment. — *Insect Conserv. Divers.* **15**: 325–336.
- PETANIDOU T. & ELLIS W.N. 1997: Interdependence of native bee faunas and floras in changing Mediterranean communities. In Matheson A., Buchmann S.L., O'Toole C., Westrich P. & Williams I.H. (eds): *The Conservation of Bees*. Academic Press, London, pp. 201–226.
- PICANÇO A., RIGAL F., MATTHEWS T.J., CARDOSO P. & BORGES P.A.V. 2018: Impact of land-use change on flower-visiting insect com-



- munities on an oceanic island. — *Insect Conserv. Divers.* **10**: 211–223.
- PISANTY G. & MANDELIC Y. 2015: Profiling crop pollinators: Life history traits predict habitat use and crop visitation by Mediterranean wild bees. — *Ecol. Appl.* **25**: 742–752.
- PORTUGUESE BOTANIC SOCIETY 2014: *Flora-On: Portuguese Interactive Flora Platform*. URL: [www.flora-on.pt](http://www.flora-on.pt) [in Portuguese] (last accessed Sep. 17, 2021).
- POTTS S.G., VULLIAMY B., DAFNI A., NE'EMAN G. & WILLMER P. 2003: Linking bees and flowers: how do floral communities structure pollinator communities? — *Ecology* **84**: 2628–2642.
- RODRIGO GÓMEZ S., ORNOSA C., GARCÍA GILA J., BLASCO-ARÓSTEGUI J., SELFA J., GUARA M. & POLIDORI C. 2021: Bees and crops in Spain: an update for melon, watermelon, and almond. — *Ann. Soc. Entomol. Fr.* **57**: 12–28.
- ROULSTON T.H. & GOODELL K. 2011: The role of resources and risks in regulating wild bee populations. — *Annu. Rev. Entomol.* **56**: 293–312.
- RUNDLÖF M., ANDERSSON G.K.S., BOMMARCO R., FRIES I., HEDERSTRÖM V., HERBERTSSON L., JONSSON O., KLATT B.K., PEDERSEN T.R., YOURSTONE J. ET AL. 2015: Seed coating with a neonicotinoid insecticide negatively affects wild bees. — *Nature* **521**: 77–80.
- RUSSO L., PARK M., GIBBS J. & DANFORTH B. 2015: The challenge of accurately documenting bee species richness in agroecosystems: Bee diversity in eastern apple orchards. — *Ecol. Evol.* **5**: 3531–3540.
- SANCHEZ J.A., CARRASCO A., SPINA M. LA, PÉREZ-MARCOS M. & ORTIZ-SÁNCHEZ F.J. 2020: How bees respond differently to field margins of shrubby and herbaceous plants in intensive agricultural crops of the Mediterranean area. — *Insects* **11**: 15–23.
- SENAPATHI D., FRÜND J., ALBRECHT M., GARRATT M.P.D., KLEIJN D., PICKLES B.J., POTTS S.G., AN J., ANDERSSON G.K.S., BÄNSCH S., ET AL. 2021: Wild insect diversity increases inter-annual stability in global crop pollinator communities. — *Proc. R. Soc. (B)* **288**: 20210212, 10 pp.
- SHEFFIELD C.S., PINDAR A., PACKER L. & KEVAN P.G. 2013: The potential of cleptoparasitic bees as indicator taxa for assessing bee communities. — *Apidologie* **44**: 501–510.
- SIRAMI C., GROSS N., BAILLOD A.B., BERTRAND C., CARRIÉ R., HASS A., HENCKEL L., MIGUET P., VUILLOT C., ALIGNIER A. ET AL. 2019: Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions. — *Proc. Natn. Acad. Sci.* **116**: 16442–16447.
- SIROHI M.H., JACKSON J., EDWARDS M. & OLLERTON J. 2015: Diversity and abundance of solitary and primitively eusocial bees in an urban centre: a case study from Northampton (England). — *J. Insect Conserv.* **19**: 487–500.
- THEODOROU P., RADZEVIČIŪTĖ R., LENTENDU G., KAHNT B., HUSEMANN M., BLEIDORN C., SETTELE J., SCHWEIGER O., GROSSE I., WUBET T. ET AL. 2020: Urban areas as hotspots for bees and pollination but not a panacea for all insects. — *Nat. Commun.* **11**: 1–13.
- THRELFALL C.G., WALKER K., WILLIAMS N.S.G., HAHS A.K., MATA L., STORK N. & LIVESLEY S.J. 2015: The conservation value of urban green space habitats for Australian native bee communities. — *Biol. Conserv.* **187**: 240–248.
- TSCHULIN T., NEOKOSMIDIS L., PETANIDOU T. & SETTELE J. 2011: Influence of landscape context on the abundance and diversity of bees in Mediterranean olive groves. — *Bull. Entomol. Res.* **101**: 557–564.
- TUOMISTO H. 2010: A consistent terminology for quantifying species diversity? Yes, it does exist. — *Oecologia* **164**: 853–860.
- WALTHER B.A. & MOORE J.L. 2005: The concepts of bias, precision and accuracy, and their use in testing the performance of species richness estimators, with a literature review of estimator performance. — *Ecography* **28**: 815–829.
- WESTRICH P. 2019: *Die Wildbienen Deutschlands*. Eugen Ulmer, Stuttgart, 824 pp. [in German].
- WINFREE R., BARTOMEUS I. & CARIVEAU D.P. 2011: Native pollinators in anthropogenic habitats. — *Annu. Rev. Ecol. Evol.* **42**: 1–22.
- WOOD T.J., CROSS I. & BALDOCK D.W. 2020: Updates to the bee fauna of Portugal with the description of three new Iberian *Andrena* species (Hymenoptera: Apoidea: Anthophila). — *Zootaxa* **4790**: 201–228.
- ZHAO C., SANDER H.A. & HENDRIX S.D. 2019: Wild bees and urban agriculture: assessing pollinator supply and demand across urban landscapes. — *Urban Ecosyst.* **22**: 455–470.

Received December 27, 2021; revised and accepted June 29, 2022  
Published online August 23, 2022

**Table S1.** Results of the EstimateS analysis, which was used to estimate the specific richness of bees at the three locations during the 15 days of sampling.

Samples	Specimens	S(est)	S Mean	Singletons Mean	Doubletons Mean	Uniques Mean	Duplicates Mean	Chao 1 Mean	Chao 1 SD	Jack 1 Mean	Jack 1 SD
1	13.5	9.1	9.2	6.5	1.6	9.2	0.0	25.3	18.4	9.2	0.0
2	26.9	16.5	16.6	10.8	3.2	14.9	1.7	39.5	20.4	24.1	1.9
3	40.4	22.3	22.4	13.4	4.8	18.2	3.8	47.0	20.6	34.5	2.9
4	53.9	27.4	27.4	15.0	6.0	20.1	5.8	50.4	16.9	42.4	3.2
5	67.3	31.8	31.9	16.5	7.3	21.8	7.2	54.3	15.3	49.3	3.5
6	80.8	35.6	35.8	17.5	8.3	22.9	8.7	57.6	14.1	54.8	3.9
7	94.3	39.0	39.0	18.0	9.3	23.3	9.8	59.3	12.7	58.9	4.1
8	107.7	42.0	41.9	18.3	10.1	23.5	10.7	60.3	11.4	62.4	4.4
9	121.2	44.6	44.5	18.5	11.0	23.8	11.5	61.6	10.4	65.6	4.6
10	134.7	47.0	46.8	18.4	12.0	23.6	12.5	62.0	9.3	68.0	4.6
11	148.1	49.2	48.8	18.1	12.7	23.3	13.1	62.4	8.3	70.0	4.7
12	161.6	51.2	50.7	17.9	13.3	23.0	13.6	63.2	7.7	71.8	4.7
13	175.1	52.9	52.6	17.5	13.7	22.7	14.4	64.2	7.2	73.5	4.6
14	188.5	54.5	54.4	17.1	14.1	22.2	15.0	64.9	6.7	75.0	4.7
15	202.0	56.0	56.0	17.0	14.0	22.0	15.0	66.3	6.5	76.5	4.7

**Table S2.** List of flowering plants recorded in the 15 transects at the sites sampled.

Family	Species	Spontaneous (S) or Cultivated (C)
Acanthaceae	<i>Acanthus mollis</i>	Both
Malvaceae	<i>Alcea rosea</i>	C
Amaryllidaceae	<i>Allium schoenoprasum</i>	C
Lamiaceae	<i>Ballota nigra</i>	C
Asteraceae	<i>Bellis perennis</i>	S
Asteraceae	<i>Bellis sylvestris</i>	S
Brassicaceae	<i>Brassica oleracea</i>	C
Buddlejaceae	<i>Buddleja davidii</i>	C
Asteraceae	<i>Calendula arvensis</i>	C
Asteraceae	<i>Centaurium pulchellum</i>	S
Asteraceae	<i>Cichorium intybus</i>	C
Asteraceae	<i>Cirsium arvense</i>	S
Apiaceae	<i>Conium maculatum</i>	C
Convolvulaceae	<i>Convolvulus althaeoides</i>	S
Convolvulaceae	<i>Convolvulus arvensis</i>	S
Apiaceae	<i>Daucus carota</i>	S
Caryophyllaceae	<i>Dianthus caryophyllus</i>	C
Boraginaceae	<i>Echium plantagineum</i>	S
Boraginaceae	<i>Echium vulgare</i>	S
Onagraceae	<i>Epilobium hirsutum</i>	S
Brassicaceae	<i>Erucastrum incanum</i>	S
Apiaceae	<i>Foeniculum sativum</i>	C
Apiaceae	<i>Foeniculum vulgare</i>	C
Papaveraceae	<i>Fumaria officinalis</i>	S
Asteraceae	<i>Galactites tomentosos</i>	S
Asteraceae	<i>Gazania rigens</i>	C
Asteraceae	<i>Glebionis segetum</i>	S
Hydrangeaceae	<i>Hydrangea macrophylla</i>	C
Balsaminaceae	<i>Impatiens balsamina</i>	C
Asteraceae	<i>Lactuca serriola</i>	S
Verbenaceae	<i>Lantana camara</i>	S
Fabaceae	<i>Lathyrus ochrus</i>	S
Lamiaceae	<i>Lavandula angustifolia</i>	C
Lamiaceae	<i>Lavandula dentata</i>	C
Lamiaceae	<i>Lavandula latifolia</i>	C
Asteraceae	<i>Leucanthemum maximum</i>	C
Asteraceae	<i>Leucanthemum vulgare</i>	C
Primulaceae	<i>Lysimachia arvensis</i>	S
Lythraceae	<i>Lythrum hyssopifolia</i>	S
Fabaceae	<i>Medicago lupulina</i>	S
Lamiaceae	<i>Melissa officinalis</i>	C
Lamiaceae	<i>Mentha pulegium</i>	Both
Lamiaceae	<i>Mentha suaveolens</i>	C
Apocynaceae	<i>Nerium oleander</i>	S
Onagraceae	<i>Oenothera lindheimeri</i>	S
Lamiaceae	<i>Origanum vulgare</i>	C
Oxalidaceae	<i>Oxalis pes-caprae</i>	S
Oxalidaceae	<i>Oxalis tetraphylla</i>	S
Papaveraceae	<i>Papaver rhoeas</i>	S
Fabaceae	<i>Phaseolus coccineus</i>	C
Plantaginaceae	<i>Plantago lanceolata</i>	S
Brassicaceae	<i>Rhapanus raphanistrum</i>	S
Brassicaceae	<i>Rorippa sylvestris</i>	S
Rosaceae	<i>Rosa chinensis</i>	C
Lamiaceae	<i>Rosmarinus officinalis</i>	C
Lamiaceae	<i>Salvia microphylla</i>	C
Lamiaceae	<i>Salvia verbenaca</i>	S
Primulaceae	<i>Samolus valerandi</i>	S
Solanaceae	<i>Solanum lycopersicum</i>	C
Fabaceae	<i>Spartium junceum</i>	S
Asteraceae	<i>Tagetes erecta</i>	C
Lamiaceae	<i>Thymus vulgaris</i>	C
Apiaceae	<i>Torilis arvensis</i>	S
Fabaceae	<i>Trifolium repens</i>	S
Verbenaceae	<i>Verbena officinalis</i>	S
Fabaceae	<i>Vicia faba</i>	C