

LONG-TERM CHANGES IN COMPOSITION AND DISTRIBUTION OF BUMBLEBEES IN URBAN AREAS

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Abstract

The distribution of bumblebee species in Wrocław (SW Poland) was studied based on data from ten UTM grid squares between 1879 and 2018, and the composition and abundance of bumblebee species between 2011 and 2018. The results were compared with historical data available for the last 139 years, including published materials and collections of the Museum of Natural History (University of Wrocław). Twenty-six bumblebee species, including six species of cuckoo bumblebees of the subgenus *Psithyrus*, were recorded. One species was not confirmed during the later period, nine were strongly decreasing both in the range of distribution, seven other were expanding significantly in Wrocław and three were new in the Wrocław city boundaries. Negative and positive tendencies resulted from both anthropogenic and natural factors. All bumblebees that appeared in the city of Wrocław and increased their abundance were species that preferred forest and shrub areas, while species that disappeared from the city and decreased in numbers were species who preferred open areas.

Keywords: bees, composition, conservation, historical data, urban areas

INTRODUCTION

Wild pollinators are of biological value and ecological importance not only in rural but also in urban landscapes, since they play an extremely important role in ecosystems enabling plant production and sustain natural plant communities (Ollerton, 2017). A number of studies on pollinator communities have found declines in abundance and species richness both regionally and globally since the 1970s (Peters, 1972; Rasmont, 1988; Goulson et al., 2005; Biesmeijer et al., 2006; Cameron et al., 2011; Bommarco et al., 2012; Williams et al., 2013; Gunnarsson & Federsel, 2014). This decline is most likely due to habitat loss and fragmentation, pesticides, diseases, parasites, and interactions among these factors (Potts et al., 2010; Kerr et al., 2015; Woodcock et al., 2016;

Nicholson et al., 2023). The main consequence of habitat loss is the deterioration of suitable alimentary resources, without which there are no prospects for the survival of bumblebee colonies (Goulson, 2010).

Research has determined that plant communities and their dependent pollinators are particularly sensitive to increased levels of urbanisation (Geslin et al., 2013), one of several factors that radically and irreversibly affect natural habitats (McKinney, 2006). The development of cities, which includes the creation of denser infrastructure, reduces and separates green areas, and such insects such as bumblebees are forced to relocate to new landscapes, not only to search for appropriate food sources (forage) or nesting sites but also to mate (Whitehorn et al., 2009). Smaller populations are also more vulnerable to extinction caused

by environmental and demographic variables (Frankham et al., 2002).

The lack of suitable habitats and the overuse of pesticides in rural landscapes justify investigations of the role that cities can play in bee conservation. The present investigation appears to be justified based on evidence that cities might serve as refuges for some bee species (McFrederick & LeBuhn, 2006; Hall et al., 2017). For bumblebees in particular, urban areas can promote greater species richness than rural or natural areas (McFrederick & LeBuhn, 2006; Winfree et al., 2007; Gunnarsson & Federsel, 2014; Hall et al., 2017). Hall et al. (2017) noted that in several cases more diverse and abundant populations of native bees live in cities than in nearby rural landscapes, and there are many studies on the conservation value of urban green space habitats for bee communities (Matteson et al., 2008; Tonietto et al., 2011; Gunnarsson & Federsel, 2014; Hall et al., 2017; Glaum et al., 2017; Micholap et al., 2017). However, there is little data describing species structure changes and bee communities' distribution over the years. Kosior et al. (2008) for Kraków (Poland) have conducted such studies which are interesting and important, as they present trends regarding the decline, expansion, or stability of the abundance and distribution of specific species in cities.

Notably, our study is the first in approximately 100 years since the earliest bee fauna research in the city of Wrocław and surrounding areas was conducted in the early twentieth century (Dittrich, 1903). The first survey by Dittrich (1903) concentrated on qualitative information regarding bee occurrence in the Silesia region. This study aimed to investigate the changes in species structure and distribution of bumblebees in the city area of Wrocław (SW Poland) between 1879 and 2018.

MATERIAL AND METHODS

Historical data

Both historical published data and information available in the Museum of Natural History, University of Wrocław, were used in this paper. We based our research on the latter source

because the museum houses a remarkable collection of bumblebees collected in the city of Wrocław from 1879 to 1945. During the twentieth century, the city expanded its area, and formerly outlying areas became city districts following their incorporation within the city's administrative boundaries. Therefore, the German names of the old areas on labels from museum specimens were assigned to present areas of Wrocław, using a German-Polish/Polish-German sightseeing dictionary (Battek & Szczepankiewicz-Battek, 2004).

The period of 1946-2010 is characterised by limited data about bumblebee occurrence in Wrocław. No bumblebees were collected and deposited in the museum's collection during this timeframe. Nevertheless, for our analyses, we utilised available data from publications that described bumblebee species found in various locations, including the Botanical Garden of the University of Wrocław (Noskiewicz, 1960), urban areas (Biliński & Ruszkowski, 1990), and agricultural areas in the outskirts of Wrocław (Gałuszkowa, 1965; Hurej & Twardowski, 1999; Kelm et al., 2004).

To assess changes in land cover over the studied period, we relied on the maps of the city of Wrocław accessible on the website <https://www.geoportalwroclaw.pl>, which provided information on forest and shrub coverage for the years 1912, 1971 and 2012. The analyses were performed with the use of QGIS (QGIS.org, 2023).

Field surveys

In addition to historical data, we have provided the results of field studies carried out between 2011 and 2018 on thirty-one sites within the city's administrative boundaries. These areas, ranging from 2 to 102 ha, included two botanical gardens, two cemeteries, nine housing estates, eight semi-natural meadows, six city parks, two railways and two wastelands (Fig. 1). The choice to study such habitats was driven by the abundance of flowering plants, which offered the greatest potential for supporting a diverse community of bumblebee species.

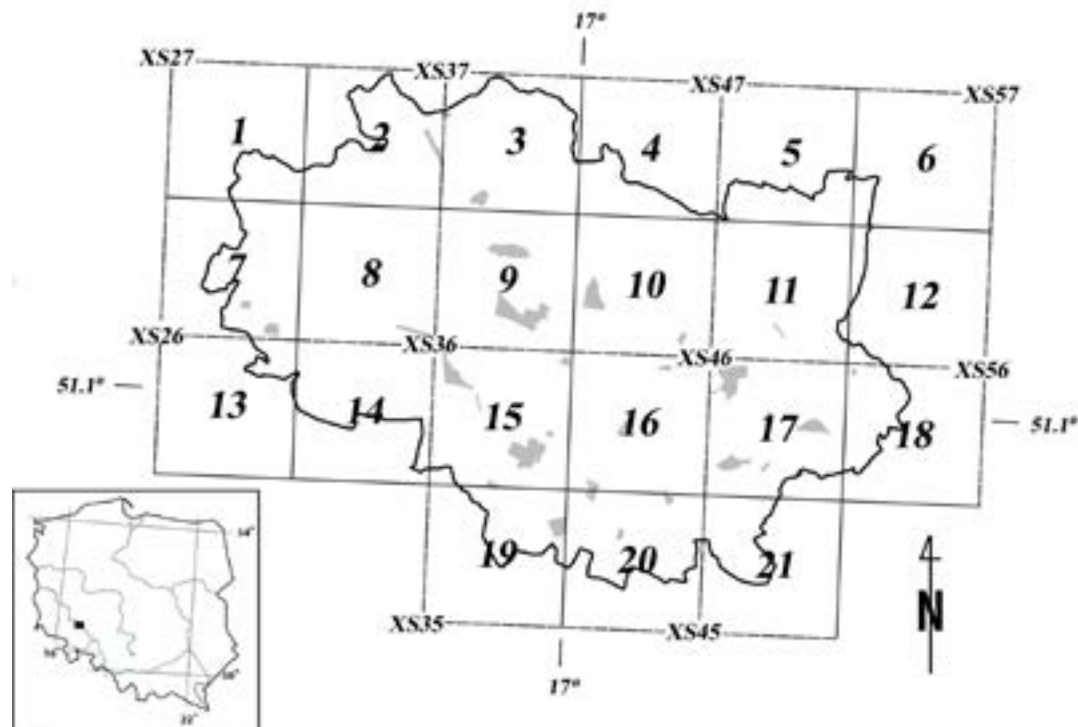


Fig. 1. Map of Wrocław city area (SW Poland). Grey colour - study sites in 2011-2018; solid line with numeral symbols - UTM faunistic grid; dashed line with numbers - the lesser squares: 1 - Mokra, 2 - Pracze Odrzańskie, 3 - Rędzin, 4 - Psary, 5 - Pawłowice, 6 - Mirków, 7 - Ratyń, 8 - Złotniki, 9 - Kozanów, 10 - Karłowice, 11 - Psie Pole, 12 - Kiełczów, 13 - Jarnołtów, 14 - Jerzmanowo, 15 - Muchobór, 16 - Old Town, 17 - Biskupin, 18 - Wojnów, 19 - Klecina, 20 - Ołtaszyn, 21 - Bieńkowiec.

The observations were conducted at least once a month from March to September. Bumblebee species composition and total numbers were determined using transect walking observations about 200 m long and 2-3 m wide, at 30-minute intervals, randomly moving through the green areas potentially most attractive for pollinators, such as lawns covered with flowering plant species, spontaneous ruderal plant communities in urban areas and planted perennial species. In cases where flowering plants grew in patches in green areas, the time spent walking between those patches was not included in the 30-minute observation period.

The observations were conducted between 10 a.m. and 4 p.m. in conditions favourable for bumblebees flights: sunny weather, cloud cover up to 30%, low wind speed (a maximum of 3 on the Beaufort scale), and minimum temperatures of 13°C in March and April and of 18°C from May to September. In total, 351 observations were made from 2011 to 2018. Bumblebee species were identified in situ (by appearance and colour

patterns) during surveys. Specimens for which the species was unclear were caught using entomological nets and then released following identification. Single workers and males that were impossible to identify due to the unusual variability of their colours were caught and killed using ethyl acetate, with official authorisation from the Regional and General Director of Environmental Protection in Poland.

Survey results

To facilitate the study, the area of Wrocław within its current administrative boundaries was divided into ten squares measuring 10×10 km, utilising the UTM grid system. Because such a large scale could introduce potential inaccuracies, each of the ten squares was further subdivided into four smaller squares, each measuring 5×5 km. Consequently, Wrocław was divided into twenty-one smaller squares within the original ten UTM squares (Fig. 1). The survey data were then attributed to these ten squares per the two specified periods

of 1879-1945 and 1946-2018. The division into these two periods is based on historical considerations, specifically the delineation of the time before and after the end of the Second World War (1945). After the war, the German population changed to Polish, resulting in a change in management protocols. After the war, the city area underwent further, gradual transformations, which resulted in increased forest cover in the urban area, including the creation of new urban parks, the gradual growth of the city on its outskirts, as well as the reduction of crops in urban areas and the creation of large farmland areas on the outskirts cities.

Statistical analysis

The main difficulties are rooted in the use of heterogeneous research methods in different periods and the lack of detailed historical data. For this reason, it was impossible to use such specific statistical analyses as chi-square. Similar problems were found during studies on the long-term distribution of bumblebees in other Polish cities (Kosior et al., 2008).

For each of the surveyed grid cells in the city, a trend metric of species richness (degree of decline or increase) was calculated (Dufrêne & Desender, 2007, Desender et al., 2008, Dekoninck et al., 2013). The degree of change in species richness for each grid cell (TREND) was calculated by $TREND = [S_{curr} - (\alpha S_{hist})] / [(\alpha S_{hist}) + S_{curr}]$, where α is a correction factor to account for differences in sampling intensity and sampling methods between both inventory systems and periods. This correction factor was calculated through the division of the sum of S_{curr} by the sum of S_{hist} for all well-surveyed grid cells. In this study, the correction factor was +0.8309. By calculating the TREND, we generated a value between -1 (all species richness lost) and +1 (all species richness new) for each well-surveyed grid cell. We considered the trend not to exceed +0.1 and -0.1 for a species as a stable distribution. This stable trend concerns species occurring in the same number of city grid cells in both periods.

RESULTS

Twenty-six bumblebee species (Hymenoptera: Apidae: *Bombus*) native to Poland (Pawlikowski, 2008) were recorded, consisting of twenty bumblebee species and six cuckoo bumblebee species (subgenus *Psithyrus*). During the first period of 1879-1945, twenty-three bumblebee species were identified in the city, and in the second period of 1946-2018, twenty-five species were recorded (Tab. 1). The analysis of species distribution shows the withdrawal of one species from the city area (Tab. 1) after 1879-1945 (*B. mesomelas*). However, three new bumblebee species (Tab. 1) were recorded in the period of 1946-2018 (*B. jonellus*, *B. soroeensis*, *B. (Ps.) sylvestris*).

During the period of 1879-1945, the greatest number of bumblebee species was noted for the Old Town area (square no. 16 - 20 species) and Mirków (square no. 6 - 17 species) (Fig. 2). During the period of 1946-2018, the greatest number of bumblebee species (17 taxa) were found in the Old Town (square no. 16), and Biskupin district (square no. 17), whereas 13 species were recorded in Pawłowice (square no. 5), Ratyń (square no. 7) and Wojnów (square no. 18).

In order to determine the tendencies of species distribution in the Wrocław city area, we used TREND rank between the periods 1879-1945 and 1946-2018 (Tab. 1). A comparison between ranks in these periods showed a decline of nine species, while six others species show a stable distribution tendency in the Wrocław city area.

During field surveys in 2011-2018 in Wrocław, the most ubiquitous and abundant bumblebee species were *B. terrestris* (dominant in the central and eastern parts of the city), *B. lapidarius* (dominant in the southern parts of the city) and *B. pascuorum* (dominant in the western parts of the city) (Supplementary material 1-3).

DISCUSSION

During the earliest survey period of 1879-1945, German scientists studied primarily species distribution. While specific specimens could be accurately assigned to precise locations

Table 1.

Bumblebee species occurrence in Wrocław area in 1879-2018

Species	1879-1945		1946-2018		Trend	Tendency
	Squares	Abundance	Squares	Abundance		
<i>Bombus jonellus</i> (Kirby, 1802)			2	3	1.00	+
<i>Bombus soroeensis</i> (Fabricius, 1776)			3	15	1.00	+
<i>Bombus</i> (Ps.) <i>sylvestris</i> (Le Peletier, 1832)			1	2	1.00	+
<i>Bombus</i> (Ps.) <i>bohemicus</i> (Seidl, 1837)	1	1	8	154	0.81	+
<i>Bombus hypnorum</i> (Linnaeus, 1758)	2	4	13	225	0.77	+
<i>Bombus lucorum</i> (Linnaeus, 1761)	2	2	13	919	0.77	+
<i>Bombus sylvarum</i> (Linnaeus, 1761)	3	3	11	228	0.63	+
<i>Bombus pratorum</i> (Linnaeus, 1758)	3	6	10	68	0.60	+
<i>Bombus ruderarius</i> (Müller, 1776)	3	3	9	102	0.57	+
<i>Bombus veteranus</i> (Fabricius, 1793)	1	1	2	5	0.41	+
<i>Bombus ruderatus</i> (Linnaeus, 1775)	2	2	2	44	0.09	NS
<i>Bombus muscorum</i> (Fabricius, 1775)	5	9	4	11	-0.02	NS
<i>Bombus subterraneus</i> (Linnaeus, 1758)	4	6	3	8	-0.05	NS
<i>Bombus lapidarius</i> (Linnaeus, 1758)	21*	3	15	3540	-0.08	NS
<i>Bombus pascuorum</i> (Scopoli, 1763)	21*	4	15	2495	-0.08	NS
<i>Bombus terrestris</i> (Linnaeus, 1758)	21*	3	15	4592	-0.08	NS
<i>Bombus hortorum</i> (Linnaeus, 1758)	21*	3	12	351	-0.19	-
<i>Bombus</i> (Ps.) <i>rupestris</i> (Fabricius, 1793)	21*	?	12	317	-0.19	-
<i>Bombus</i> (Ps.) <i>vestalis</i> (Fourcroy, 1785)	21*	1	11	393	-0.23	-
<i>Bombus distinguendus</i> (Morawitz, 1869)	2	2	1	1	-0.25	-
<i>Bombus pomorum</i> (Panzer, 1805)	2	2	1	1	-0.25	-
<i>Bombus confusus</i> (Schenck, 1859)	5	10	2	60	-0.35	-
<i>Bombus</i> (Ps.) <i>campestris</i> (Panzer, 1801)	3	5	1	2	-0.43	-
<i>Bombus humilis</i> (Illiger, 1806)	21*	30	4	26	-0.63	-
<i>Bombus</i> (Ps.) <i>barbutellus</i> (Kirby, 1802)	21*	3	2	2	-0.79	-
<i>Bombus mesomelas</i> (Gerstäcker, 1869)	1	1			-1.00	-
Total number of specimens		104		13564		

Ps. - *Psithyrus* subgenus, * - species reported as very common in Lower Silesia Region,

? - number of specimens not determined, + - expansion, - - regression, NS - non significant.

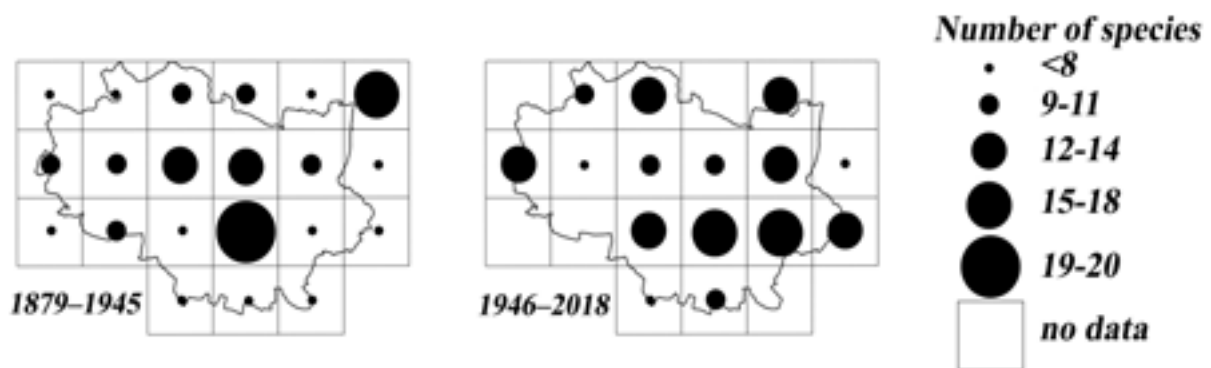


Fig. 2. Number of bumblebee species in two periods in Wrocław (SW Poland).

in Wrocław, the assessment of bumblebee community densities was challenging. In the second survey period of 1946-2018, we obtained precise estimates of species densities from our field surveys conducted between 2011 and 2018. Despite encountering statistical challenges, we identified distinct trends in *Bombus* spp. species richness within Wrocław. Based on their current status, the studied bumblebee species were classified into four groups: 1) extinct, 2) exhibiting a strong tendency towards decline, 3) relatively stable in the area, and 4) showing a strong tendency towards expansion (Fig. 3).

Since 1879, one bumblebee species, *B. mesomelas*, has disappeared from the area of Wrocław. Several other species have experienced significant declines. Similar negative trends have been documented for these species in Poland and Europe (Pawlikowski, 2008; Rasmont et al., 2015), and their protection status reflects their vulnerable state (Tab. 2) (Banaszak, 2002; Nieto et al., 2014). These bumblebee species predominantly inhabit open areas and mountain meadows and depend on the pollen and nectar of plants from the Fabaceae family (Rasmont et al., 2015). Thus, their retreat from the urban space could be attributed to the reduction of

non-forest areas and the scarcity of suitable food sources. The conversion of wetlands through drainage and their allocation for building purposes was one of the possible reasons for the decline of habitats occupied by *B. muscorum* (Alford, 1975), which is now a rare species. Moreover, *B. muscorum* presence is highly related to the open areas and their proportions in the landscape (Diekötter et al., 2006). Furthermore, *B. mesomelas*, a species favouring sunlit mountain meadows, was solely observed near Wrocław before 1945 and is considered extinct in Poland now (Pawlikowski, 2008). Moreover, declining bumblebee species occupy distinctive niches is connected with their preferred habitats and the plants used as foraging resources. In the case of cuckoo bumblebees, parasites of bumblebee species, the reduction in suitable host areas presents a complex factor. Presumably, these species are among the first to be impacted negatively by environmental changes in the urban area due to their dependence on thriving host populations. Seven bumblebee species are expanding significantly in Wrocław, while three species *B. jonellus*, *B. soroeensis* and *B. (Ps.) sylvestris* (Tab. 1) are new. This phenomenon is because

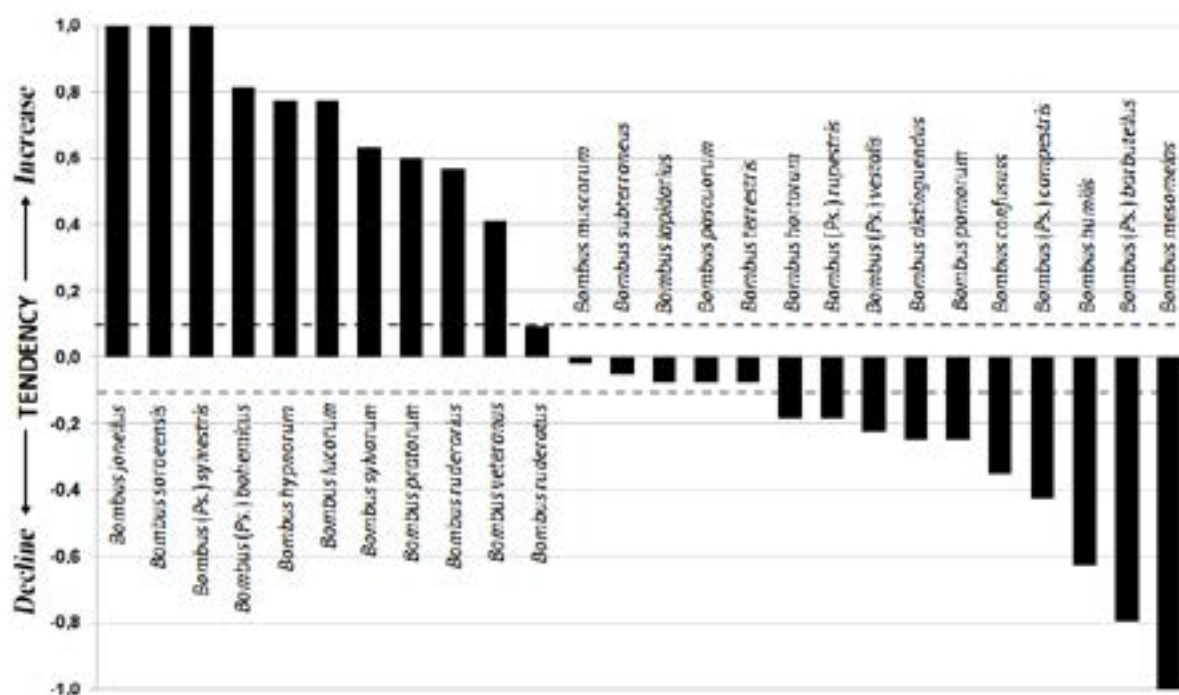


Fig. 3. Tendency of bumblebees occurrence in Wrocław (SW Poland) between two periods: 1879-1945 and 1946-2018.

Table 2.

Comparison of bumblebees tendencies in Wrocław area, with data for Kraków (Kosior et al., 2008) and all of Poland (data from Pawlikowski, 2008 and Pawlikowski et al., 2016)

Species	Wrocław	Kraków	Whole Poland	Conservation status in Europe	Conservation status in Poland
<i>Bombus confusus</i>	-	-	-	VU	VU
<i>Bombus cullumanus</i>	NP	NP	?	CR	
<i>Bombus distinguendus</i>	-	-	-	VU	
<i>Bombus fragrans</i>	NP	NP	-	EN	EX
<i>Bombus gerstaeckeri</i>	NP	NP	-	VU	
<i>Bombus hortorum</i>	-	NS	0	LC	
<i>Bombus humilis</i>	-	-	-	LC	VU
<i>Bombus hypnorum</i>	+	NS	+	LC	
<i>Bombus jonellus</i>	+	+	+	LC	VU
<i>Bombus laesus</i>	NP	-	-	NT	VU
<i>Bombus lapidarius</i>	NS	NS	0	LC	
<i>Bombus lucorum</i>	+	+	0	LC	
<i>Bombus lucorum cryptarum</i>	?	NS	?	LC	DD
<i>Bombus lucorum magnus</i>	?	+	?	LC	DD
<i>Bombus mesomelas</i>	-	NP	-	LC	DD
<i>Bombus muscorum</i>	NS	-	-	VU	
<i>Bombus pascuorum</i>	NS	NS	0	LC	
<i>Bombus pomorum</i>	-	-	-	VU	VU
<i>Bombus pratorum</i>	+	+	+	LC	
<i>Bombus pyrenaeus</i>	NP	NP	0	LC	DD
<i>Bombus ruderarius</i>	+	NS	0	LC	
<i>Bombus ruderatus</i>	NS	NS	-	LC	VU
<i>Bombus schrencki</i>	NP	NP	+	LC	DD
<i>Bombus semenoviellus</i>	NP	+	+	LC	
<i>Bombus sichelii</i>	NP	NP	-	LC	EX
<i>Bombus soroensis</i>	+	NP	0	LC	VU
<i>Bombus subterraneus</i>	NS	NS	-	LC	VU
<i>Bombus sylvarum</i>	+	-	0	LC	
<i>Bombus terrestris</i>	NS	NS	0	LC	
<i>Bombus veteranus</i>	+	NS	0	LC	VU
<i>Bombus wurflenii</i>	NP	NP	0	LC	DD
<i>Bombus (Ps.) barbutellus</i>	-	-	0	LC	
<i>Bombus (Ps.) bohemicus</i>	+	+	+	LC	
<i>Bombus (Ps.) campestris</i>	-	-	+	LC	
<i>Bombus (Ps.) flavidus</i>	NP	NP	+	LC	
<i>Bombus (Ps.) norvegicus</i>	NP	NP	+	LC	DD
<i>Bombus (Ps.) quadricolor</i>	NP	NP	-	LC	DD
<i>Bombus (Ps.) rupestris</i>	-	NS	+	LC	
<i>Bombus (Ps.) sylvestris</i>	+	+	+	LC	
<i>Bombus (Ps.) vestalis</i>	-	-	+	LC	

For comparison purposes, the conservation status of species in Europe (Nieto et al., 2014) and Poland (Banaszak, 2002) was added. Status of *Bombus lucorum* according to Bossert (2015).

Ps - *Psithyrus* subgenus, + - expansion, - - regression, 0 - stable, ? - unknown, NS - non significant, NP - Not present, EX - extinct, CR - critically endangered, EN - endangered, VU - vulnerable, NT - near threatened, LC - least concern, DD - data deficient.

these species are associated with areas covered by shrubs and forests (Iserbyt et al. 2016), where they often visit flowering trees and shrubs (Sikora & Kelm, 2012; Sikora et al., 2016; Sikora et al., 2018; Sikora et al., 2020). A similar tendency, widely reported in Great Britain (Goulson & Williams, 2001), has been demonstrated for *B. hypnorum*, which became the most common in Belgium over the twentieth century, probably due to urbanisation (Rasmont, 1988). Over time, the city of Wrocław underwent expansion through the incorporation of neighboring villages, where rural landscapes were prevalent. Despite the development of new building areas, some of these spaces were transformed into urban parks. Furthermore, tree planting was a common practice in the vicinity of new constructions. In certain surveyed areas, there was a slight increase in the expansion of forest and shrub areas. The expansion of *B. (Ps.) bohemicus* and *B. (Ps.) sylvestris* could be related to the increase of their primary hosts: *B. lucorum* and *B. pratorum* respectively. An expansion in tree-covered areas could potentially influence the restructuring of the bumblebee community in the studied area, as proposed by Iserbyt et al. (2016).

The occurrence of *B. jonellus*, proposed to be a glacial relict (May, 1959) restricted to woods and mountain areas, can be explained by the presence of such suitable alimentary plants as Ericaceae species. This species was recorded near railway lines, where anthropogenic vegetal habitats were created on rocks to resemble heather-covered land. The expansionist tendency of this species was also recorded in Kraków (Tab. 2, Kosior et al., 2008), which supports the flexibility of this bumblebee in occupying new anthropogenic habitats.

The bumblebee community in Wrocław was primarily comprised of widely distributed and highly adaptable polyphagous species (*B. lapidarius*, *B. pascuorum*, *B. terrestris*). These species, common in Poland (Pawlikowski, 2008), are also characterised by a wide distribution across Europe (Rasmont et al., 2008, 2015) and in European cities (Goulson, 2010;

Gunnarsson & Federsel, 2014; Eggenberger et al., 2019; Haaland, 2023). Over the studied period, their range within Wrocław did not decrease (Tab. 1). *B. terrestris*, as a species with a wide range of food preferences, occurred most frequently in urban areas and areas with low forest and shrubs coverage. *B. pascuorum* was most commonly recorded in densely wooded areas, whereas *B. lapidarius* showed a preference for warm and open habitats including railway tracks and ruderal areas, where they could construct nests among stones and feed on vegetation from the Fabaceae family. Compared to other urban areas, such sites are abundant with nectar plants due to limited mowing operations (Michołał et al., 2017; Sikora et al., 2020). Plant species from the Fabaceae family are known to be pioneers in poor and stony areas found on tracks and wastelands.

Several species of bumblebees found in Wrocław (current paper, Tab. 1), Kraków (Kosior et al., 2008), and throughout the country show stable tendencies in the occupation of habitats. *B. jonellus*, *B. (Ps.) sylvestris* and *B. (Ps.) bohemicus* were observed to have expanded in Poland, Kraków and Wrocław (Kosior et al., 2008; Pawlikowski, 2008; current paper, Tab. 1). *B. veteranus* was confirmed to be stable in Kraków (Kosior et al., 2008) and Poland (Pawlikowski, 2008) and to have expanded in Wrocław (current paper, Tab. 1). *B. hypnorum* was stable in Kraków (Kosior et al., 2008) and expanded in Poland (Pawlikowski, 2008) and Wrocław (current paper, Tab. 1). *B. lucorum*, tendend to expanded in cities (current paper, Tab. 1; Kosior et al., 2008) and to stabilize throughout the country (Pawlikowski, 2008). *B. subterraneus* tends to stabilize in Kraków (Kosior et al., 2008) and Wrocław (current paper, Tab. 1), but the number of sites dropped elsewhere in Poland (Pawlikowski, 2008).

The most contentious situation is that of *B. sylvarum*, for which is stable in Poland (Pawlikowski 2008) but declining in Kraków (Kosior et al., 2008) and increasing in Wrocław (current paper, Tab. 1). Several cuckoo bumblebees have shown to increase in

the countryside (Pawlikowski, 2008), whereas a decline in occupied sites has been observed in cities (Kosior et al., 2008; current paper, Tab. 1). However, urbanised areas seem to have an adverse effect on these insects, with the exception of *B. (Ps.) sylvestris* and *B. (Ps.) bohemicus*, which show an increase, influenced by the of expansion of their main bumblebees host species (Kosior et al., 2008; current paper, Tab. 1). Furthermore, several bumblebee species in Poland, including in Kraków and Wrocław (Pawlikowski, 2008; Kosior et al., 2008; current paper) shows decreases among *B. distinguendus*, *B. confusus*, *B. pomorum*, and *B. humilis*.

Within the city area, a series of anthropogenic factors could significantly cause the decline and extinction of bumblebees (Kosior et al., 2008). Both bumblebee species that disappeared and regressed in Wrocław prefer open areas and those that appeared and expanded preferred forested areas. Over the years, the city's multiple expansions has lead to the enlargement of compactly developed areas. Therefore, we consider urbanisation (Ahrné et al., 2009; Banaszak-Cibicka & Żmihorski, 2012; Martins et al., 2013), lack of floral resources (Nunes et al., 2024) and the fragmentation and isolation of habitats (Darvill et al., 2010; Hatten et al., 2013) as the most likely causes for the retreat of bumblebees from city areas.

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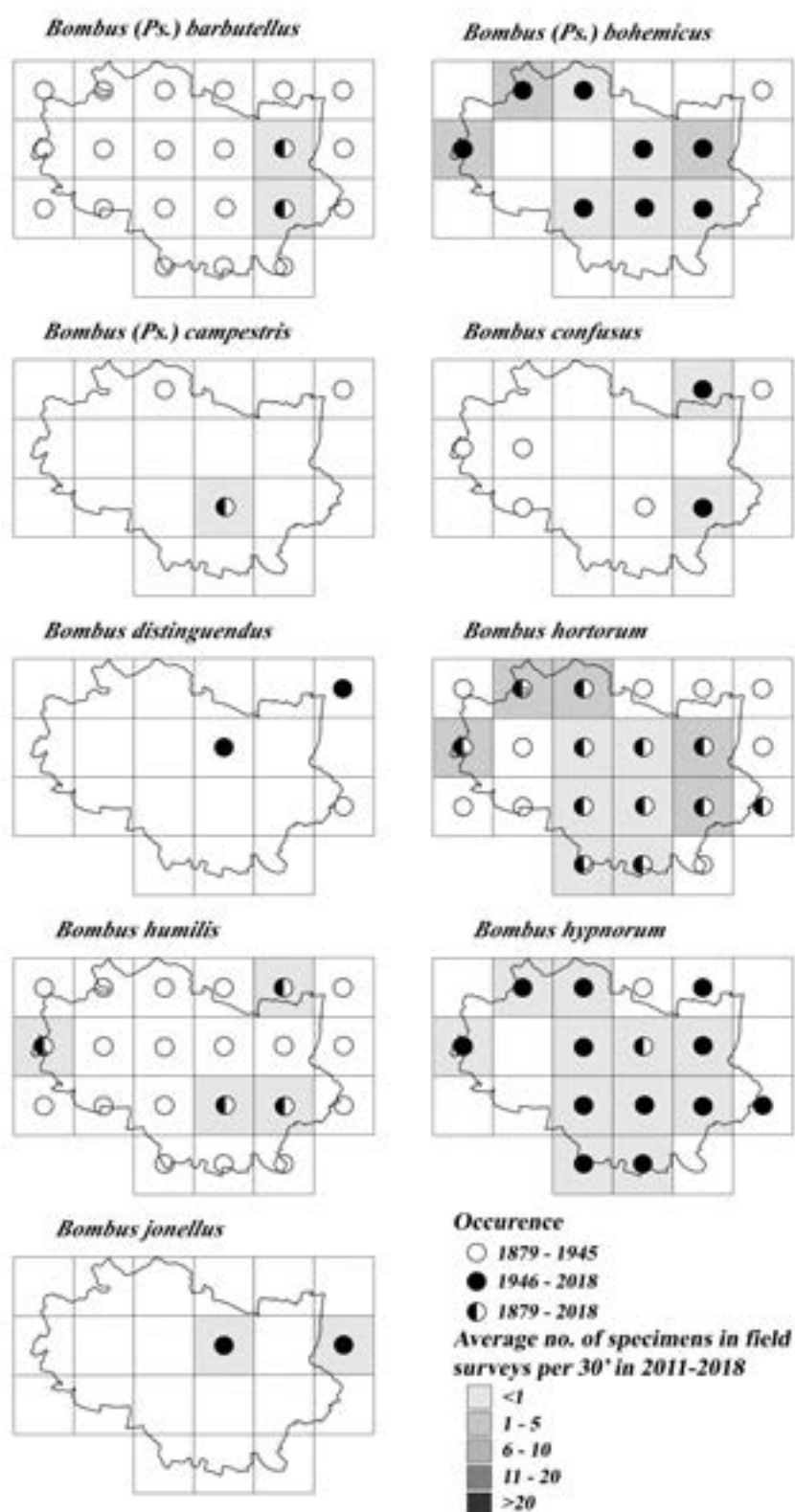
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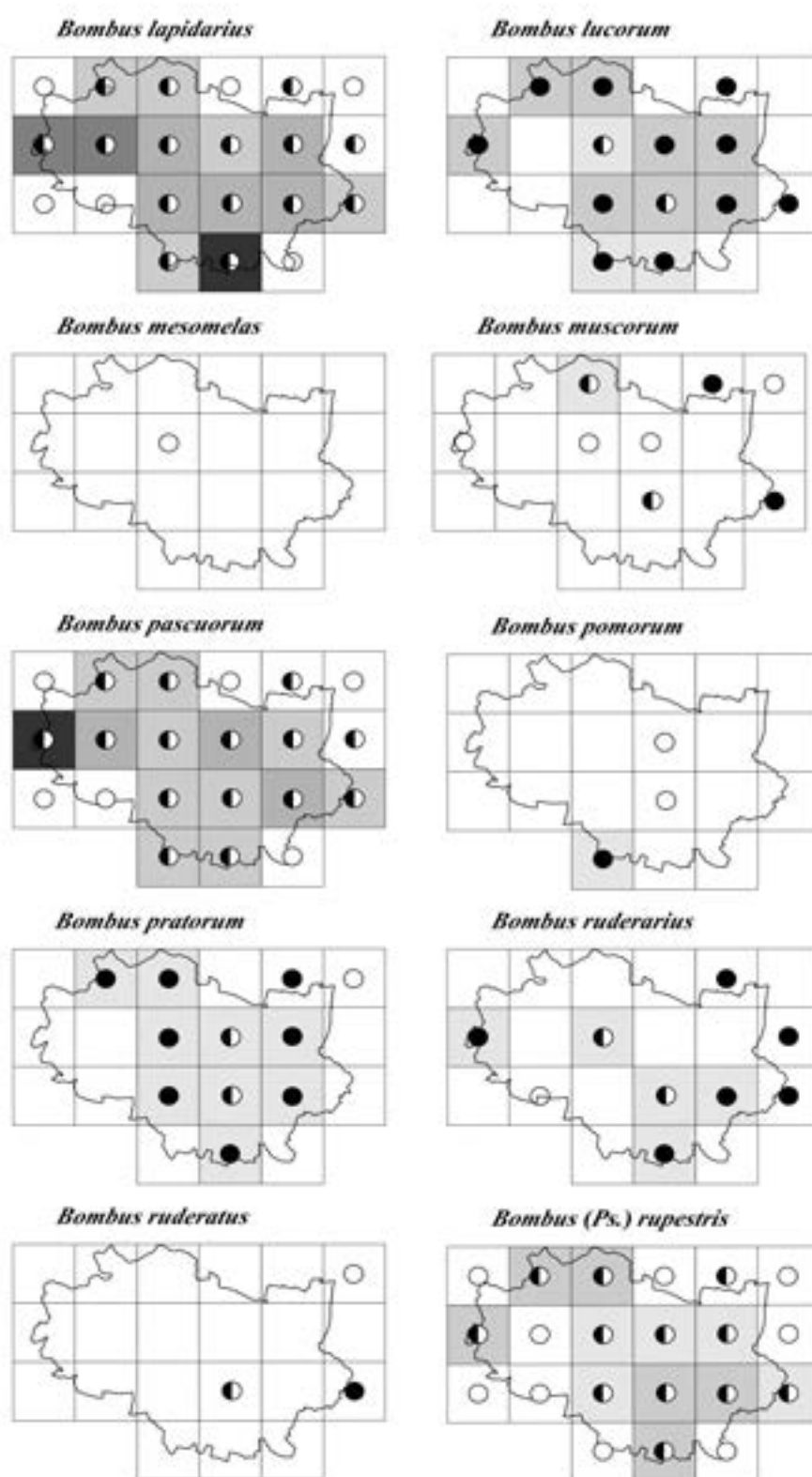
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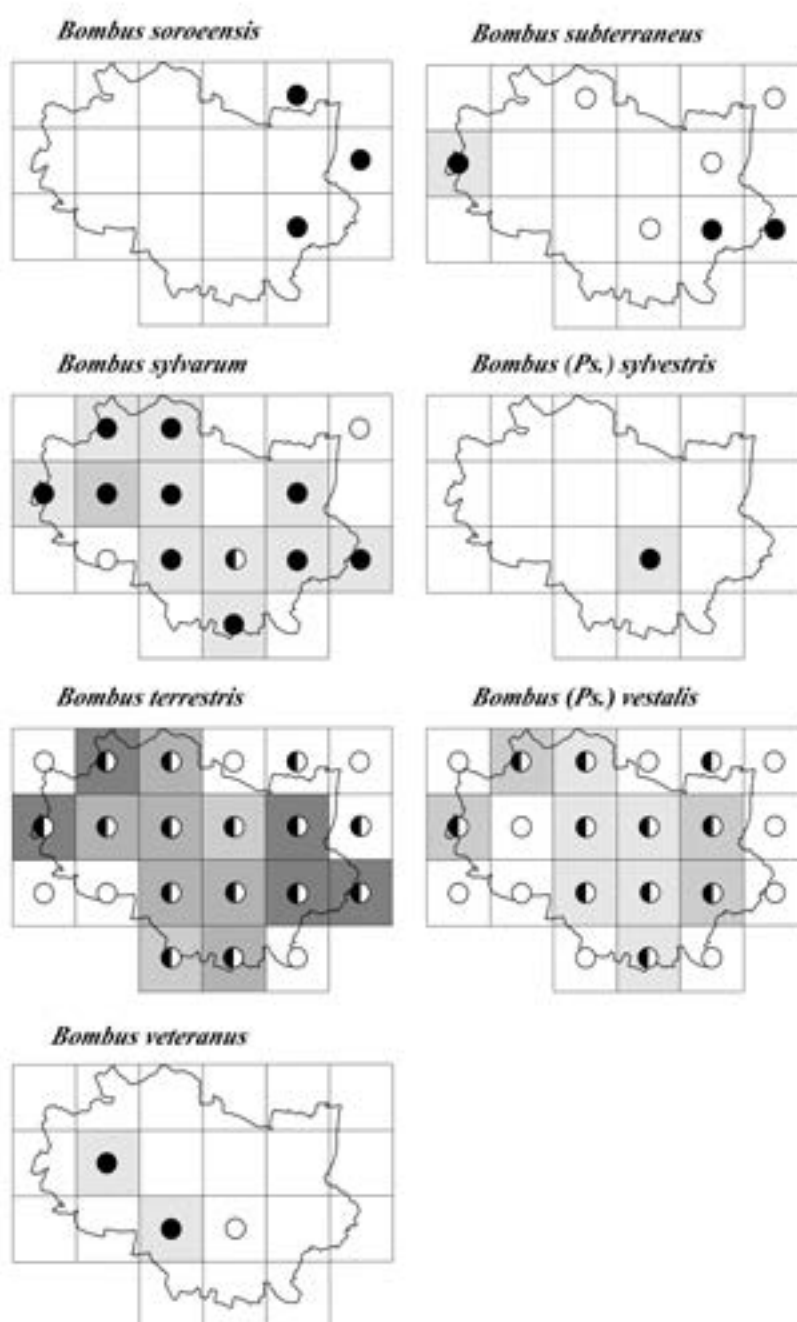
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Supplementary material 1. Distribution of bumblebee species in two periods in Wrocław (SW Poland). *Bombus* (Ps.) *barbutellus*; *B.* (Ps.) *bohemicus*; *B.* (Ps.) *campestris*; *B.* *confusus*; *B.* *distinguendus*; *B.* *hortorum*; *B.* *humilis*; *B.* *hypnorum*; *B.* *jonellus*.



Supplementary material 2. Distribution of bumblebee species in two periods in Wrocław (SW Poland). *Bombus lapidarius*; *B. lucorum*; *B. mesomelas*; *B. muscorum*; *B. pascuorum*; *B. pomorum*; *B. pratorum*; *B. ruderarius*; *B. ruderatus*; *Bombus (Ps.) rupestris*.



Supplementary material 3. Distribution of bumblebee species in two periods in Wrocław (SW Poland). *B. soroeensis*; *B. subterraneus*; *B. sylvarum*; *B. (Ps.) sylvestris*; *B. terrestris*; *B. (Ps.) vestalis*; *B. veteranus*.