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How does ecosystem diversity contribute to the diversity of beetles, honeybees and bumblebees in Dolinka Służewska Park in Warsaw?

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Abstract: *How does ecosystem diversity contribute to the diversity occurrence of beetles, honeybees and bumblebees in Dolinka Służewska Park in Warsaw?* Studies regarding the benefits from urban green areas, among them parks, are of very high importance. In order to improve our understanding of biological diversity in urban parks, the presented study was carried out in one of the green areas of Warsaw, the Dolinka Służewska Park. We recorded beetles, honeybees and bumblebees using standard methods in six study plots representing different ecosystems located in the park, among them a leisure space represented by a small horticultural element with sitting places. The main objectives were to figure out (1) to what extent the plots studied contribute to the diversity of the species (2) if the pattern of contribution to biodiversity differs with respect to beetles and honeybees and bumblebees and (3) to what extent does a small man-made leisure space contribute to the diversity of beetles (Coleoptera), honeybees and bumblebees. The results indicated that the diversity of the studied ecosystems influences positively the diversity in species of beetles, honeybees and bumblebees. Individual plots may be of different significance for different taxonomic groups. In park areas like the one researched by us even small man-made places for leisure may be of high value in this context.

Key words: Coleoptera, Carabidae, *Apis*, *Bombus*, biological diversity, landscape

INTRODUCTION

The increase in human activities in natural spaces is a huge problem nowadays, which is why various studies have been carried out to preserve the ecological value of landscapes (Bertrand et al. 2015). It has been demonstrated that changes in land use can greatly affect the dispersal of species, leading to population fragmentation processes and subsequent problems for their conservation (Waldhart et al. 2003). In big cities with very high human pressure, the role of urban green spaces is of particular significance. Since there is a need for more sustainable cities (Yigitcanlar and Kamruzzaman 2015), studies regarding the benefits from their green areas, among them parks, are of very high importance (Sikorski et al. 2021).

Warsaw tops the list in the ranking of sustainable cities in Poland and is known as the green city (Urząd m.st. Warszawy 2021a). Parks, in addition to water reservoirs and forests, are considered basic elements of green infrastructure (GI) that provide ecosystem services (ES) in urban areas (Giedych and Maksymiuk 2017).

As the conservation and good management of the green spaces in the city of Warsaw is essential, a green fund has been created, the platform whose objective is the green transformation of the city, thereby contributing to the development of leisure spaces for residents, for example by increasing the green space in Warsaw, supporting urban gardening or creating horticultural elements with sitting places, and at the same time supporting the increase of the biodiversity of the city of Warsaw (Urząd m.st. Warszawy 2021b).

One interesting green element is Dolinka Służewska Park, located in one of the protected landscape areas of Warsaw, as it plays an important role as an ecological corridor, among others due to the appearance of beaver in the park (BioBlitz 2019). The park is an area of special study interest due to its diversity of ecosystems like forest areas, open areas, artificial parks, leisure areas or places near residential areas. One way of evaluating the ecological value of this park is using insects as indicators. Insects are suitable for assessing the environmental impact and biodiversity of the area in which they are studied due to the great variety of existing species and the fact that we can find them in almost all habitats (Rosenberg et al. 1986).

Therefore, a study was carried out in selected study plots located in the park, which were selected in such a way that they represented different ecosystems present as well as possible, over the period of three months, focusing on studying insects such as beetles (Coleoptera), honeybees (*Apis*) and bumblebees (*Bombus*). The objective of the research was to study the contribution of the ecosystems to the biodiversity of these insects. Such knowledge is crucial for understanding biological diversity in urban parks and its conservation. Since one study plot represented a small horticultural element with sitting places, it was also possible to assess the influence of such areas dedicated especially to leisure, by analysing the presence of the studied insects in this area. A study of the plant species present was also conducted in order to characterise the selected study plots more detailed regarding their vegetation.

Beetles were chosen for study because they represent a crucial part of biodiversity (Djoudi et al. 2019). Their presence in ecosystems in which they are found is of great importance since their activity and the way in which they use the available resources of the ecosystems can influence the environment in various ways (Bennewicz and Barczak 2020).

Same as beetles, pollinators are an essential component of biodiversity and they also play an important role in human food production. Bumblebees are important pollinators (Bretagnolle and Gaba 2015). They need a habitat that meets their needs for proper development, they require a suitable belowground area to nest, a place to hibernate and a large number of wild flowers for food (Theodorou et al. 2017). Honeybees are considered highly important pollinators, so their study is very useful for the evaluation of ecosystems. The honeybee as a biological indicator has several important morphological, ecological and behavioural requirements and its monitoring contributes to ecological impact assessment (Celli and Maccagnani 2003).

Based on the inventory of beetles, honeybees and bumblebees the following research questions should be studied:

1) To what extent do the plots studied in Dolinka Służewska Park contribute to the diversity of the species, i.e. does the variety in the presence of these species depend on the plots studied?
2) Does the pattern of contribution to biodiversity differ with respect to beetles and honeybees and bumblebees?
3) To what extent does a small man-made leisure space contribute to the diversity of beetles, honeybees and bumblebees?

MATERIAL AND METHODS

Study area and sampling plots

The study was carried out in Dolinka Służewska Park, located in the city of Warsaw in the Mokotów District. The park stretches along the Służewiecki Stream and has a total area of 26 ha. Formerly this area was an agricultural landscape, but over time it has been adapted by creating several ponds to receive rainwater (BioBlitz 2019). This park is located in the Warsaw Protected Landscape Area, whose purpose is to protect this landscape and its diverse ecosystems since it is an ecological corridor.

Inside Dolinka Służewska Park six research plots were established (the figure). Plot 1 was a forest fragment, which is characterised by varied vegetation from tall dominating trees such as *Fraxinus excelsior*, *Acer platanoides* or invasive alien species as *Robinia pseudoacacia*, to large shrubs. Most of the study plot is covered by a large shrub, *Syringa vulgaris*, also an alien species. Plot 2 was located next to one of the ponds in the park, close to Plot 1. In Plot 2 grasses of fresh meadows as *Dactylis glomerata*, *Lolium perenne* and *Agrostis capillaris* dominate. Plot 3 was located close to Dolina Służewiecka Street, one of Warsaw's main arteries. Here we can find a patchwork of areas covered by arboreal species such as *Fraxinus excelsior* and open areas with grass species, among them *Festuca rubra*, *Agrostis capillaris* or *Holcus lanatus*. Plot 4 was located in a former garden area, but now fresh meadow species of grass are of high importance in the plot plant cover and we can also observe few flowering perennials such as *Trifolium pratense*, *Trifolium repens* and *Medicago varia*. Plot 5 was located in the so-called Green Służew down the Valley, which is one of the projects that have been carried out in this park with the aim to create a leisure space with a collection of ornamental flowering plants (ornamental varieties of *Achillea millefolium*, *Geranium* sp., *Nepeta* sp., *Rosa* sp., etc.) in order to draw people's attention away from those areas of the park of greater ecological value. The present species increase the natural value of the area as they attract pollinators among other animals. The last study plot (Plot 6) was located near the Służewiecki Stream and the residential area of the park. We can find here tree plants as *Robinia pseudoacacia*, but the most numerous species are *Glechoma hederacea*, *Urtica dioica*, and *Lamium album* among perennials, typical for fresh to moist and relatively fertile grounds. Its proximity to the stream made it a bit difficult to collect data during rain periods as then the area was completely covered with water.

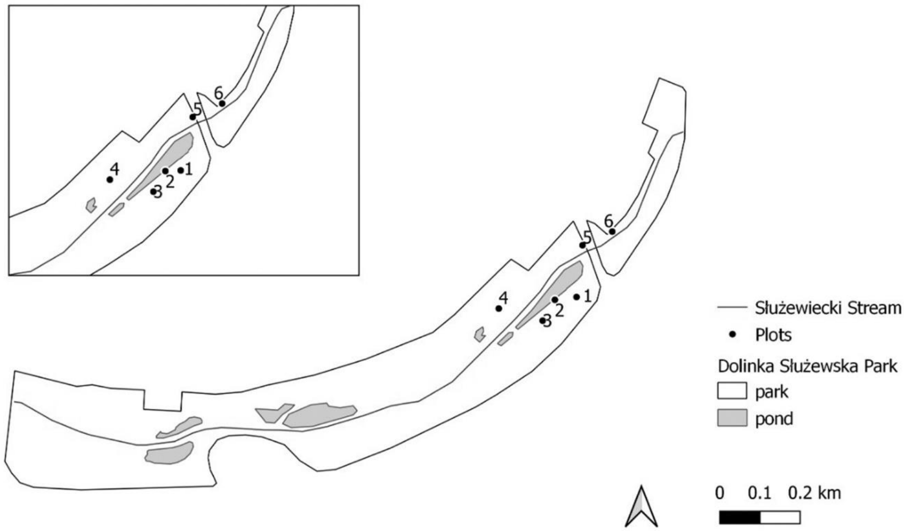

FIGURE. Scheme of the research object "Dolinka Służewska Park" and location of the study sites (Plots 1–6)

Field and laboratory methods

In each of the study plots, an inventory of beetles and bumblebees and honeybees as well as a description of the existing plant species were carried out.

Regarding the beetles, both direct and indirect collection methods were used during the months of July, August and September, by taking samples every two weeks, adding up to a total amount of five of them.

As indirect method pitfall traps (live traps) were used (Barber 1931). In each study plot, three traps were placed with a maximum distance of 2 m between them. These traps consisted of plastic cups that were placed at an adequate depth in the ground to be able to collect the beetles and they were left for at least 24 hours until their removal. As a direct method for collection of beetles a sweep net was used (50 sweeps per collection). All collected beetles were identified to the family level and carabid beetles (Carabidae) were identified to the species level. Identification and nomenclature was done according to Brohmer (1984) and Freude et al. (2004).

As for honeybees and bumblebees we observed their occurrence from 2nd August to 10th September in the study plots (Westphal et al. 2008) and supplemented these observations with some data collected along the routes with currently blooming plants (Banaszak-Cibicka and Żmihorski 2012, Zajdel et al. 2019) in the proximity of 10–20 m from the places of the pitfall traps at intervals of 7–14 days by direct observation on sunny, windless days, between 10 am and 3 pm. Altogether, six visits of the study area were carried out. The insects were counted and identified to the species level in the field (Krzysztofiak et al. 2004).

Descriptive analysis of data

For each study plot the number of species//families and individuals of the respective taxonomic group were calculated (alpha-diversity, Whittaker 1972). We also determined the numbers of species/families occurring only on one individual plot (beta-diversity, Whittaker 1972).

With respect to carabid beetles the ecological preferences of the respective species (Table 2) were identified based on literature (Burakowski et al. 1973, 1974, Freude et al. 2004).

RESULTS

With respect to the beetles, altogether 293 individuals from 14 families were collected at the 5 sampling plots (Table 1). The highest number of 152 individuals belongs to the Curculionidae family, being more present in Plot 1 (forest area), and Plot 4 (open field). The second most numerous family with 61 individuals collected are the Carabidae, found mostly in the artificial park (Plot 5) and the area near the stream (Plot 6). In contrast, the lowest number of one individual per family corresponds to Dryopidae, Latridiidae and Phalacridae. Plot 4 (open field area) is the one with the highest amount of individuals, 90 in total. The lowest amount of total individuals was collected in the plot close to the pond (Plot 2, 16 individuals). With respect to five families beetles were collected only in one plot, each one in Plot 1 (forest fragment, Latridiidae), Plot 2 (close to the pond, Dryopidae) and Plot 4 (open field, Phalacridae) and two in Plot 5 (artificial park, Endomychidae, Erotylidae).

Regarding the species of the Carabidae family collected in the different plots (Table 2), 20 different species were identified. Of those, the mostly represented

TABLE 1. Numbers of individuals of different beetle families at the study plots. Numbers concerning families registered at only one study plot are printed bold

Specification	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Sum
Anthicidae	1				1		2
Bruchinae				7		1	8
Byrrhidae	9		1				10
Carabidae	7	2	3	11	18	20	61
Chrysomelidae	8	4	3	1	3	8	27
Coccinellidae			2	8	2	4	16
Curculionidae	41	6	34	61	6	4	152
Dryopidae		**1**					1
Endomychidae					**2**		2
Erotylidae					**4**		4
Latridiidae	**1**						1
Phalacridae				**1**			1
Silphidae		2		1			3
Staphylinidae	1	1	3				5
Number of individuals	68	16	46	90	36	37	293
Number of families	7	6	6	7	7	5	14

TABLE 2. Numbers of individuals of carabid beetle species at the study plots and their ecological preferences (after Burakowski et al. 1973, 1974, Freude et al. 2004). Numbers concerning species registered at only one study plot are printed bold

Specification	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Sum	Ecological preference
Amara familiaris		1		1			2	moderate moist and dry soils, grasslands, farmland
Anchomenus dorsalis	1			1		1	3	unshaded, dry to moderately humid habitats
Anisodactylus binotatus					**2**		2	moderately humid habitats
Bembidion lampros					**2**		2	eurytopic species, wet and dry areas, poorly shaded
Calathus fuscipes	2	1	1	3	1		8	open habitats, bright deciduous forests, meadows, fields, gardens
Calathus melanocephalus					**1**		1	eurytopic species, mostly open habitats
Chlaenius nigricornis						**1**	1	edges of stagnant and slowly flowing waters, strongly shaded
Harpalus affinis				**1**			1	unshaded, dry to moderately humid habitats
Harpalus griseus	1				5		6	dry sandy soils, farmland
Harpalus latus	**1**						1	eurytopic species
Harpalus rufipes				3	6		9	dry meadows and arable fields, clay soils
Limodromus assimilis						**12**	12	forests, also close to waters
Loricera pilicornis			2			1	3	moist soils, edges of water
Nebria brevicollis	1					2	3	forests
Notiophilus palustris	**1**						1	forests
Ophonus puncticeps				**1**			1	open habitats, sparsely overgrown, clay and calcareous soils
Poecilus cupreus						**1**	1	mostly open habitats, also close to waters
Poecilus versicolor					**1**		1	meadows, pastures, fields, edges of waters with vegetation
Pterostichus melanarius						**2**	2	eurytopic species, mostly open habitats
Pterostichus niger				**1**			1	mostly forests
Number of individuals	7	2	3	11	18	20	61	
Number of species	6	2	2	7	7	7	20	

species was *Limodromus assimilis*. This species was collected in Plot 6, which was located next to Służewiecki Stream. The highest numbers of individuals were collected in the artificial park (Plot 5, 18 individuals) and Plot 6 (20 individuals), whereas very low numbers were collected close to the pond (Plot 2, 2 individuals) and the old garden area (Plot 3, 3 individuals). These two plots had also the lowest numbers of species. Among the recorded species those characteristic for open habits dominate. Four species are typical of forests. Only two of them were collected in the forest fragment (Plot 1). Five species have affinity to edges of waters, of which four were collected close to the stream (Plot 6) but none close to the pond (Plot 2). Thirteen species were collected exclusively in single plot, the most of them in Plot 5 (artificial park, 4 species) and Plot 6 (close to the stream, 4 species).

Regarding the count of honeybees and bumblebees, a total number of 879 individuals was obtained (Table 3). As expected, the highest number of individuals (689) occurred in Plot 5 (artificial park). A high number of individuals (136) was also observed in the open field area (Plot 4). No individuals were found in Plot 2, close to the pond. A low number was also registered for Plot 1 (forest fragment), because a total of only four individuals was spotted there. Two species (*Bombus rupestris*, *B. vestalis*) were detected only in one plot, both in Plot 5 (artificial park).

DISCUSSION

Our study confirmed that the plots studied in Dolinka Służewska Park contribute to the biodiversity of the taxonomic groups analysed in this research, such as beetles, honeybees and bumblebees (research question 1). The presence of individual species varied between the plots, as for example the carabid beetle *Limodromus assimilis* was observed in only one of the studied plots (Plot 6) and this may be due to the fact that the species is rarely found outside forests (Assmann 1999) and often close to waters. Plot 6 was located close to the Służewiecki Stream and the plot vegetation varied from arboreal species to herbs.

The high number of individuals of beetles collected in the open field (Plot 4) might be due to the presence of

TABLE 3. Numbers of individuals of honeybees and bumblebee species at the study plots. Numbers concerning species registered at only one study plot are printed bold

Specification	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Sum
Bombus terrestris			1	20	88		109
Bombus pascuorum			9	35	24	3	71
Apis mellifera	4		18	58	408	13	501
Bombus lapidarius			6	23	138		167
Bombus rupestris					**2**		2
Bombus vestalis					**29**		29
Number of individuals	4	0	34	136	689	16	879
Number of species	1	0	4	4	6	6	6

plants such as, among others, *Achillea millefolium* or *Trifolium repens*, which are flowering plants species favourable particularly to predatory beetles such as soft-winged flower beetles (Melyridae) or ladybird beetles (Coccinellidae) (Macdonald 2020). The diversity in ecosystems is also expressed by the diversification in habitat preferences between the identified carabid beetle species.

Regarding honeybees and bumblebees, their greater presence in Plot 5 (artificial park) may be due to the fact that it is a favourable ecosystem for them because of the high amount of nectar providing plants and therefore the plant species present in it attract them. *Trifolium repens* and *T. pratense* are some of the plants that mostly attract both honeybees and bumblebees (Theodorou et al. 2017). For the same reason numbers of individuals were high in Plot 4 (open field) since species such as *Taraxacum officinale* or *Trifolium repens* cover much of the area there, which is favourable for the diversity of pollinators. In Plot 2 close to the pond, however, honeybees and bumblebees were not found and the reason for it may be the area is mostly covered by plant species that do not attract pollinators.

The results confirm that species diversity is strongly affected by landscape structure. Different species prefer different ecosystems and stages of succession. The spatial arrangement of ecosystems and stages of succession in ecological landscape is assumed to be of importance with respect to overall diversity (Szyszko et al. 2011). In agricultural landscapes, for example, landscape structure, land use intensity and habitat diversity influence species diversity patterns (Hendrickx et al. 2007). Regarding carabid beetles it could be demonstrated that tillage systems and application of chemical plant protection treatments have impact on the assemblages (Kosewska 2016, Kosewska et al. 2020). Application and differences in such treatments may also have an impact on the species composition in urban gardens and parks.

We have also observed that the studied ecosystems contributed differently to beetles compared to honeybees and bumblebees (research question 2). For example, Plot 1 (forest fragment) contributed considerably to the diversity of beetles, but only to a low degree to the diversity of honeybees and bumblebees, since it is an area whose vegetation does not foster their presence. Differences in contribution of ecosystems to various taxonomic groups have been observed before, for example Koivula (2011) states that sets of carabid beetles are often poorly correlated with sets of other taxonomic groups, e.g. spiders. Of particular interest is the small man-made leisure space (Plot 5) and how it supports the overall biodiversity of beetles, honeybees and bumblebees in the study area (research question 3). Based on our results it is possible to conclude that it has a significantly positive impact on both species numbers and numbers of individuals.

CONCLUSIONS

In general, the diversity of the studied ecosystems influences positively the diversity in species of beetles, honeybees and bumblebees. Individual plots may be of different significance for different taxonomic groups. In park areas like the one studied by us even small man-made places for leisure may be of high value in this context. Further studies should focus on additional taxonomic groups as the aquatic fauna in the stream and the ponds, birds and small mammals.

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Streszczenie: *Jak różnorodność ekosystemów wpływa na różnorodność chrząszczy, pszczół miodnych oraz trzmieli w Parku Dolinka Służewska w Warszawie?* Analizy korzyści płynących z miejskich terenów zieleni, w tym parków, odgrywają znaczącą rolę. Celem poniższego badania przeprowadzonego na jednym z warszawskich terenów zieleni – Park Dolinka Służewska – było lepsze zrozumienie różnorodności biologicznej w parkach miejskich. Używając standardowych metod, przeprowadzono w parku inwentaryzację chrząszczy, pszczół i trzmieli w sześciu różnych miejscach reprezentujących różne ekosystemy. Wśród nich znalazła się zaprojektowana przez człowieka duża rabata kwietna z miejscem do wypoczynku. Głównymi celami pracy (1) było sprawdzenie, do jakiego stopnia różne tereny zieleni przyczyniają się do różnorodności gatunków oraz (2) czy i jak wpływ ten różni się w odniesieniu do chrząszczy, pszczół i trzmieli, a także (3) jaka jest sytuacja w przypadku terenów rekreacyjnych stworzonych przez człowieka. Wyniki badań wykazują pozytywną korelację różnorodności ekosystemów z różnorodnością wcześniej wymienionych gatunków.

Dotyczy to nawet małych, stworzonych przez człowieka rekreacyjnych części parków. Zauważono, iż poszczególne miejsca charakteryzują się różnym oddziaływaniem na wybrane grupy owadów.

Słowa kluczowe: Coleoptera, Carabidae, *Apis*, *Bombus*, różnorodność biologiczna, krajobraz

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