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New records for the wild bee fauna (Hymenoptera, Anthophila) of Serbia

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Abstract

Numerous scientific projects have been initiated with the aim of tackling the decline in insect pollinators, a crucial group for the functioning of terrestrial ecosystems. One of the first steps is to address information gaps on species spatial distribution, diversity, and abundance that prevent effective conservation actions in Europe. Given that Serbia belongs to the understudied areas, efforts are being made to improve knowledge of its bee diversity and abundance. The present study includes the monitoring of bees at 54 sites, surveyed three times during 2022. The conducted protocol combined two methods, transect walks and pan traps, resulting in the discovery of 312 bee species. The main results present the records of 25 species, not previously mentioned in Serbia, while another important finding is the confirmation of the presence of 26 species, without any available records from the 21st century. Moreover, 79 here examined species were known only from literature-based data. Six of the recorded species are considered threatened and 67 (10 newly recorded) have been assessed as Data Deficient in the European Red List of Bees. Therefore, the present study not only contributes to an update and confirms the list of bee species in Serbia, that now counts 731 species, but also provides additional information about European distribution, required for new assessment at the European level. In addition, the results indicate that the combination of complementary sampling methods is an effective way to assess bee diversity and abundance.

Keywords

bees, Data Deficient, monitoring, new data, pan traps, transect walks

Introduction

It has become common knowledge that pollinators play a crucial role in ecosystems by supporting sexual reproduction for most flowering plants (e.g., Ollerton et al. 2011), with bees being the most important pollinator group (Ballantyne et al. 2017; Willmer et al. 2017). It is also widely known that the global entomofauna is declining (Goulson 2019; Sánchez-Bayo and Wyckhuys 2019; Wagner 2020), primarily due to urbanization and agriculture (Uhler et al. 2021). Most pollinators, including wild bees, show negative population trends (Potts et al. 2010, 2015; Goulson et al. 2015; Dicks et al. 2021; but see Ghisbain et al. 2021). Loss of habitat caused by changes in land use and management (e.g., Kremen et al. 2002; Steffan-Dewenter and Westphal 2008; Kennedy et al. 2013), pollution (Gill et al. 2012), diseases (Power and Mitchell 2004; Colla et al. 2006; Purkiss and Lach 2019), exotic species and climate change (González-Varo et al. 2013; Martinet et al. 2021), as well as the interaction of these factors, are the main drivers of change and the decline in pollinator communities (LeBuhn and Vargas Luna 2021). The last decade has seen a considerable increase in interest among the scientific and general public with respect to the conservation of pollinators (Drossart and Gérard 2020). The research on biodiversity has generally expanded, however, the under-representation of insects in published literature, compared to vertebrates, is caused by the fact that working with more diverse taxa is more challenging, particularly in terms of species identification (Titley et al. 2017). Although there is evidence of changes in bee abundance and species richness, there is still a lack of data on global decline (IPBES 2016; Zattara and Aizen 2021).

Regarding the status and trends of bees (Anthophila) in Europe, the European Red List of Bees (Nieto et al. 2014) indicates that 37% of bee species, excluding Data Deficient, have declining populations, while other national Red Lists in Europe imply that up to 40% of bee species are threatened (IPBES 2016; Drossart et al. 2019). However, available knowledge on the spatial distribution of most bee species is incomplete (Nieto et al. 2014) and uneven between countries (Potts et al. 2021). According to Nieto et al. (2014), more than half (56.7%) out of 1,942 assessed species have been listed as Data Deficient in Europe. Significant work has been conducted under the EU (European Union) Biodiversity Strategy for 2030, with one of its key commitments being the reversal of the decline of pollinators (European Commission 2021). The European Commission established the EU Pollinators Initiative, the first-ever EU framework for tackling the decline of wild pollinators, and set up the EU Pollinator Monitoring Scheme (EU-PoMS) to harmonize the systematic monitoring of the status and trends of pollinators across the EU. It has been emphasized that significant data gaps prevent effective conservation actions, especially in the south-eastern part of Europe (Potts et al. 2021).

Currently, at the European level, numerous scientific projects are being implemented, simultaneously, directed towards gathering information on pollinators, including bees. Apart from the widely recognized need for systematic monitoring, these projects stress the need to strengthen education and communication, through training of taxonomists, engaging the potential of citizen science, creating platforms for facilitating

information sharing and the collaboration between stakeholders. Some projects, such as the PoshBee (2018–2023), address direct threats with the aim of providing the first pan-European assessment of the hazard to managed and wild bees from chemical exposure (Brown et al. 2021). Other projects aim to tackle gaps in pollinators' taxonomy, distribution and extinction risk. Namely, the project Safeguard (2021–2025) provides a comprehensive re-assessment of the status and trends of European wild pollinators, including their diversity and abundance, filling knowledge gaps associated primarily with Data Deficient species. The objective of the project SPRING (2021–2023) is to strengthen taxonomic capacity in EU Member States with regard to pollinating insects, and provide support for the implementation of the EU-PoMS (Potts et al. 2021). The project PULSE (2022–2023) prepares updates for the European Red List of Bees, collecting databases from taxonomists and national champions and digitizing museum collections. The project ORBIT (2021–2024) aims to create a centralized taxonomic facility that lays the groundwork for the identification of European wild bees, supporting all the above mentioned European projects. Furthermore, initiatives at national levels represent a very important contribution to filling information gaps, especially in understudied areas. In Serbia, the project SPAS (2022–2024) has been established as a preparatory phase for the EU-PoMS, with the objective of building a long-term national monitoring strategy for wild insect pollinators compatible with the European one.

Recognizing the above mentioned issues, primarily the lack of publicly available data on national occurrence records, two European studies have been recently published to update the checklist of European bees (Ghisbain et al. 2023) and European bees country records (Reverté et al. 2023). Moreover, focusing on Serbia, Mudri-Stojnić et al. (2021) recently published a preliminary list of 706 bee species. For the first time, all accessible records had been summarized, emphasizing the fact that, undoubtedly, more species are yet to be discovered. The main purpose of the present study is to propose an update, including the most recent observations on wild bee species occurrences in Serbia. The specific goals of the study are: (1) to introduce the first published records from Serbia for 25 species; (2) to confirm the presence of 26 species, for which records referring to the 21st century are lacking; (3) to contribute to the information about distribution, needed for the evaluation of Data Deficient species in Europe; (4) to discuss various monitoring and sampling methods. The results aim to contribute to updating knowledge on wild bee diversity in Serbia, necessary for determining conservation priorities and future endeavors at the national level, but also for improving an understanding of the status of European pollinators.

Materials and methods

Survey methodology

The data for the present study was primarily gathered during the implementation of the national project, Serbian Pollinator Advice Strategy – for the next normal (SPAS

2022–2024), and partially within the EU-funded project, Safeguarding European wild pollinators (Safeguard 2021–2025). Both projects aim to address the diversity of major pollinator taxa with a focus on bees, hoverflies and butterflies as the most species-rich and functionally relevant groups.

In order to monitor the diversity and abundance of insect pollinators in Serbia, 54 sites were selected (Fig. 1) on the basis of expert opinion; the intention was to include as many semi-natural habitats as possible. For the Safeguard project, localities were chosen to represent the open semi-natural habitat type – steppe grasslands. The SPAS project localities included other habitat types as well: forest-steppe, forest meadow, wet meadow, mountain meadow, sub-Mediterranean grassland, and rocky grassland, with a minimum separation distance of 2 km to reduce spatial autocorrelation. The goal was to achieve a representative depiction of geographical regions, while enabling proportional representation of different habitats in the sample. The sites were surveyed three times each, throughout the 2022 season (March–May, June, and August–September), so as to reduce the phenology effects and to increase species richness accumulation, i.e., sampling completeness. The survey period was adapted to the expected weather conditions and flower availability.

The assessment of bee diversity and abundance was conducted in accordance with the methodology and recommendations of the EU-PoMS (Potts et al. 2021). The protocol combined two methods: the passive method (does not rely on attracting insects), i.e., transect walks, conducted at all 54 studied sites, and the active method (relies on attracting insects), i.e., pan traps, conducted as an additional method at a subset of 31 sites.

Pan traps, a lethal sampling technique designed to survey nectar-searching insects, consisted of a cluster of three water-filled bowls (with some soap to break the surface) of three colors (blue, white and yellow per group) and set on stakes at a vegetation height to mimic flowers and attract insects. Based on the EU-PoMS (Potts et al. 2021) the protocol included the placement of 10 pan trap clusters (around 8 a.m.), across the grid square, and the collection of specimens, after approximately 12 hours (around 8 p.m.), which were then transported to the laboratory for further identification.

Transect walks were undertaken ~100 m apart from the pan traps. This method, designed to survey flying insects, included walks along the transect route, at a steady speed, to record every bee individual observed along a transect route of constant width ahead and to the side of the surveyor. The transects were ~500 m in length and 2 m in width (1 m to each side of the surveyor), resulting in ~1000 m^2 of transect area. The transect time per site was 30 min with 5 min sub-transects (~80 m), not including handling time (i.e., transferring and labelling the specimens), namely only time spent for searching and catching bees. Specimens that could not be identified with certainty to species level in the field, were collected in plastic vials with the aid of drops of acetone on a cotton ball. These specimens were subsequently identified in the laboratory of the Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad, Serbia (FSUNS) and by expert Józan Zsolt (Mernye, Hungary).

The QGIS Geographic Information System (QGIS Development Team 2022) was used to create the map of 54 examined sites (Fig. 1).

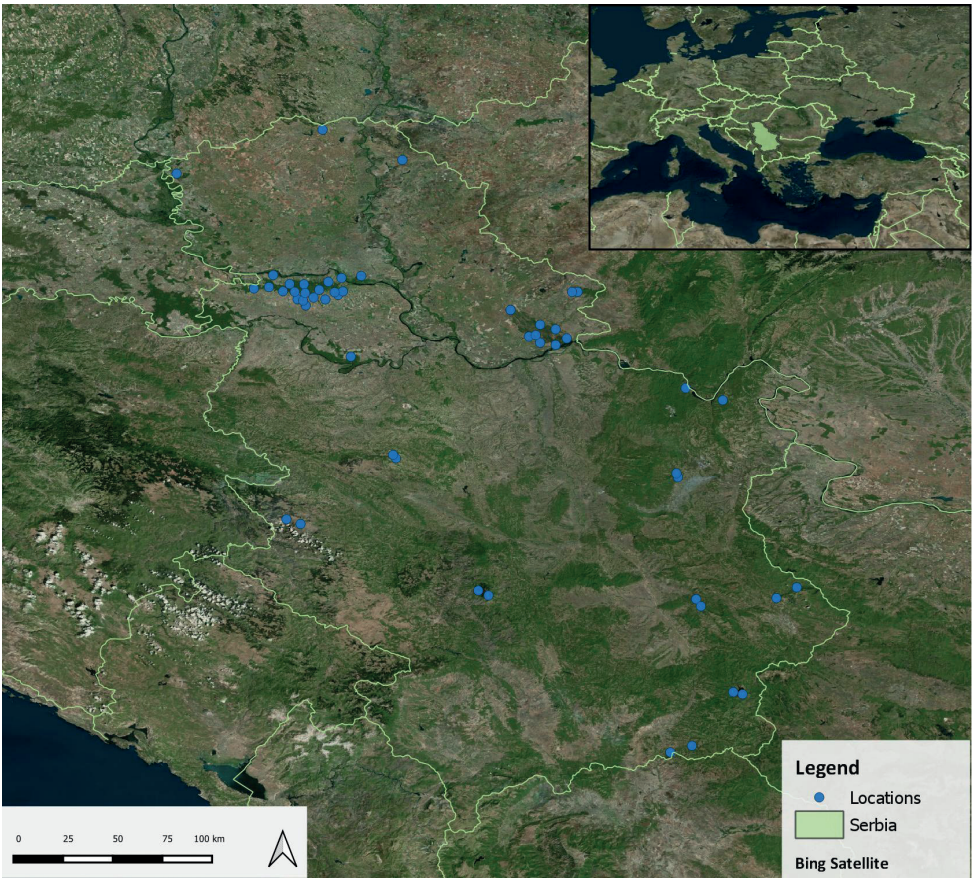

Figure 1. Map of Serbia showing the localities where bee specimens were collected.

Examined material

All of the examined specimens were dry pinned and stored in FSUNS's entomological collection. The list of previously unpublished records of bee species for Serbia has been given in full, as has the list of species considered threatened in Europe according to the European Red List (Nieto et al. 2014), with families, genera and species arranged in alphabetical order. The recently published annotated checklist of the wild bees of Europe (Ghisbain et al. 2023) has been consulted for the nomenclature. Information on examined material has been provided in the following order: number and sex of specimens after a bullet point (indicating the beginning of material citation); locality data; geographical coordinates; collection date; collector followed by "leg." (if specimens were detected during the transect walks) or the color of pan trap, depending on collection methodology; institution code and specimen codes, i.e., unique identifiers ("to" indicates range). If a species was found in multiple localities, the specimens have been listed by increasing latitude (south to north). The IUCN (The International Union for Conservation of Nature) Red List Categories (Europe) (Nieto et al. 2014) were indicated in square brackets for each species (abbreviations: EN – Endangered, VU – Vulnerable,

NT – Near Threatened, LC – Least Concern, DD – Data Deficient). For the records of wild bee species considered threatened in Europe, additional data has been provided, regarding habitat type and the main floral resources. The latter refers to the plant species on whose flowers the insects were caught during transect walks, whereas this information is lacking for the specimens caught on flight, on the ground, or collected from pan traps.

The list of all recorded species can be found in the Suppl. material 1. Additional information has been provided for each species: IUCN categories; collection methodology types; data on the presence of listed species in the online maps of the Checklist of the Western Palaearctic Bees (Kuhlmann et al. 2023); data on the species with occurrences previously available only from sources prior to year 2000. The list of references and collections' abbreviations cited in Suppl. material 1 follows the list of species at the end of the table.

Results

The present study included field research which resulted in the recording of 2,645 bee (Anthophila) specimens, 851 collected from pan traps (334 in blue, 278 in yellow and 239 in white) and 1,794 observed during transect walks. An identification of the material revealed 312 species in total (see Suppl. material 1). These species belong to the following IUCN categories: EN (four species), VU (two species), NT (22 species), LC (216 species), DD (67 species) and *Dasypoda morawitzi* Radchenko still uncategorized. According to sampling methodologies, 166 species were detected during transect walks, 51 were caught in pan traps and 95 species were found both in pan traps and during transect walks (Fig. 2A). Considering only the subset of 31 sites where both sampling methods were conducted, 247 species were detected, i.e., 101 by transect walks, 68 by pan traps and 78 by both methods (Fig. 2B).

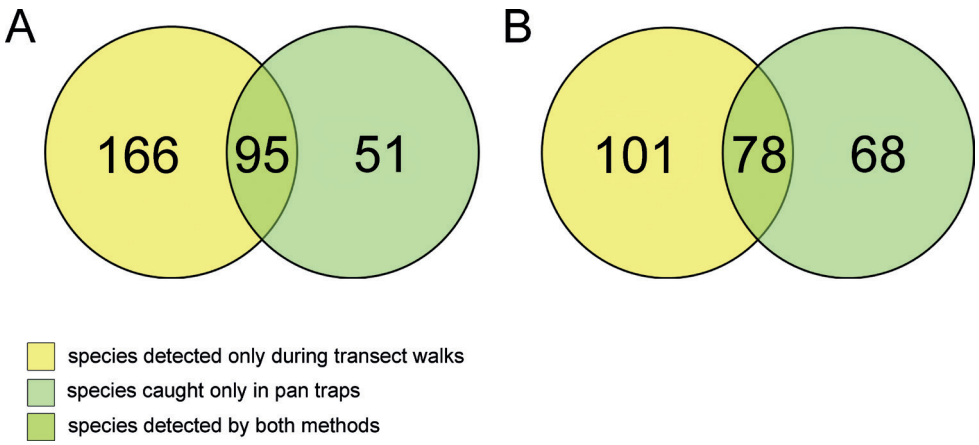

Figure 2. Graphic view of the number of species detected depending on the sampling methods **A** at all studied sites **B** at a subset of sites where both sampling methods were conducted.

Concerning available information on the presence of here listed species in Serbia, 25 are without previous records, 26 have records only from sources prior to year 2000, 15 have data of occurrence only from Kuhlmann et al. (2023), while 52 species are from both older literature sources and Kuhlmann et al. (2023) (see Suppl. material 1). The newly detected species were found in 37 out of 54 studied localities across Serbia. Regarding sampling methodologies, 12 of these 25 species were detected during transect walks, seven were caught in pan traps, and six were found using both methods. The records of species without previously published occurrences in Serbia, as well as of the six species considered threatened in Europe (according to Nieto et al. (2014)), have been presented in the following lists.

New records of wild bee species in Serbia

Family Andrenidae
***Andrena* Fabricius**

***Andrena bisulcata* Morawitz [LC]**

• 1 ♀; Pčinja, Vražji kamen; 42.3838°N, 22.0528°E; 20 Apr. 2022; Laura Likov leg.; FSUNS SPAS10082.

***Andrena braunsiana* Friese [DD]**

• 7 ♀♀; Fruška gora, Stejanovci; 45.0428°N, 19.7199°E; 5 May 2022; Ante Vujić leg.; FSUNS SG0018, SG0021, SG0022, SG0025 to SG0028 • 1 ♂; Fruška gora, Šuljam; 45.0814°N, 19.6717°E; 5 May 2022; Ante Vujić leg.; FSUNS SG0073.

***Andrena florivaga* Eversmann [LC]**

• 1 ♂; 'The great bustard pastures' ['Pašnjaci velike droplje'], Mokrin; 45.9217°N, 20.3033°E; 4 May 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00161.

***Andrena fulva* (Müller) [DD]**

• 1 ♀; Zlot, towards Malinik; 44.0055°N, 21.9676°E; 27 Apr. 2022; yellow pan trap; FSUNS SPAS20492.

***Andrena fulvata* Stöckhert [DD]**

• 1 ♀; Zlatibor, Obudovica; 43.7227°N, 19.6881°E; 11 May 2022; yellow pan trap; FSUNS SPAS30391 • 2 ♀♀; Zlatibor, Semegnjevo; 43.7514°N, 19.6037°E; 10 May 2022; white pan trap; FSUNS SPAS30407, SPAS30409.

***Andrena mitis* Schmiedeknecht [DD]**

• 1 ♂; Jelašnica river gorge, Čukljenik; 43.2686°N, 22.0779°E; 22 Apr. 2022; blue pan trap; FSUNS SPAS10396.

***Andrena pallitarsis* Pérez [DD]**

• 1 ♀; Fruška gora, Vrdnik; 45.1372°N, 19.8013°E; 30 Aug. 2022; Ante Vujić leg.; FSUNS SG0885.

***Andrena russula* Lepeletier [DD]**

• 1 ♂; Rajac, Slavkovica; 44.1408°N, 20.2474°E; 9 May 2022; Ana Grković leg.; FSUNS SPAS30072.

***Andrena saxonica* Stöckhert [DD]**

• 2 ♀♀; Zlatibor, Semegnjevo; 43.7514°N, 19.6037°E; 18 Jun. 2022; Ana Grković leg.; FSUNS SPAS30211, SPAS30215 • 1 ♀; Zlot, towards Malinik; 44.0055°N, 21.9676°E; 27 Apr. 2022; white pan trap; FSUNS SPAS20513 • 1 ♀; Đerdap, Ciganski potok; 44.5436°N, 22.0146°E; 26 Apr. 2022; yellow pan trap; FSUNS SPAS20425 • 1 ♀; Fruška gora, Šuljam; 45.0814°N, 19.6717°E; 5 May 2022; Ante Vujić leg.; FSUNS SG0044.

***Andrena tscheki* Morawitz [DD]**

• 1 ♀; Suva planina, Bojanine vode; 43.2260°N, 22.1068°E; 22 Apr. 2022; white pan trap; FSUNS SPAS10337 • 1 ♂; same data as for preceding; yellow pan trap; FSUNS SPAS10339 • 1 ♀; Stara planina, Topli Do; 43.3400°N, 22.6856°E; 30 Apr. 2022; Tamara Tot leg.; FSUNS SPAS20095 • 1 ♀; Zlatibor, Obudovica; 43.7227°N, 19.6881°E; 11 May 2022; Ana Grković leg.; FSUNS SPAS30122 • 1 ♀; Zlot, towards Malinik; 44.0055°N, 21.9676°E; 27 Apr. 2022; white pan trap; FSUNS SPAS20499 • 3 ♀♀; same data as for preceding; Tamara Tot leg.; FSUNS SPAS20069 to SPAS20071 • 1 ♂; same data as for preceding; FSUNS, SPAS20065 • 1 ♀; Lazar's canyon, Lazar's cave; 44.0286°N, 21.9587°E; 28 Apr. 2022; Tamara Tot leg.; FSUNS SPAS20076 • 1 ♀; Đerdap, Ciganski potok; 44.5436°N, 22.0146°E; 26 Apr. 2022; Tamara Tot leg.; FSUNS SPAS20042 • 1 ♀; Vršački breg, Kula; 45.1245°N, 21.3283°E; 24 Jun. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00083.

Family Apidae
***Ceratina* Latreille**

***Ceratina gravidula* Gerstaecker [LC]**

• 1 ♀; Lazar's canyon, Lazar's cave; 44.0286°N, 21.9587°E; 27 Aug. 2022; Tamara Tot leg.; FSUNS SPAS20557 • 1 ♀; Fruška gora, Neradin Česma; 45.1061°N, 19.9156°E; 14 Sep. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00740.

Family Colletidae
***Hylaeus* Fabricius**

***Hylaeus nigrifacies* Bramson [LC]**

• 1 ♀; Deliblato sands, Čardak II; 44.8628°N, 21.1059°E; 27 Aug. 2022; Ante Vujić leg.; FSUNS SG1104 • 1 ♀; Fruška gora, Šuljam; 45.0814°N, 19.6717°E; 18 Jun. 2022; Ante Vujić leg.; FSUNS SG0692.

Family Halictidae
***Lasioglossum* Curtis**

***Lasioglossum bluethgeni* Ebmer [LC]**

• 6 ♀♀; Suva planina, Bojanine vode; 43.2260°N, 22.1068°E; 15 Jun. 2022; blue pan trap; FSUNS SPAS10510, SPAS10511, SPAS10515 to SPAS10517, SPAS10519 • 3 ♀♀; same data as for preceding; white pan trap; FSUNS SPAS10522 to SPAS10524 • 1 ♀; same data as for preceding; yellow pan trap; FSUNS SPAS10526 • 1 ♀; Jelašnica river gorge, Čukljenik; 43.2686°N, 22.0779°E; 22 Apr. 2022; yellow pan trap; FSUNS SPAS10382 • 4 ♀♀; same data as for preceding; 15 Jun. 2022; blue pan trap; FSUNS SPAS10489 to SPAS10492 • 2 ♀♀; same data as for preceding; white pan trap; FSUNS SPAS10477, SPAS10478 • 2 ♀♀; Lazar's canyon, Lazar's cave; 44.0286°N, 21.9587°E; 9 Jun. 2022; blue pan trap; FSUNS SPAS20324, SPAS20325 • 1 ♀; Rajac, Gornji Banjani; 44.1199°N, 20.2645°E; 16. Jun. 2022; Ana Grković leg.; FSUNS SPAS30188 • 2 ♀♀; Đerdap, Ciganski potok; 44.5436°N, 22.0146°E; 7 Jun. 2022; blue pan trap; FSUNS SPAS20335, SPAS20337 • 1 ♀; Obedska bara, Debela gora; 44.7336°N, 19.9921°E; 2 Jun. 2022; blue pan trap; FSUNS SPAS10332. • 7 ♀♀; Vršački breg, Kula; 45.1245°N, 21.3283°E; 20 Jun. 2022; blue pan trap; FSUNS SPAS00872, SPAS00877 to SPAS00882 • 1 ♀; same data as for preceding; 25 Aug. 2022; FSUNS SPAS00758 • 1 ♀; Vršački breg, Dom; 45.1253°N, 21.3615°E; 20 Jun. 2022; blue pan trap; FSUNS SPAS00546 • 2 ♀♀; Fruška gora, Grabovo; 45.1717°N, 19.6227°E; 14 Jun. 2022; blue pan trap; FSUNS SPAS20293, SPAS20294.

***Lasioglossum damascenum* (Pérez) [DD]**

• 1 ♀; Deliblato sands, Šušara; 44.9261°N, 21.1353°E; 21 Jun. 2022; blue pan trap; FSUNS SPAS00556.

***Lasioglossum laterale* (Brullé) [DD]**

• 1 ♀; Pčinja, Vogance; 42.3436°N, 21.9215°E; 20 Apr. 2022; white pan trap; FSUNS SPAS10358 • 1 ♀; Bačko podunavlje, Bezdan; 45.8390°N, 18.9400°E; 6 Apr. 2022; blue pan trap; FSUNS SPAS00899.

***Seladonia* Robertson**

***Seladonia confusa* (Smith) [LC]**

• 1 ♀; Pčinja, Vražji kamen; 42.3838°N, 22.0528°E; 16 Jun. 2022; white pan trap; FSUNS SPAS10441.

Family Megachilidae
***Heriades* Spinola**

***Heriades rubicola* Pérez [LC]**

• 1 ♂; Bačko podunavlje, Bezdan; 45.8390°N, 18.9400°E; 6 Sep. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00477 • 1 ♂; Subotica, Ludaš lake; 46.1040°N, 19.8212°E; 15 Jun. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00293.

***Hoplitis* Klug**

***Hoplitis mazzuccoi* (Schwarz & Gusenleitner) [LC]**

• 1 ♂; Fruška gora, Grgurevci; 45.1228°N, 19.6504°E; 19 Jun. 2022; Ante Vujić leg.; FSUNS SG0795.

***Hoplitis papaveris* (Latreille) [LC]**

• 2 ♀♀; Zlatibor, Obudovica; 43.7227°N, 19.6881°E; 18 Jun. 2022; blue pan trap; FSUNS SPAS30454, SPAS30455 • 1 ♂; same data as for preceding; yellow pan trap; FSUNS SPAS30436.

***Hoplitis villosa* (Schenck) [LC]**

• 1 ♂; Kopaonik, Mali Karaman; 43.2910°N, 20.8235°E; 20 Jun. 2022; Ana Grković leg.; FSUNS SPAS30248.

***Osmia* Panzer**

***Osmia bischoffi* Atanassov [LC]**

• 3 ♀♀; Đerdap, Ciganski potok; 44.5436°N, 22.0146°E; 26 Apr. 2022; yellow pan trap; FSUNS SPAS20401, SPAS20457, SPAS20461 • 7 ♀♀; same data as for preceding; white pan trap; FSUNS SPAS20341, SPAS20397, SPAS20402, SPAS20405, SPAS20411, SPAS20413, SPAS20415 • 5 ♀♀; same data as for preceding; blue pan trap; FSUNS SPAS20395, SPAS20435, SPAS20436, SPAS20440, SPAS20443 • 1 ♂; same data as for preceding; FSUNS SPAS20433 • 2 ♀♀; Fruška gora, Vrdnik; 45.1372°N, 19.8013°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0570, SG0573 • 1 ♀; Fruška gora, Sremski Karlovci; 45.2089°N, 19.9358°E; 20 Jun. 2022; Ante Vujić leg.; FSUNS SG0497.

***Osmia scutellaris* Morawitz [LC]**

• 1 ♂; Fruška gora, Vrdnik; 45.1372°N, 19.8013°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0572.

***Osmia xanthomelana* (Kirby) [LC]**

• 1 ♂; Kopaonik, Mali Karaman; 43.2910°N, 20.8235°E; 20 Jun. 2022; Ana Grković leg.; FSUNS SPAS30242.

***Pseudoanthidium* Friese**

***Pseudoanthidium nanum* (Mocsáry) [LC]**

• 1 ♀; Stara planina, Temska; 43.2751°N, 22.5626°E; 28 Aug. 2022; blue pan trap; FSUNS SPAS20665 • 1 ♂; same data as for preceding; Tamara Tot leg.; FSUNS SPAS20595 • 1 ♀; Deliblato sands, Grebenac; 44.8991°N, 21.2286°E; 26 Aug. 2022; Ante Vujić leg.; FSUNS SG0259 • 1 ♀; Deliblato sands, Alibunar; 45.0674°N, 20.9667°E; 26 Aug. 2022; Ante Vujić leg.; FSUNS SG1043 • 1 ♀; Fruška gora, Bešenovo; 45.0718°N, 19.7035°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0656 • 1 ♀; Fruška gora, Jazak; 45.0911°N, 19.7668°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0523 • 1 ♀; Fruška gora, Neradin; 45.1219°N, 19.8940°E; 20 Jun. 2022; Ante Vujić leg.; FSUNS SG0741 • 1 ♀; same data as for preceding; 31 Aug. 2022; FSUNS SG0892 • 1 ♀; Fruška gora, Vrdnik; 45.1372°N, 19.8013°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0576 • 1 ♀; 'The great bustard pastures' ['Pašnjaci velike droplje'], Mokrin; 45.9217°N, 20.3033°E; 14 Jun. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00251 • 1 ♀; same data as for preceding; 29 Aug. 2022; FSUNS SPAS00469.

Family Melittidae
***Dasypoda* Latreille**

***Dasypoda morawitzi* Radchenko**

• 1 ♂; Deliblato sands, Šumarak; 44.8173°N, 21.1346°E; 27 Aug. 2022; Ante Vujić leg.; FSUNS SG1070 • 2 ♂♂; Deliblato sands, Labudovo okno; 44.8440°N, 21.2958°E; 27 Aug. 2022; Ante Vujić leg.; FSUNS SG1109, SG1112 • 1 ♂; Deliblato sands, Čardak I; 44.8550°N, 21.0681°E; 21 Jun. 2022; yellow pan trap; FSUNS SPAS00632 • 1 ♀; Deliblato sands, Šušara; 44.9261°N, 21.1353°E; 26 Aug. 2022; blue pan trap; FSUNS SPAS00838 • 2 ♂♂; same data as for preceding; 28 Aug. 2022; Ante Vujić leg.; FSUNS SG0955, SG0957 • 1 ♀; same data as for preceding; FSUNS SG0970.

Records of wild bee species considered threatened in Europe

Family Colletidae
***Colletes* Latreille**

***Colletes anchusae* Noskiewicz [EN]**

• 1 ♀; Đerdap, Ciganski potok; 44.5436°N, 22.0146°E; 07 Jun. 2022; Tamara Tot leg.; FSUNS SPAS20151.

Habitat type is stream within deciduous forest.

***Colletes chengtehensis* Yasumatsu [VU]**

• 1 ♂; Deliblato sands, Čardak I; 44.8550°N, 21.0681°E; 26 Aug. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00704 • 1 ♂; Deliblato sands, Alibunar; 45.0674°N, 20.9667°E; 14 Jun. 2022; Ante Vujić leg.; FSUNS SG0308.

Habitat type at locality Čardak is a mosaic of steppe grassland on sand with forests and shrubs. Main floral resource of this species at this locality is *Berteroa incana* (L.) DC. (Brassicaceae). At locality Alibunar, habitat type is a mosaic of steppe grassland on loess with forest patches and shrubs.

***Colletes nasutus* Smith [EN]**

• 2 ♀♀; Deliblato sands, Čardak I; 44.8550°N, 21.0681°E; 21 Jun. 2022; Sonja Mudri-Stojnić leg.; FSUNS SPAS00383, SPAS00390.

Habitat type is mosaic of steppe grassland on sand with forests and shrubs. Main floral resource of this species at this locality is *Carduus acanthoides* L. (Asteraceae).

Family Halictidae
***Systropha* Illiger**

***Systropha planidens* Giraud [VU]**

• 1 ♂; Stara planina, Temska; 43.2751°N, 22.5626°E; 10 Jul. 2022; Tamara Tot leg.; FSUNS SPAS20230 • 2 ♂♂; Fruška gora, Stejanovci; 45.0428°N, 19.7199°E; 18 Jun. 2022; Ante Vujić leg.; FSUNS SG0680, SG0688 • 1 ♂; Fruška gora, Šuljam; 45.0814°N, 19.6717°E; 18 Jun. 2022; Ante Vujić leg.; FSUNS SG0595 • 1 ♀; same data as for preceding; FSUNS SG0608 • 1 ♀; Fruška gora, Krušedol; 45.1279°N, 19.9442°E; 20 Jun. 2022; Ante Vujić leg.; FSUNS SG0538.

At the Fruška gora localities (Stejanovci, Krušedol and Šuljam), habitat type is steppe grassland with shrubs. Main floral resource of this species at these localities is *Convolvulus arvensis* L. (Convolvulaceae). At locality Temska, habitat type is meadow in agricultural mosaic.

***Seladonia* Robertson**

***Seladonia semitecta* (Morawitz) [EN]**

• 3 ♀♀; Fruška gora, Bešenovo; 45.0718°N, 19.7035°E; 21 Jun. 2022; Ante Vujić leg.; FSUNS SG0672.

Habitat type is steppe grassland with shrubs. Main floral resource of this species at this locality is *Teucrium chamaedrys* L. (Lamiaceae).

Family Melittidae
***Dasypoda* Latreille**

***Dasypoda braccata* Eversmann [EN]**

• 1 ♂; Deliblato sands, Čardak I; 44.8550°N, 21.0681°E; 21 Jun. 2022; blue pan trap; FSUNS SPAS00607.

Habitat type is mosaic of steppe grassland on sand with forests and shrubs.

Discussion

The results of the present study include new records for 25 bee species that have not been previously recorded for Serbia. Most of them are from the family Andrenidae, i.e., 10 species of the genus *Andrena*. They are followed by eight species from Megachilidae (three from genera *Hoplitis* and *Osmia* respectively, and one from *Heriades* and

Pseudoanthidium), four from Halictidae (three *Lasioglossum* and one *Seladonia*), and one from Apidae (*Ceratina*), Colletidae (*Hylaeus*), and Melittidae (*Dasypoda*) respectively. The latest published list of bee species occurring in Serbia, as provided by Mudri-Stojnić et al. (2021), presented 706 species. Therefore, with the current extension, the total number of species is 731. Furthermore, Mudri-Stojnić et al. (2021) included 56% (392) species that were only known from literature data, i.e., those species were not confirmed by material examination. The present study provides confirmation of 79 of those species.

Ten of the newly recorded species have been listed as DD in the European Red List of Bees (Nieto et al. 2014), 14 are in the LC category, while one species is uncategorized (*Dasypoda morawitzi* Radchenko, 2016) as it was described after the publication of the IUCN Red List. The majority (69%) of all bee species (312) recorded within the present study belong to the LC category; however, 7% are classified as NT, two species as VU and four species as EN in Europe. Moreover, 21% of the here listed species were assessed as DD (Nieto et al. 2014), since there was not enough scientific data to evaluate their risk of extinction. Ten of these species were not previously recorded for Serbia. Furthermore, the preparation of an update of the European Red List of Bees is ongoing (PULSE 2022–2023) and many species could be expected to have their IUCN categories revised, primarily the ones previously assessed as DD. Therefore, the results of the present study could act as a contribution to the information about distribution, needed for the threat evaluation of these species in Europe. It is also worth mentioning that the Pannonian steppe grasslands on loess (Fruška gora localities) and on sand (Deliblato sands localities), on which bee species considered threatened in Europe were recorded, belong to the habitat types of conservation priority in Serbia (Official Gazette RS 2010).

Another important finding includes the confirmation of the presence of 26 species without available records for Serbia dating from the 21st century. Mudri-Stojnić et al. (2021) emphasized the fact that further research is needed in order to confirm older data, as the current presence of these species, within the given localities, is not certain. Therefore, the present study gives a relevant contribution towards clarifying such information, especially with several literary records dating back more than a century, i.e., *Melitta dimidiata* Morawitz (NT) in Apfelbeck (1896), *Triepeolus tristis* (Smith) (NT) and *Pseudoanthidium tenellum* Mocsáry (DD) in Mocsáry (1897), and *Eucera caspica* Morawitz (LC) in Vorgin (1918).

According to the available distribution maps of bees (Kuhlmann et al. 2023; Rasmont and Haubruge 2023) and literature sources (e.g., Michez et al. 2019), the new bee species' records for Serbia were not surprising; i.e., they were expected based on the known distributions. The findings of the present study thus indicate the need for additional research in terms of bees' diversity, biology and ecology (including habitat types, floral resources and nesting sites), in order to expand knowledge about them, both locally and at the European level. From 15 bee species recorded in the present study, whose sole previous source of occurrence in Serbia was the Checklist of the Western Palaearctic Bees (Kuhlmann et al. 2023), two of these species are threatened at the European level (one EN and VU respectively), one is NT, eight are LC, and four are DD. Moreover, available data for 52 species came only from Kuhlmann et al. (2023) and from published occurrences prior to

the year 2000. On the other hand, 103 here recorded species are not listed in Kuhlmann et al. (2023), thus they are a potential addition to the distribution maps for the Checklist.

Two different collection methodologies were used in the present study, i.e., the transect walks, a passive method designed to survey flying insects, and the pan traps, an active method designed to survey nectar-searching insects, both recognized as suitable for the monitoring of bees (Nielsen et al. 2011; Potts et al. 2021). The advantage of pan traps is in that they provide data on bee abundance without observer bias (Cane et al. 2000; Roulston et al. 2007; Westphal et al. 2008), whereas the validity of transect walks is dependent on the experience of collectors (Nielsen et al. 2011). Due to bee species with flower color preferences, an exhaustive survey of bee fauna requires the use of multiple pan trap colors (Toler et al. 2005). Moreover, there is evidence suggesting the presence of not only species-specific but also sex-specific color preferences in Aculeata (Heneberg and Bogusch 2014). However, the effectiveness of pan traps is related to surrounding floral resources (Roulston et al. 2007) and the resulting data does not always represent the local community (Cane et al. 2000). Due to their respective limitations, none of the methods for sampling pollinators are ideal, hence a combination of complementary approaches has been suggested as the most effective (Nielsen et al. 2011; Potts et al. 2021; Leclercq et al. 2022). Considering the localities of the present study where both methods were conducted, most of the species (41%) were detected during transect walks, 32% were found using both methods, while 27% were caught in pan traps. Concerning the number of individuals recorded in pan traps, the highest share (39%) was found in blue ones, followed by 33% in yellow traps, while the lowest share (28%) was found in white pan traps. Taking into account new records for the 25 bee species that had not been previously recorded for Serbia, out of the 123 recorded specimens, 54 were detected during transect walks, whereas 69 specimens were caught in pan traps (39 in blue, 19 in white, and 11 in yellow pan traps). Out of these 25 species, 48% were detected during transect walks, 28% were caught in pan traps, and 24% species were detected by both methods. Given the fact that many species were detected by only one of the two used sampling methods, the results of the present study indicate that the use of both is the best way to assess bee diversity and abundance. Identifying the most suitable monitoring and sampling techniques is an important step towards assessing the bee populations' status and trends, a prerequisite for comprehensive knowledge of bee diversity and, consequently, for effective conservation practices.

By presenting new records and confirming some old ones, the results of the present study contribute to updating and reverifying data on bee species occurrences in Serbia. Given the fact that more than half of the European bee species have been assessed as Data Deficient (Nieto et al. 2014), investigations such as this one add to tackling the existing lack of information. Furthermore, the knowledge gaps recognized across certain geographic regions, such as the Mediterranean and Eastern European areas, could be addressed through the implementation of the standardized monitoring activities (Potts et al. 2021). Therefore, by taking part in ongoing scientific projects and applying consistent methodologies, we aim to continue gathering data through the systematic monitoring of pollinators in order to update and revise current evidence.

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Supplementary material 1

The list of all bee species recorded during the surveys of selected sites in 2022

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Data type: xlsx

Explanation note: The list of all recorded bee species with additional information: IUCN categories; collection methodology types; data on the presence of listed species in the online maps of the Checklist of the Western Palaearctic Bees; data on the species with occurrences previously available only from sources prior to year 2000.

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