Urban Ecosystems – a Place for Pollinators? A Mini-review and Social Implications

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Abstract

The world is facing a great ecological crisis: the global pollinators loss. Hence, there is an urgent need for new conservation arenas including urban environments that might act as attractive habitats for bees and other pollinators. We explore the studies on the urban bee populations and their requirements to assess the conditions that must be provided for effective conservation programmes. We argue that the green sites in the city can be designed in a sustainable way in order to support the basic ecological functions, offering high-quality food base and nesting sites. In addition to practical solutions based on detailed scientific findings, the needs of citizens must be taken into account and the social component of urban conservation should not be neglected.

Key words: *pollinators, conservation, ecosystem, bee populations.*

Anotacija

Pasaulis išgyvena didelę ekologinę krizę: globalinį augalų apdulkintojų nykimą. Taigi, skubiai reikalingos naujos apdulkintojų išsaugojimo arenos, įskaitant miestų aplinką, kurios galėtų būti patraukliomis bičių ir kitų apdulkintojų buveinėmis. Mes atlikome tyrimus apie miesto bičių populiacijas ir reikalavimus joms siekiant įvertinti sąlygas, kurios turi būti numatytos veiksmingose išsaugojimo programose. Mes teigiame, kad žalios aikštelės mieste gali būti suprojektuotos laikantis tvarumo principo, siekiant palaikyti pagrindines ekologines funkcijas, siūlančias aukštos kokybės maisto bazę ir lizdavietes. Be praktinių sprendimų, kurie remiasi išsamiais moksliniais duomenimis, turi būti atsižvelgiama į piliečių poreikius, ir neturėtų būti ignoruojamas miestų išsaugojimo socialinis komponentas.

Reikšminiai žodžiai: *apdulkintojai, išsaugojimas, ekosistemos, bičių populiacijos.*

Introduction

Global pollination crisis. Pollination by animals, especially insects is essential for effective reproduction of vast majority of plants, hence it remains a crucial process for maintenance of functionality of ecological networks (Willmer, 2011, Potts et al., 2010). According to Ollerton et al. (2011) more than 87 % of flowering plants both wild and cultivated, are zoogamic. It clearly demonstrates the scale of risk related to the global extinction of mostly wild pollinators (Ollerton et al., 2011). Although significant declines in their populations all over the world have been reported for last three decades (Willmer, 2011), the extensive studies explaining this phenomenon in terms of complex structure of the pollination networks on different ecological levels are still lacking. Therefore, global pollinator crisis is now presented as one of the most challenging ecological and conservation issue of our times (Potts et al., 2010).

Among other pollinators, these are bees that play crucial role in many ecosystems both natural and anthropogenic (Willmer, 2011). Thus, public attention has been recently turned to their significant position in the global economy and food production processes (Williams et al., 2010). Unfortunately, despite the warnings of population decline, agriculture is constantly switching to the bees-depended production (Potts et al., 2010). At the same time, most of the observations are focused on the honey bees, *Apis mellifera*, as the mostly embroiled in the global market, resulting in the subsequent reports on Colony Collapse Disorder (CCD), a phenomenon responsible for decimation of managed bee populations all over the world (van Engelsdorp et al., 2009). However, honeybees and another well-recognized group of social bees, e.g. bumblebees (*Bombus*), make up only a small minority of all bee species. Most of them are solitary, often called ‘wild bees’ and belong to a monophyletic lineage within the superfamily Apoidea, often considered as the

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Apiformes or currently, the clade *Anthophila* (Michener, 2000, Willmer, 2011). In case of rapidly increasing losses in pollination services, these wild and less known pollinators are gaining in importance (Potts et al., 2010). Some of them, for instance *Osmia rufa,* are already used on a large scale, primarily to pollinate crops, that honey bee can manage less effectively (Michener, 2000). Yet a global condition of native bees is not better than in case of the honey bee, and their status might be even worse, if the immense lack of data on their numbers and diversity is taken into account (Potts et al., 2010). Nevertheless, some of the surveys allow assessing at least the reasons of the crisis, giving a credible hope for searching and implementation of practical solutions.

Industrial agriculture with its ceaseless intensification, together with the landscape changes and urbanization has been recognized as one of the villains of the piece (Vanbergen and the Insect Pollinators Initiative, 2013). The CCD, as most of the researchers recently agreed, is mostly caused by pesticides (Kiljanek et al. 2016). For the rest of pollinators the biggest bane seems to be the loss of natural and seminatural habitats. Meadows full of wildflowers but also balks, wastelands, shelterbelts, shrubs, buffer stripes and railway embankments are important food sources for wild pollinators (Denisow and Wrzesień, 2015, Wrzesień et al., 2016a, 2016b). Their disappearance together with impoverishment of plant species diversity and landscape unification are directly associated with the wild bees nesting sites decrease and dramatic decline in available food base (Kremen et al., 2007). According to Biesmeijer et al. (2006) the observed drop of pollinators in Great Britain and the Netherlands is correlated with biodiversity loss of cultivated fields. Furthermore, common use of herbicides is reducing current temporal and spatial availability of food, causing the considerable displacement of species from previously optimal areas. In addition, the migration opportunities are becoming significantly hampered due to the rapidly progressing habitat fragmentation on the global scale. Wild bees, especially oligolectic species exhibiting specialized preference for pollen sources, are particularly disturbed by spatial isolation as shown by Steffan-Dewenter et al. (2006). Therefore, the importance of elaborate research on fragmentation, followed by practical findings on minimum size of the areas and maximum distance between separated, protected islands should be underlined (Willmer, 2011). There are already some positive examples showing that maintenance of even small corridors among the degraded sites allow to preserve and support functional biodiversity of complex ecosystem networks as for instance pollen transfer in bees- and butterflies-pollinated plants (Townsend and Levey, 2005).

Urban ecology. Against this background, urban areas are brought into the limelight as extremely converted sites with the highest concentration of threats, but at the same time, as potentially complex, high-quality *refuge* ecosystems. The most eminent consequence of urbanisation is transformation of the land structure and considerable reduction of biologically active surfaces towards the hostile impervious ones (Zanette et al., 2005; Fortel et al., 2014). However, more and more studies on urban ecology present the novel perspective of perception of cities that often act as rich and attractive ecosystems for many plant and animal species, due to their heterogeneity. The wide range of microhabitats is crucial, enabling colonization by species with different requirements (Banaszak-Cibicka, 2015). Therefore, taking into account the inevitable global expansion of urbanisation processes, cities and in particular urban green spaces within them steadily acquire special importance for global biodiversity conservation (Frankie et al., 2005), especially that these environments become prevalent in some landscapes (Seto et al., 2011).

Contrarily to previous assumptions many current studies on urban bee populations from all over the world demonstrate their value for insect protection (Hernandez et al., 2009). Furthermore, some researchers presume that cities are becoming even more attractive than the non-urban areas around them and thus they exhibit higher species richness (Banaszak-Cibicka, 2015). Several authors, for instance, demonstrated that some peri-urban or garden sites may be source of pollinators to agricultural systems (Goulson et al., 2002, 2010; Samnegard et al., 2011).

Undoubtedly to create a suitable habitat, some basic conditions of pollinators population functioning must be fulfilled (Tscharntke et al., 2005). Firstly, the food base available in appropriate

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temporal and spatial scales is essential to cover requirements of different species (Frankie et al., 2005, Gaston et al., 2005). Secondly, the nesting sites are needed. Although many of them are still present in the cities in form of decayed wood or bare soil their disappearance is progressing (Ahrne et al., 2009). Despite that, contrary to natural or agricultural areas, cities are more susceptible to small modifications, therefore they may turn out to be better places for introduction of insects-friendly solutions. According to the study by Tommasi et al. (2004), performed in Vancuver, Canada, a sustainable urban planning is necessary to realise the urban potential of becoming pollinator reservoirs. Through examination of various green areas (i.e. parks and squares, community and botanic gardens, abandoned semi-wild patches, traditional flowerbeds and backyards) these researchers mapped how floral diversity is defined by different type of the urban setting and showed that bee preferences for specific plant groups and species determine their abundance and distribution.

Another point of the urban flexibility is related to the use of chemicals. While elimination of the pesticides and herbicides in the agriculture in the reality of global economy seems to be almost impossible, urban green management is situated in the completely different context, reflecting different needs and hence could be depended on local political decisions and citizen's tastes. Chemicals utilization for parks and flowerbeds does not have such strong reasonable grounds as in crop production, hence might be easily limited, for instance, because of growing public dislike. Thus, urban green space management, followed by high-quality food base development presents a considerable potential for conservation of pollinators. And in fact, this capability is increasingly acknowledged by, for instance, establishing wild flower meadows composed of native plants, leaving unmown lawns or even creating comprehensive projects as 'world first bee highway' in Oslo (Agence France Press, 2015).

However, the most considerable publicity is being given to the diverse proposals of building artificial nests, often called 'bee hotels'. Unfortunately, this public acclamation is not well supported by the scientific justification and some researchers suggest more attentive and critical approach to such remedies. Firstly, most of the wild bee species are ground-nesting (Michener 2000), while artificial shelters are usually made of wood and straw, which greatly limits their utility in conservation of bees. Secondly, as shown by MacIvore and Packer (2015), who have conducted the sole relevant study so far, bee hotels may in fact become a double-edged tool. Based on examination of almost 600 bee hotels in Toronto over three years (2011–2013), these authors showed that these were rather wasps than bees that utilized artificial nest sites. Furthermore, native bees dwelling in bee hotels were parasitized more than any other inhabitants of these sites, be that introduced bee species or wasps. Therefore, many more biological factors need to be taken into account while planning such artificial-nests' networks, especially investigations of different conservation methods and relation between various aspects of niche realisation opportunities seem essential in the case of providing protection for wild pollinators.

Methods

In order to present the current knowledge on urban bee populations and their relation to the habitat we conducted a literature review based on up-to-date research papers. Furthermore, in order to examine the public attitudes and social context of urban bee conservation we performed a short sociological study in six public parks in the city of Warsaw, which is the capital of Poland and the largest city in the country, covering 517.2 km^2, with a population of approx. 1.7 million people (based on 2008 data; Czerwińska-Jędrusiak, 2009). Our study based on a simple questionnaire took place in 2015 (May–July) and included interviews with 38 citizens. Apart of open questions we intended to engage the interviewed persons in discussion about bees, bee hotels, urban green management, their preferences and perception of urban green spaces.

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Results and discussion

Green habitat. Many studies show the relation between diversity and abundance of bees and the surface type. Green surfaces influence the urban populations positively, while impervious have definitely negative impact (Ahrne, 2008; Fortel, 2014; Siemaszko, 2016). The ground surface depends on the land use type. In general, it determines the food base structure for pollinators. Green areas, including managed flower beds, usually offer much more abundant and diverse food composition than highly up-built sites. They provide succession flowering during the whole vegetation season and availability of building materials indispensable for nest construction (Tscharntke et al., 2005; Zanette, 2005). Such spaces may act as habitats for self-maintaining populations or rather as ecological corridors that enable migrations and support natural flow and connectivity, faster expansion, adaptation to changing conditions and colonization of new, suitable habitats (Steffan-Dewenter, 2001; McIntyre and Hostetler, 2001).

Maintaining all these functions seems to be difficult in many cities and particularly their centres with still typical physiognomy of compact settlements with surface covered by concrete, stone and other impervious materials (McKinney, 2006). *Landscape connectivity* (Fortel et al., 2014) and support of network structure greatly influences the bee population (Scheper et al., 2013; Steffan-Dewenter, 2001). These features constitute fundamental limiting factors so examining the services of non-impervious surfaces may be more informative than the selective analysis of flower availability.

The distance to the city centre and connections with the other green sites, for instance bigger and more natural forests or suburban areas may play a significant role as a conditional factor for the population replenishment (Urban and Keitt, 2001; Kremen et al., 2007).

Further aspect is the layout and positions of green and impervious patches among the mosaic urban arrangement. The impervious sites, for instance wide arterial roads that incorporate all negative environmental features such as physical barriers, pollution, noise and lack of refugia may act as unbreakable barriers (Townsend and Levey, 2005; Willmer, 2011). In contrary, Fortel et al. (2014) studying bee communities in Lyon documented the highest species richness in the sites of 50% impervious cover. Moreover, the species composition seems to depend on this parameter. The parasitic species exhibit the highest abundance in the medium impervious cover, while for medium and higher imperviousness the cavity-nesting bees and long-tongued species were the most numerous. It might be partly explained by the *disturbance heterogeneity model* whereby the maximum degree of environmental heterogeneity is reached along 50% disturbance, in this case the area of impervious cover.

Banaszak-Cibicka and Żmihorski (2012) suggest that city with a broad range of microhabitats may be an attractive ecosystem for many bee communities. It is proved by many studies all around the world (Fortel et al., 2014; Matteson et al., 2008; Tommasi et al., 2005; Zannete et al., 2005). Although high specificity of habitats of the city centres might act as an ‘ecological filter’, supporting the expansion of only certain species. Hence, the preservation of mosaic structure should be underlined.

Some species choose to populate city centres more often (mostly representatives of groups active later in the year), while other show preferences for peripheral sites. Regardless the disparities, both groups exhibit stability along the entire urban gradient, which confirms the high quality of this habitat. It is worth underlining that in contrary to eusocial and parasitic bees that thrive in the centre, solitary bees are predominantly related to the suburbs. This is important observation, corresponding with MacIvor and Packer (2014) findings on ‘bee hotels’ effectiveness.

The base condition for bee occurrence is the food base (Bąk-Badowska, 2012). Thus, apart from the urban heterogeneity, green spaces rich in flowers are necessary element of urban habitat (Frankie et al., 2005). Banaszak-Cibicka and Żmihorski (2012) reported that bee populations surveyed in the Botanical Garden and Arboretum in Poznań, Poland, offering obviously the best

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possible food base, are the most similar to the communities from the National Park of Wielkopolska. According to these authors urban areas are rather preferred by insects' generalists, whereas flower-specialists are observed less frequently. Polylectic species seems to be privileged in the urban parks and gardens' conditions where the dominating vegetation usually consists of various cultivars and exotic varieties. For example, pollination networks in the centre of Warsaw were composed mostly of generalists (Jędrzejewska Szmek and Zych, 2013).

The most frequently listed oligolectic species in Poznań was *Andrena vaga*, known for foraging predominantly on willows (*Salix* spp.) that are often planted in the parks, squares and some city gardens (Banaszak-Cibicka and Żmihorski, 2012). The colony of other mining bee species – *Andrena fulva* has been observed for years in the small city square in Poznań (Banaszak, 1993). In fact, the urban communities of trees are one of the most essential food sources for bees in the city, for instance for mining bees (Andrenidae) (Banaszak-Cibicka and Żmihorski, 2012). Hence, only by including trees into the flower analysis we can present an overall picture of the habitat capacity.

Building 'bee hotels'. Artificial nests have at least few serious drawbacks. Undoubtedly the most significant is an exposure for the parasitism and predators (MacIvor and Packer, 2015), and diseases. Banaszak (1993) shows how leaf-cutting cuckoo bees (*Coelioxys*) may puncture the closed brood cell of their Megachile hosts. Furthermore, standard hotel construction does little to imitate natural habitats mostly because of large number of brood cells in a small restricted area. It usually results in artificially high densities of residing bees of the same species, as well as high concentration of diverse taxa.

The overcrowding and sometimes even the arrangement of cavities may boost the competition and the chances of infection, by facilitating acquisition of new hosts by parasites and further transfer inside the shelter. For example, parasitic wasp *Monodontomerus* can successfully bite through the thin walls of the nests. There are no data precisely indicating the impact of parasites, although according to MacIvor and Packer (2015) native bees are more often infected than the alien species found in the hotels. This result, however, does not necessarily indicate inferior performances of urban populations since many researchers underline that parasites are good indicators of the ecosystem condition, that stabilise bee communities. The high diversity of parasites may point to the high stability and quality of habitats (Fortel, 2014; Banaszak, 1993) and according to Cane (2005) there is generally a low number of parasitic species in the urban areas that might be explained by small and labile populations of their hosts. Therefore, the relations between cleptoparasites and their hosts require more attention and studies in order to precisely assess their role, identify the threats and methods that may support the natural balance.

In conclusion, artificial nests should be designed based on scientific findings to avoid distortion in natural equilibrium.

Wet or weather? Water is another indispensable requirement for survival of bee populations. The availability of water in the environment, as essential to the insects' lives is often emphasized (Michener, 2000). Notwithstanding, some studies point out the negative influence of water, as for instance some local decreases in bee numbers and diversity in the natural environment are often caused by the rainfall flooding of their nests (Michener, 2000). It may be also observed through the pollen limitation in the flower populations (Zych et al., 2013).

In fact, the presence of water means two completely different environmental factors: firstly, the diverse and ubiquitous sources of drinking water and secondly the type of surface represented by ponds, lakes, rivers etc. Commonly, the urban habitats are described as concrete jungle with the urban heat island, intensification of droughts and handicapped accessibility of water (McKinney, 2006). However, it may look much more favourable from the bee ecology perspective. The abundance of various water features, e.g. fountains, ponds and predominantly puddles and leakages from gutters, planters and other water sources, that persist easily in the impervious urban surfaces might be fully satisfying the bees' needs. Hence, the water should not be a limiting factor for bee populations in the city or at least is much less significant than the food base or nesting sites.

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On the contrary, large water bodies like rivers, lakes or ponds are not needed for bee reproduction or survival (in contrary to many other insects like Diptera etc.), moreover water surface might be perceived even as a 'space wasting' (without food sources and nesting sites). However, the most important hypothesis is related to the local climate, modified by the presence of water bodies. It takes on special significance in the cities, where still or flowing water cools the microclimate, increases the humidity and stimulates the ventilation (Grimm et al., 2008). It precisely means reducing exactly all the specific factors of urban environment that are attractive for bees. Arguably, in spite of numerous benefits offered for the city it may have negative influence on bees being predominantly xerothermophilic organisms (Michener, 2000).

The urban heat island makes the urban areas bee-friendly habitats, and moreover often decides about their attractiveness for the species with climatic preferences characteristic for the habitats of others geographical regions (MacIntyre and Hostetler, 2001). Banaszak-Cibicka and Żmihorski (2012) used this hypothesis to explain their findings from Poznań of rare in Poland, more southern species *Megachile pilidens*, *Andrena florea*, *A. mitis* and *Osmia mustelina*.

In view of all these, it comes out that urban climate dynamics and fluctuations in humidity should be taken into consideration while planning further research on urban bee communities. In addition, the very specific weather, thermal and humidity conditions play an important role regarding the construction of artificial nests. Even subtle changes of location and humidity may decide about the hotel effectiveness (MacIvore and Packer, 2015; Siemaszko, 2016; Zych M. personal observations from the Botanical Garden).

Social implications. Last but not least, the human component of conservation of wild bees in the cities has great significance. Basically, all of the nature conservation programmes are somehow related to the politics and economy, hence never remain socially neutral (Nadasdy, 2007). There is a statement represented in many methodological approaches that social acceptance is the indispensable requirement for introduction and maintenance of any changes (Howe, 2009). The society, as a powerful and crucial actor in the public political debates often becomes the addressee and subject of various educational activities. It works likewise with the bee conservation, thus we argue that recognition of social attitudes, sentiments and expectations related to the bees and urban green management is the first step for efficient and successful application of conservation activities.

There are several key observations emerging from the public assessment that should be taken into account while introducing the bee-friendly solution to the urban management. Our results show that the social awareness of the global population crisis exhibits two main tendencies. Firstly, the issue is widely recognized and seems to be perceived as generally serious and important, but at the same time knowledge seems to be shallow and based mainly on media coverage or resulting from repetition of popular opinions. More than 80 % of interlocutors did not know that there are any other bees apart from the honey bee, thus they associated pollination services and crisis mainly with *Apis mellifera*. However, most of the people were truly fascinated in the subject and eager to learn about the bee ecology. It clearly shows how great importance should be attached to the environmental education.

Concerning the urban habitat for bees, we tried to assess the possibilities of applying various wild bee-friendly modifications in the city that might also appeal to the tastes and needs of the citizens. Most of the people strongly support the idea of bee conservation in the cities, although unassisted they do not have any ideas how to construct it.

In general, people understand the association between the chemicals and the threat for bees. One third of the respondents were definitely against the usage of chemicals in the urban parks, while another third consider the dilemma as a complex and difficult to solve. The aversion to mosquitoes results in the partial consent for the insecticides, while the pesticides and other plant protection products are regarded as unnecessary. The majority of citizens clearly understand the negative impact of the chemicals, thus would prefer to minimize their amount. The favourable social attitude might be easy to work on, while preparing the changes in law, what might enable

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greens to be released from the harmful substances. It might allow creating the safe spaces with the lesser effort than in the case of agriculture.

There are some common expectations towards the urban greens, though few of them contradict each other. Nevertheless, their implementation could successfully provide the conditions for pollinators-positive changes. Basically, almost all people like nature and they ask for more green spaces in the city. The favourite gardens are represented mostly by two types: firstly, the natural, wilder areas that offer the feeling of freedom and fulfillment of many different opportunities and functions; and secondly, well-designed, aesthetically attractive and safe parks. Some respondents indicated the necessity of broader perspective of the nature in the city, of acceptance of natural patches and the introduction of diverse vegetation. In particular, the constantly recurring motif of flowers showing the audience appreciation of colourful, attractive plants might be stimulating for greens designers. Moreover, it might create one of the best solutions also for bees, in the form of various flower-beds, flowering stripes, backyards, flowering trees etc. that provide a proper food base. These preferences reflect the answers about the implementation of new ideas for bee-friendly green management. Hence, the idea of flowering meadows had the most enthusiastic perception, while the remaining wild patches and unmown lawns need to be precisely discussed, followed by the revealing and minimization of threats.

Conclusions

In conclusion, we believe that the urban spaces may act as attractive habitats for wild bees and a useful refugium in the time of pollination crisis. However, its quality highly depends on the type of urban green management. Primarily, practical solutions should be based on the detailed scientific findings on the ecological requirements of bees, in order to avoid conservation misconceptions (as for example wrongly designed artificial nests) and ecological traps (where for instance the sustainable food base is not provided throughout the whole season). At the same time the conservation practices must take into consideration the social attitudes towards pollinators and urban green sites. Thereby, there is a chance to work out a compromise and create the green spaces in the city that may act as bee and human -friendly habitats. The diversity of urban areas and abundance of opportunities allow meeting the needs of all actors and fulfilling various functions, from aesthetics and recreation to ecology and education. There is a place for well-arranged beds of flowers that attracts pollinators, colourful flower arbours and for wild, natural patches with unmown weeds or dead wood and non-raked leaves in the restricted sites.

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