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LIST OF BEE SPECIES (HYMENOPTERA, APOIDEA) OF LVIV CITY (UKRAINE). PART II: FAMILIES COLLETIDAE LEPELETIER, 1841; HALICTIDAE THOMSON, 1869; MEGACHILIDAE LATREILLE, 1802 AND MELITTIDAE MICHENER, 2000

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Background. The article presents the results of the research on bees (Hymenoptera, Apoidea) that occur in the city of Lviv. Bees are one of the most important pollinators of many species of angiosperm plants. Research on species diversity of bees is very important not only on the wild nature territories, but also on the urbanized areas. Cities have a significant impact on bee species diversity, their biology and conservation. A comprehensive study of all Apoidea on the whole territory of the city of Lviv has been conducted for the first time in more than 80 years and we hope that the presented materials will lay the foundation for further more detailed studies in this area.

Materials and Methods. Lviv is the largest city in Western Ukraine located on the eastern edge of the Roztochia Upland. The material was collected during the warm period of 2017–2019. The Moericke (yellow) pan traps and the entomological nets were used. Besides, we collected dead bees (killed by traffic) along the roads. We have analyzed the entomological collection of the Zoological Museum of the Ivan Franko National University [ZMD] (Lviv). The stereoscopic microscope and a variety of specialized keys for bee species identification were used. We used the Shannon's diversity index to assess species diversity. We also calculated the Shannon evenness measure to facilitate the interpretation of the results.

Results. We analyzed 960 specimens of bees that belong to 106 species, 25 genera and 6 families.

The current (second) part of our study deals with review of the Colletidae (3 species), Halictidae (22 species), Megachilidae (11 species) and Melittidae (5 species) families. Species diversity of the bees from Andrenidae and Apidae families was analyzed in previous (first) the part of our research [27].

Conclusions. All species from the six families are native for the territory of Europe. The majority of them are polylectic ($\approx 61\%$), while the number of oligolectic species ($\approx 23\%$), or species that do not need to collect pollen ($\approx 16\%$) is much smaller. The Shannon's diversity index is approx. 3.718 and the Shannon evenness measure is 0.799 (the honeybee *Apis mellifera* was excluded in both calculations). Analysis of the impact of urbanization and various environmental factors on the species diversity of bees requires further detailed studies.

Keywords: bees, species diversity, Lviv, Ukraine

INTRODUCTION

Bees are one of the most important pollinators of many species of wild angiosperm plants, so they are an integral component of many ecosystems. However, apart from wild plants, bees are also effective pollinators of many crops, orchards and ornamental flower beds on the farmlands and cities.

Research on species diversity of bees is very important not only for the wild nature territories, but also for urbanized areas. Research of wild bees in urban context started recently [3]. Over the past two decades, numerous contributions on the implications of urbanization for biodiversity conservation have been published [5, 12].

Cities have a significant impact on bee species diversity, their biology and conservation. For example, the effects of pesticides, emerging pathogens from managed bees, climate change and land-use change are negatively correlated with bee species richness [6, 7, 9, 10, 11]. Higher diversity of flowering plants due to domestic orchards and ornamental flowers attract many polylectic species, but the abundance of oligolectic species could decrease at the same time. Urbanization often degrades nesting habitats for ground-nesting bees, but various structures like buildings and fences, can lead to an increase in abundance of cavity-nesters in urban habitats [6]. Despite a large number of investigations, many urbanization factors that influence biodiversity and pollination remain unstudied [13]. We are only beginning to understand the possible effects of habitat fragmentation on bees [4].

Significant research on bees on the territory of Western Ukraine was conducted by Maximilian Nowicki, Antoni Wierzejski (19th century), Jan Noskiewicz (the beginning of 20th century) and by Hanna Osychnyuk (the second half of the 20th century) [27]. A comprehensive study of all Apoidea on the whole territory of the city of Lviv has been conducted for the first time in more than 80 years and we hope that the presented materials will lay the foundation for further more detailed studies in this area.

MATERIALS AND METHODS

A brief description of the territory of Lviv City is given in the first part of the study [27].

The objects of our research were bees (Hymenoptera, Apoidea) that occur on the territory of the city of Lviv. We collected the specimens during the warm period of 2017–2019. We used the Moericke (yellow) pan traps and the entomological nets. Moericke yellow trap is a type of attraction traps (insects are attracted by colour) [17]. We used pans of 18 cm in diameter and 7 cm in depth as the most affordable. Traps were filled with water and a few drops of detergent were added.

Also, we collected dead bees (mostly killed by traffic) along the roads. Besides, we analyzed the entomological collection of Zoological Museum of Ivan Franko National University of Lviv (ZMD), collected during 2001–2016 by students and faculty staff.

We used MBS-2 stereoscopic microscope and a variety of specialized keys for bee species identification [1, 2, 8, 16, 19–26]. Higher level classification of bees follows Ch. D. Michener [15]. Information about belonging to the IUCN Red List Categories was obtained from the “European Red List of bees” [18]. Information about species biology was taken from the relevant literature [1, 2, 8, 16, 19, 23–26].

We used the Shannon’s diversity index (H) to assess species diversity. We also calculated the Shannon evenness measure (J) (the ratio of the observed diversity to maximum possible diversity of a given number of taxa) to facilitate the interpretation of the result [14]:

$$J = \frac{H}{\ln S} = \frac{-\sum_i \frac{n_i}{N} \ln \frac{n_i}{N}}{\ln S},$$

where S is the total number of species; N is the total number of specimens and n_i is the number of specimens in species i .

Statistical analysis of the data was performed by the PAST (PAleontological STatistics, Version 2.17c) program.

RESULTS AND DISCUSSION

During the research, 960 specimens of bees that belong to 106 species, 25 genera and 6 families (Apidae, Andrenidae, Colletidae, Halictidae, Megachilidae and Melittidae) were examined. Species diversity of bees of Andrenidae and Apidae families was presented in the first part of our research [27]. In this part of our study, we have reviewed Colletidae Lapeletier, 1841 (10 examined specimens), Halictidae Thomson, 1869 (73 specimens), Megachilidae Latreille, 1802 (86 specimens) and Melittidae Michener, 2000 (32 specimens) families.

In our collection, the Colletidae family is presented only by 3 species from a single genus – *Colletes* Latreille, 1802 (**Table 1**).

Table 1. Bees of the Colletidae family occurring on the territory of the city of Lviv

Таблиця 1. Бджолині родини Colletidae, поширені на території міста Львова

No	Species	Species biology	Conservation
1.	<i>Colletes cunicularius</i> (Linnaeus, 1761)	Solitary. Univoltine (April–June). Polylectic. Nest in soil	LC
2.	<i>C. daviesanus</i> Smith, 1846	Solitary. Univoltine (June–September). Oligolectic on Asteraceae. Nest in soil	LC
3.	<i>C. similis</i> Schenck, 1853	Solitary. Univoltine (June–September). Oligolectic on Asteraceae. Nest in soil	LC

Comments: Species conservation (IUCN Red List Categories): LC – Least concern

Примітки: Охорона видів (категорії Червоного списку МСОП): LC – “Найменший ризик”

Colletidae is the poorest family in the number of species in our collection. All three species are native for the territory of Europe, solitary and nesting in soil. These species are listed in the category “Least concern” of the IUCN Red List. One species is polylectic and two other species are oligolectic.

In our collection, the Halictidae family is presented by 22 species from 5 genera – *Halictus* Latreille, 1804, *Lasioglossum* Curtis, 1833, *Rophites* Spinola, 1808, *Sphecodes* Latreille, 1804 and *Systropha* Illiger, 1806 (**Table 2**).

Table 2. Bees of the Halictidae family occurring on the territory of the city of Lviv

Таблиця 2. Бджолині родини Halictidae, поширені на території міста Львова

No	Species	Species biology	Conservation
1.	<i>Halictus rubicundus</i> (Christ, 1791)	Primitively eusocial. Flight from April to October. Polylectic. Nest in soil	LC
2.	<i>H. subauratus</i> Rossius, 1792	Primitively eusocial. Flight from May to October. Oligolectic on Asteraceae. Nest in soil	LC
3.	<i>H. tumulorum</i> (Linnaeus, 1758)	Primitively eusocial. Flight from April to October. Polylectic. Nest in soil	LC
4.	<i>Lasioglossum albipes</i> (Fabricius, 1781)	Primitively eusocial. Flight from April to October. Polylectic, with preference to <i>Ranunculus</i> L. (Ranunculaceae). Nest in soil	LC
5.	<i>L. fulvicorne</i> (Kirby, 1802)	Solitary. Univoltine (April–October). Polylectic. Nest in soil	LC
6.	<i>L. laevigatum</i> (Kirby, 1802)	Solitary. Univoltine (April–September). Polylectic. Nesting unknown	NT
7.	<i>L. laticeps</i> (Schenck, 1870)	Primitively eusocial. Flight from April to September. Polylectic. Nest in soil	LC
8.	<i>L. lativentre</i> (Schenck, 1853)	Solitary. Probably univoltine (March–October). Polylectic. Nesting unknown	LC
9.	<i>L. leucozonium</i> (Schränk, 1781)	Solitary. Univoltine (April–October). Polylectic, with preference to Asteraceae. Nest in soil	LC
10.	<i>L. majus</i> (Nylander, 1852)	Solitary. Univoltine (April–October). Polylectic. Nest in soil	NT
11.	<i>L. morio</i> (Fabricius, 1793)	Primitively eusocial. Flight from April to September. Polylectic. Nest in soil	LC
12.	<i>L. nigripes</i> (Lepeletier, 1841)	Primitively eusocial. Flight from April to October. Polylectic. Nest in soil	LC
13.	<i>L. pauxillum</i> (Schenck, 1853)	Primitively eusocial. Flight from April to October. Polylectic. Nest in soil	LC
14.	<i>L. politum</i> (Schenck, 1853)	Primitively eusocial. Flight from April to September. Polylectic. Nest in soil	LC
15.	<i>L. sabulosum</i> (Warncke, 1986)	Primitively eusocial. Flight from April to October. Polylectic. Nesting unknown	NT
16.	<i>L. sexnotatum</i> (Kirby, 1802)	Solitary. Univoltine (April–October). Polylectic. Nesting unknown	NT
17.	<i>L. villosulum</i> (Kirby, 1802)	Solitary. Bivoltine (April–October). Polylectic, with preference to Asteraceae. Nest in soil	LC
18.	<i>L. xanthopus</i> (Kirby, 1802)	Solitary. Univoltine (May–August). Polylectic. Nest in soil	NT
19.	<i>L. zonulum</i> (Smith, F., 1848)	Solitary. Univoltine (May–October). Polylectic. Nest in soil	LC
20.	<i>Rophites quinquespinosus</i> Spinola 1808	Solitary. Univoltine (May–October). Oligolectic on Lamiaceae. Nest in soil	NT
21.	<i>Sphecodes gibbus</i> (Linnaeus, 1758)	Kleptoparasite. Flight from April to September. It does not collect pollen. Parasite in nests of <i>Halictus</i> spp. and <i>Lasioglossum</i> spp.	LC
22.	<i>Systropha curvicornis</i> (Scopoli, 1770)	Solitary. Univoltine (June–August). Oligolectic on <i>Convolvulus</i> L. (Convolvulaceae). Nest in soil	NT

Comments: Species conservation (IUCN Red List Categories): LC – Least concern, NT – Near Threatened

Примітки: Охорона видів (категорії Червоного списку МСОП): LC – “Найменший ризик”, NT – “Близький до загрозливого стану”

All collected Halictidae species are native for the territory of Europe. These species are listed in two categories of the IUCN Red List: “Least concern” (15 species) and “Near Threatened” (7 species).

Among the collected Halictidae, 11 species are solitary, 10 are primitively eusocial and 1 species is a kleptoparasite. 17 species nest in soil, and for 4 species, the mode of nesting is unknown. Polylectic species predominate in our collection of Halictidae (18 species or $\approx 82\%$ of all collected Halictidae), the number of oligolectic species is significantly lower (3 species or $\approx 14\%$) and one species ($\approx 4\%$) does not need to collect pollen, because of its kleptoparasitism.

In our collection, the Megachilidae family is presented by 11 species from 4 genera – *Anthidium* Fabricius, 1805, *Chelostoma* Latreille, 1809, *Megachile* Latreille, 1802, *Osmia* Panzer, 1806 (Table 3).

Table 3. Bees of the Megachilidae family occurring on the territory of the city of Lviv

Таблиця 3. Бджолині родини Megachilidae, поширені на території міста Львова

No	Species	Species biology	Conservation
1.	<i>Anthidium manicatum</i> (Linnaeus, 1758)	Solitary. Univoltine (May–August). Polylectic. Nest in cavities in different substrates	LC
2.	<i>A. oblongatum</i> (Illiger, 1806)	Solitary. Univoltine (May–August). Polylectic. Nest in cavities in different substrates	LC
3.	<i>Chelostoma campanularum</i> (Kirby, 1802)	Solitary. Univoltine (June–August). Oligolectic on <i>Campanula</i> L. (Campanulaceae). Nest in cavities in the wood	LC
4.	<i>C. florissomne</i> (Linnaeus, 1758)	Solitary. Univoltine (May–July). Oligolectic on Ranunculaceae. Nest in cavities in the wood	LC
5.	<i>Megachile centuncularis</i> (Linnaeus, 1758)	Solitary. Univoltine (June–August). Polylectic. Nest in cavities in different substrates	LC
6.	<i>M. circumcincta</i> (Kirby, 1802)	Solitary. Univoltine (May–August). Polylectic. Nest in cavities in different substrates	LC
7.	<i>M. ericetorum</i> Lepeletier, 1841	Solitary. Univoltine (June–August). Oligolectic on Fabaceae. Nest in cavities in the wood	LC
8.	<i>M. willughbiella</i> (Kirby, 1802)	Solitary. Univoltine (June–August). Polylectic. Nest in cavities in the wood or soil	LC
9.	<i>Osmia bicornis</i> (Linnaeus, 1758)	Solitary. Univoltine (April–June). Polylectic. Nest in cavities in different substrates	LC
10.	<i>O. cornuta</i> Latreille, 1805	Solitary. Univoltine (March–June). Polylectic. Nest in cavities in different substrates	LC
11.	<i>O. leaiana</i> (Kirby, 1802)	Solitary. Univoltine (May–August). Oligolectic on Asteraceae. Nest in cavities in different substrates	LC

Comments: Species conservation (IUCN Red List Categories): LC – Least concern

Примітки: Охорона видів (категорії Червоного списку МСОП): LC – “Найменший ризик”

All collected Megachilidae species are native for the territory of Europe, solitary cavity-nesters and listed in the category “Least concern” of the IUCN Red List. Seven species ($\approx 64\%$ of all collected Megachilidae) are polylectic and four species ($\approx 36\%$) are oligolectic.

In our collection, the Melittidae family is presented by 5 species from 3 genera – *Dasygoda* Latreille, 1802, *Macropis* Panzer, 1809, *Melitta* Kirby, 1802 (**Table 4**).

Table 4. Bees of the Melittidae family occurring on the territory of the city of Lviv

Таблиця 4. Бджолині родини Melittidae, поширені на території міста Львова

No	Species	Species biology	Conservation
1.	<i>Dasygoda hirtipes</i> (Fabricius, 1793)	Solitary. Univoltine (June–August). Oligolectic on Asteraceae. Nest in soil	LC
2.	<i>Macropis europaea</i> Warncke, 1973	Solitary. Univoltine (July–September). Oligolectic on <i>Lysimachia</i> L. (Primulaceae). Nest in soil	LC
3.	<i>M. fulvipes</i> (Fabricius, 1804)	Solitary. Univoltine (July–September). Oligolectic on <i>Lysimachia</i> L. (Primulaceae). Nest in soil	LC
4.	<i>Melitta leporina</i> (Panzer, 1799)	Solitary. Univoltine (June–August). Oligolectic on Fabaceae. Nest in soil	LC
5.	<i>M. tricineta</i> Kirby, 1802	Solitary. Univoltine (July–September). Monolectic on <i>Odontites vernus</i> Dumort., 1827 (Orobanchaceae). Nest in soil	NT

Comments: Species conservation (IUCN Red List Categories): LC – Least concern, NT – Near Threatened

Примітки: Охорона видів (категорії Червоного списку МСОП): LC – “Найменший ризик”, NT – “Близький до загрозливого стану”

All collected Melittidae species are native for the territory of Europe, solitary and nesting in soil. Four of them are listed in the category “Least Concern” and one – in the category “Near Threatened” of the IUCN Red List. Melittidae species are pollen specialists and forage on the plants from one family, genus or even species.

The summarized data for all six families of bees show a predominance of polylectic species ($\approx 61\%$), while the number of oligolectic species ($\approx 23\%$), or species that do not need to collect pollen ($\approx 16\%$) is much smaller. The Shannon’s diversity index is ≈ 3.718 and the Shannon evenness measure is ≈ 0.799 (the honeybee *Apis mellifera* was excluded in both calculations).

CONCLUSIONS

The current composition of the bees’ fauna within the city of Lviv includes 106 species, which belong to 25 genera and 6 families (Apidae, Andrenidae, Colletidae, Halictidae, Megachilidae and Melittidae).

The family Apidae is presented by 33 species and is the richest by the number of species among all the six families. The family Andrenidae is presented by 32 species, Halictidae – 22 species, Megachilidae – 11 species and Melittidae – 5 species. The family Colletidae is presented by 3 species only and is the poorest family in the number of species in our collection.

All species discussed above are native for the territory of Europe. The majority of them are polylectic ($\approx 61\%$), while the number of oligolectic species ($\approx 23\%$), or species that do not need to collect pollen ($\approx 16\%$) is much smaller.

The Shannon's diversity index is ≈ 3.718 and the Shannon evenness measure is ≈ 0.799 (the honeybee *Apis mellifera* was excluded in both calculations). This index indicates a high species diversity that can be associated with the variety of habitats and food sources.

Analysis of the impact of urbanization and various environmental factors on the species diversity of bees requires further detailed studies. This research can lay the basement for further studies in this field.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Human Rights: This article does not contain any studies with human subjects performed by any of the authors.

Animal studies: All institutional, national and institutional guidelines for the care and use of laboratory animals were followed.

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СПИСОК ВИДІВ БДЖОЛИНИХ (HYMENOPTERA, APOIDEA) НА ТЕРИТОРІЇ ЛЬВОВА (УКРАЇНА). ЧАСТИНА II: РОДИНИ COLLETIDAE LEPELETIER, 1841; HALICTIDAE THOMSON, 1869; MEGACHILIDAE LATREILLE, 1802 TA MELITTIDAE MICHENER, 2000

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Вступ. У статті представлено результати досліджень бджолиних (Hymenoptera, Apoidea), які трапляються на території м. Львова. Бджолині є одними з найважливіших запилювачів багатьох покритонасінних рослин. Дослідження видового різноманіття бджолиних дуже важливі не тільки на природних територіях, але і на урбанізованих. Міста мають значний вплив на видове різноманіття бджолиних, їхню біологію та збереження. Дослідження сукупності усіх бджолиних на території м. Львова проводиться вперше за більш ніж 80 років, і ми сподіваємося, що ці матеріали стануть основою для подальших детальніших досліджень у цьому напрямі.

Матеріали та методи. Львів є найбільшим містом у західній Україні й розташований на краю горбистого пасма Розточчя. Матеріал збирали упродовж теплого періоду 2017–2019 років. Для лову комах ми використовували ентомологічні сачки та пастки Меріке. Також збирали комах, збитих транспортом на дорозі. Крім цього, аналізували ентомологічні колекції Зоологічного музею Львівського національного університету імені Івана Франка. Для визначення комах використовували стереоскопічний мікроскоп і спеціальні визначники. Для оцінювання видового різноманіття використали індекс Шеннона. Також для полегшення інтерпретації результату обчислили вирівняність індексу Шеннона.

Результати. Упродовж досліджень ми проаналізували 960 екземплярів бджолиних, котрі належать до 106 видів, 25 родів і 6 родин. У цій статті представлено аналіз таксономічного різноманіття бджолиних родини Colletidae (3 види), Halictidae (22 види), Megachilidae (11 видів) і Melittidae (5 видів). Різноманіття бджолиних із родин Andrenidae й Apidae було представлено у першій частині цього циклу публікації [27].

Висновки. Усі види бджолиних із шести родин є аборигенними для території Європи. Більшість із них є полілектами ($\approx 61\%$), а кількість оліголектичних видів ($\approx 23\%$) і видів, котрі не збирають пилок ($\approx 16\%$), є значно меншою. Індекс видового різноманіття Шеннона становить $\approx 3,718$, а індекс вирівняності Шеннона – $\approx 0,799$ (в обох розрахунках медоносна бджола *Apis mellifera* не була взята до уваги). Аналіз впливу урбанізації та різних чинників середовища на видове різноманіття бджолиних потребує подальших детальних досліджень.

Ключові слова: бджолині, видове різноманіття, Львів, Україна