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ARTYKUŁ ORYGINALNY

Wpływ presji antropogenicznej na strukturę zgrupowań parazytoidów z podrodziny Pimplinae (Hymenoptera, Ichneumonidae) występujących w terenach zieleni miejskiej

The influence of anthropogenic pressure on the structure of communities of parasitoids of the Pimplinae subfamily (Hymenoptera, Ichneumonidae) inhabiting urban green areas

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Streszczenie

W terenach zieleni miejskiej powstają sprzyjające warunki dla rozwoju gatunków fitofagicznych, które żerując, zmniejszają walory estetyczne rosnących tam roślin. Liczebność szkodników roślin może być ograniczana przez parazytoidy z podrodziny Pimplinae. Celem badań było ustalenie wpływu małej, średniej i dużej presji antropogenicznej na strukturę jakościową i ilościową zgrupowań Pimplinae zasiedlających tereny zieleni miejskiej oraz określenie wpływu presji na odławianie owadów. Badania prowadzono w ogródkach działkowych miasta Poznania, w Ogrodzie Botanicznym i w Ogrodzie Zoologicznym w latach 2014–2016, stosując metodę odłowu owadów dorosłych do żółtych pułapek Moericke'go. Badania wykazały, że największy wpływ na strukturę jakościową i ilościową zgrupowań Pimplinae miało bogactwo gatunkowe roślin, a w mniejszym stopniu wielkość terenu, odległość od centrum miasta i wielkość zanieczyszczenia powietrza.

Słowa kluczowe: presja antropogeniczna, Pimplinae, zieleń miejska, Poznań

Abstract

Urban green areas have favourable conditions for the development of phytophagous species, which feed on plants and thus reduce their aesthetic value. The population of plant pests can be limited by parasitoids of the Pimplinae subfamily. The aim of this study was to determine the influence of low, medium, and high anthropogenic pressure on the qualitative and quantitative structure of Pimplinae communities inhabiting urban green areas and to determine the influence of this pressure on the catchability of insects. The research was conducted between 2014 and 2016 in allotment gardens, Botanical Garden and Zoological Garden in the city of Poznań, using the method of catching adult insects in yellow Moericke traps. The research showed that the richness of plant species had the greatest influence on the qualitative and quantitative structure of Pimplinae communities, whereas the size of the area, distance from the city centre, and the intensity of air pollution exerted lesser influence.

Key words: anthropogenic pressure, Pimplinae, urban greenery, Poznań

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Wstęp / Introduction

Urban greenery is a valuable structural element of the urban biocoenosis. It developed as a result of human activity and humans can still gradually transform it. Therefore, the biocoenosis of urban green areas is exposed to greater or lesser anthropogenic pressure. Urban vegetation is characterised by high density and species diversity. Therefore, urban green areas have favourable environmental conditions for the development of various groups of animals, including insects. However, phytophagous insects feed on plants and thus worsen their health.

It is difficult or sometimes impossible to chemically protect plants in the city due to the presence of people and animals. It is also difficult to protect plants from pests and diseases because there are communication problems between municipal services, scientists, and the local community (Tomalak 2003, 2006).

Urban green areas are the environment in which beneficial insects, including entomophages such as parasitoids of the Ichneumonidae family (Hymenoptera, Apocrita), may also develop. These are ectoparasitoids and endoparasitoids of eggs, larvae, and pupae of various phytophagous species of the Lepidoptera, Coleoptera, Hymenoptera, and Diptera orders (Fitton et al. 1988; Gauld et al. 2002; Yu 2012). The Pimplinae subfamily is an important group of parasitoids, because these insects effectively reduce the number of pests feeding on fruits in orchards and on other agricultural crops (Piekarska-Boniecka et al. 2008; Bąkowski et al. 2013).

So far there have been few studies on the occurrence of parasitoids of the Ichneumonidae family in the urban greenery environment. These were faunistic studies of contributory nature (Sawoniewicz 1982, 1986; Teder et al. 1999; Piekarska-Boniecka et al. 2009a, b; Schnitzler et al. 2011; Tanque et al. 2015). Therefore, the authors of this manuscript decided to conduct research on parasitoids of the Pimplinae subfamily, which can regulate the number of pests feeding on plants in urban green areas.

The aim of this study was to determine the influence of low, medium, and high anthropogenic pressure on the qualitative and quantitative structure of Pimplinae communities inhabiting urban green areas and to determine the influence of this pressure on the catchability of insects.

Materiały i metody / Materials and methods

Lokalizacja / Locality

The study was conducted between 2014 and 2016 at five sites located in urban green areas in Poznań, which were exposed to low, medium or high anthropogenic pressure. The pressure was expressed on the basis of the following parameters: the ratio of the area covered with vegetation to the built-up area per km^2, the distance of the research site from the city centre and air pollution with PM_{10} (a mixture of particulate matter with a diameter of 10 µm or less). The ratio of the area covered with vegetation to the built-up area per km^2 was determined on the basis of land cover maps prepared in the QGIS 2.18 Las Palmas program. The maps were based on the database of topographic items BDOT10k (Official Journal 2015, Item 2028). The program was also used to calculate the distance of the research sites from the city centre. Data from stations located in different zones of Poznań were used to present the air pollution level. These are stations located at Polanka, Dąbrowskiego, Chwiałkowskiego and Szymanowskiego Streets.

A list of vascular plants growing at each site was prepared on the basis of an area of 500 m^2 (50 m^2 around 10 traps at each site). The species of vascular plants growing on an area of 50 m^2 around each trap were identified.

The following sites were selected (fig. 1):

- Family Allotment Garden in Dębińska Road (D), (52°38′71″N 16°93′23″E), exposed to low anthropogenic pressure; large area (21.27 ha); dispersed buildings, high greenness level (87.3%); located 2.216 km away from the geographical centre of Poznań; annual mean concentrations of PM_{10} derived from the total emission of all types ranged from 25.0 µg/m^3 to 29.9 µg/m^3; an area with the greatest species richness of flora (161 species),
- Botanical Garden, Adam Mickiewicz University, Poznań (BG), (52°25′11″N 16°52′55″E), exposed to low anthropogenic pressure; large area (21.94 ha); adjacent to compact development, high greenness level (70.8%); 3.4 km away from the geographical centre of Poznań; annual mean concentrations of PM_{10} derived from the total emission of all types ranged from 25.0 µg/m^3 to 29.9 µg/m^3; an area with lesser species richness of flora (125 species) and the greatest species richness of trees,
- Family Allotment Garden in Serbska Street (S), (52°43′18″N 16°95′54″E), exposed to medium anthropogenic pressure; small area (3.80 ha); immediate vicinity of dense development, medium greenness level (57.1%); 3.53 km away from the geographical centre of Poznań; annual mean concentrations of PM_{10} derived from the total emission of all types ranged from 25.0 µg/m^3 to 29.9 µg/m^3; high species richness of flora (154 species); the highest species richness of shrub plants, the lowest species richness of woody plants,
- Family Allotment Garden in Piątkowska Street (P), (52°42′93″N 16°91′59″E), exposed to high anthropogenic pressure; small area (4.85 ha); immediate vicinity of dense development, low greenness level (30.5%); 2.57 km away from the geographical centre of Poznań; annual mean concentrations of PM_{10} derived from the total emission of all types ranged from 25.0 µg/m^3 to 29.9 µg/m^3; high species richness of flora (159 species) and the greatest richness of vegetable plantations,

- Zoological Garden in Zwierzyniecka Street (ZG), (52°24′30″N 16°54′23″E), exposed to high anthropogenic pressure; small area (5.24 ha); immediate vicinity of dense development, very low greenness level (7.2%); 1.44 km away from the geographical centre of Poznań; annual mean concentrations of PM_{10} derived from the total emission of all types ranged from 40.0 μg/m^3 to 47.6 μg/m^3; permissible PM_{10} level exceeded; the lowest richness of flora (107 species) and the lowest richness of herbaceous plants, ornamental flowering plants and shrubs.

Metoda / Method

Imagines of parasitoids were caught into yellow Moericke traps (Moericke 1953). These were plastic vessels with a diameter of 20 cm, filled with water, a liquid reducing surface tension and glycol, which was a preserving liquid. There were ten traps at each research site. They were at least 20 m away from each other and hung about 1.5 m above the ground. Parasitoids were caught from 1 April to 31 October each year. Samples were collected each ten days. Insects caught in one trap within ten days were considered one sample. Species of the Pimplinae subfamily were identified according to the Kasparyan key (Kasparyan 1981).

Analiza statystyczna / Data analysis

The communities of parasitoids of the Pimplinae subfamily at individual sites were analysed for species richness and the frequency of species occurrence. The analysis was based on dominance diversity curves. Principal component analysis (PCA) of parasitoid species abundance was used to illustrate the qualitative and quantitative structure of parasitoid species in individual years of the study, allowing for parasitoid hosts and the type of parasitism. The results of the PCA were illustrated in biplots (Gabriel 1971). The relationship between the intensity of anthropogenic pressure and the catchability of parasitoids was analysed with the chi-square test (Agresti 2007) and then with principal component analysis (PCA). These results were also illustrated in a biplot. The R 4.0.3 software was used for statistical calculations (R Core Team 2020).

Wyniki i dyskusja / Results and discussion

Between 2014 and 2016 3,096 samples were collected in the urban green areas in Poznań. As a result, 659 specimens of parasitoids belonging to 51 species of the Pimplinae subfamily were caught (tab. 1, 2). The highest abundance and species diversity of parasitoids was noted at the Serbska (S) site, where 214 specimens of 37 species were caught. This site was under medium anthropogenic pressure. The smallest number of specimens and the lowest species richness (51 specimens and 19 species) were noted at the Zoological Garden (ZG) site, which was affected by high anthropogenic pressure. The same nature of the relationship between the qualitative and quantitative structure of the parasitoid communities and the intensity of anthropogenic pressure exerted on these communities was confirmed by the values of the following parameters: the total average number of parasitoids (caught per Moericke trap during the three-year study period at the sites with low, medium, and high anthropogenic pressure and the total average number of species found at these sites (tab. 1). The site exposed to medium anthropogenic pressure [Serbska (S)] had the highest average number of parasitoids (21.4) and the highest average number of species (5.8). On the other hand, the sites exposed to high anthropogenic pressure [Dębina (D) and Botanical Garden (BG)] had the lowest average number of parasitoids (7.7) and the lowest average number of species (3.3).

Among the parasitoid communities the following eight species had the highest frequency of occurrence at indi-

Tabela 1. Wskaźniki biocenotyczne zgrupowań Pimplinae występujących w zieleni miejskiej Poznania w latach 2014–2016
Table 1. The biocenotic parameters of Pimplinae communities in green areas in Poznań between 2014 and 2016

Stanowiska badań Research sites	Liczba prób Number of samples (n)	Liczba osobników Number of specimens (N)	Średnia liczba osobników na pułapkę Mean number of specimens per trap ($\overline{xi}$)	Liczba gatunków Number of species (S)	Średnia liczba gatunków Mean number of species
D – Dębina	609	168	14.5	28	5.5
BG – Ogród Botaniczny Botanical Garden	627	123		25	
S – Serbska	619	214	21.4	37	5.8
P – Piątkowska	623	103	7.7	26	3.3
ZG – Ogród Zoologiczny Zoological Garden	618	51		19	
Ogólnie – Total	3096	659	65.9	51	12.9

Tabela 2. Wykaz gatunków, liczba osobników (N), indeks dominacji (D), rodzaj pasożytnictwa i powiązania żywicielskie zgrupowań Pimplinae występujących w zieleni miejskiej Poznania w latach 2014–2016

Table 2. The list of species, the number of specimens (N), the dominance index (D), the kind of parasitism and the host relationships of Pimplinae communities in green areas in Poznań between 2014 and 2016

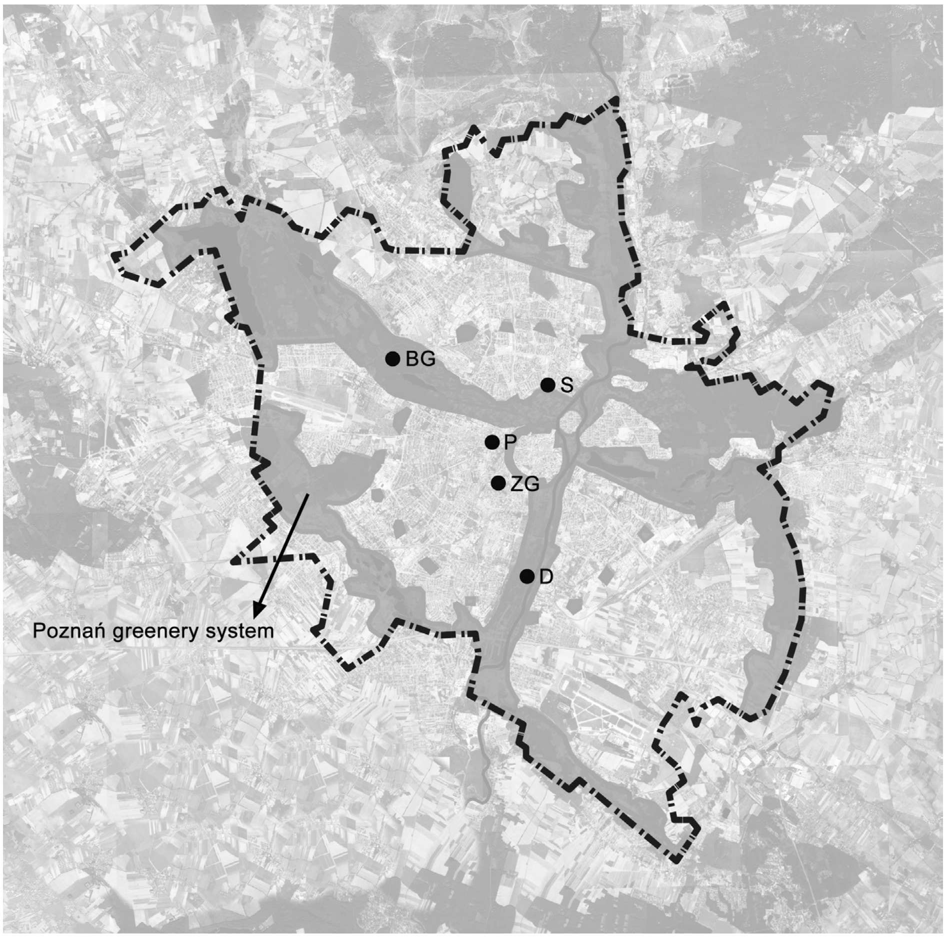
	Gatunki Species N	Razem – Total		Rodzaj pasożytnictwa Kind of parasitism	Żywiciel Host
		N	D		
S1	*Acrodactyla degener* (Haliday, 1839)	3	0.46%	Ec, A	Ar.
S2	*Acropimpla didyma* (Gravenhorst, 1829)	1	0.15%	Ec, L	Lep.
S3	*Acropimpla pictipes* (Gravenhorst, 1829)	4	0.61%	Ec, L	Lep., Col.
S4	*Apechthis compunctor* (Linnaeus, 1758)	1	0.15%	En, P	Lep.
S5	*Apechthis quadridentata* (Thomson, 1877)	2	0.30%	En, P	Lep., Hym.
S6	*Apechthis rufata* (Gmelin, 1970)	2	0.30%	En, P	Lep., Hym.
S7	*Clistopyga canadensis* Provancher, 1880	1	0.15%	Ec, E	Ar.
S8	*Clistopyga incitator* (Fabricius, 1793)	6	0.91%	Ec, E	Ar.
S9	*Clistopyga rufator* Holmgren, 1856	1	0.15%	Ec, E	Ar.
10	*Delomerista mandibularis* (Gravenhorst, 1829)	3	0.46%	Ec, L	Lep., Hym.
S11	*Dolichomitus mesocentrus* (Gravenhorst, 1829)	6	0.91%	Ec, L	Col., Lep.
S12	*Dolichomitus populneus* (Ratzeburg, 1848)	3	0.46%	Ec, L	Col., Lep.
S13	*Dolichomitus pterelas* (Say, 1829)	1	0.15%	Ec, L	Col., Lep.
S14	*Dolichomitus tuberculatus* (Geoffroy, 1785)	1	0.15%	Ec, L	Col., Lep.
S15	*Dolichomitus* sp.	1	0.15%	Ec, L	Col., Lep.
S16	*Endromopoda detrita* (Holmgren, 1860)	10	1.52%	Ec, L	Pol.
S17	*Gregopimpla inquisitor* (Scopoli, 1763)	1	0.15%	Ec, L	Lep., Hym.
S18	*Itoplectis alternans* (Gravenhorst, 1829)	45	6.83%	En, P	Pol.
S19	*Itoplectis maculator* (Fabricius, 1775)	66	10.01%	En, P	Pol.
S20	*Itoplectis tunetana* (Schmiedeknecht, 1914)	10	1.52%	En, P	Lep.
S21	*Liotrypphon caudatus* (Ratzeburg, 1848)	13	1.97%	Ec, L	Lep.
S22	*Liotryphon crassiseta* (Thomson, 1877)	36	5.46%	Ec, L	Lep., Col.
S23	*Liotryphon punctulatus* (Ratzeburg, 1848)	11	1.67%	Ec, L	Lep., Col.
S24	*Perithous divinator* (Rossi, 1790)	12	1.82%	Ec, L	Hym.
S25	*Perithous septemcinctorius* (Thunberg, 1824)	2	0.30%	Ec, L	Hym.
S26	*Pimpla contemplator* (Mueller, 1776)	182	27.62%	En, P	Lep., Hym.
S27	*Pimpla flavicoxis* Thomson, 1877	33	5.01%	En, P	Lep., Col.
S28	*Pimpla insignatoria* (Gravenhorst, 1807)	3	0.46%	En, P	Lep., Col.
S29	*Pimpla melanacrias* Perkins, 1941	6	0.91%	En, P	Lep.
S30	*Pimpla rufipes* (Miller, 1759)	16	2.43%	En, P	Lep., Hym.
S31	*Pimpla spuria* Gravenhorst, 1829	6	0.91%	En, P	Lep.
S32	*Pimpla turionellae* (Linnaeus, 1758)	6	0.91%	En, P	Pol.
S33	*Polysphincta tuberosa* Gravenhorst, 1829	3	0.46%	Ec, A	Ar.
S34	*Scambus brevicornis* (Gravenhorst, 1829)	4	0.61%	Ec, L	Pol.
S35	*Scambus calobatus* (Gravenhorst, 1829)	9	1.37%	Ec, L	Pol.
S36	*Scambus inanis* (Schrank, 1802)	42	6.37%	Ec, L	Pol.
S37	*Scambus nigricans* (Thomson, 1877)	7	1.07%	Ec, L	Pol.
S38	*Scambus planatus* (Hartig, 1838)	14	2.12%	Ec, L	Pol.
S39	*Scambus pomorum* (Ratzeburg, 1848)	31	4.70%	Ec, L	Pol.
S40	*Scambus sudeticus* (Głowacki, 1967)	3	0.46%	Ec, L	Lep., Col.
S41	*Schizopyga circulator* (Panzer, 1800)	3	0.46%	Ec, A	Ar.
S42	*Schizoppyga podagrica* (Gravenhorst, 1829)	1	0.15%	Ec, A	Ar.
S43	*Tromatobia lineatoria* (Villers, 1789)	4	0.61%	Ec, E	Ar.
S44	*Tromatobia ornata* (Gravenhorst, 1829)	2	0.30%	Ec, E	Ar.

Tabela 2. Wykaz gatunków, liczba osobników (N), indeks dominacji (D), rodzaj pasożytnictwa i powiązania żywicielskie zgrupowań Pimplinae występujących w zieleni miejskiej Poznania w latach 2014–2016 – cd.

Table 2. The list of species, the number of specimens (N), the dominance index (D), the kind of parasitism and the host relationships of Pimplinae communities in green areas in Poznań between 2014 and 2016 – continued

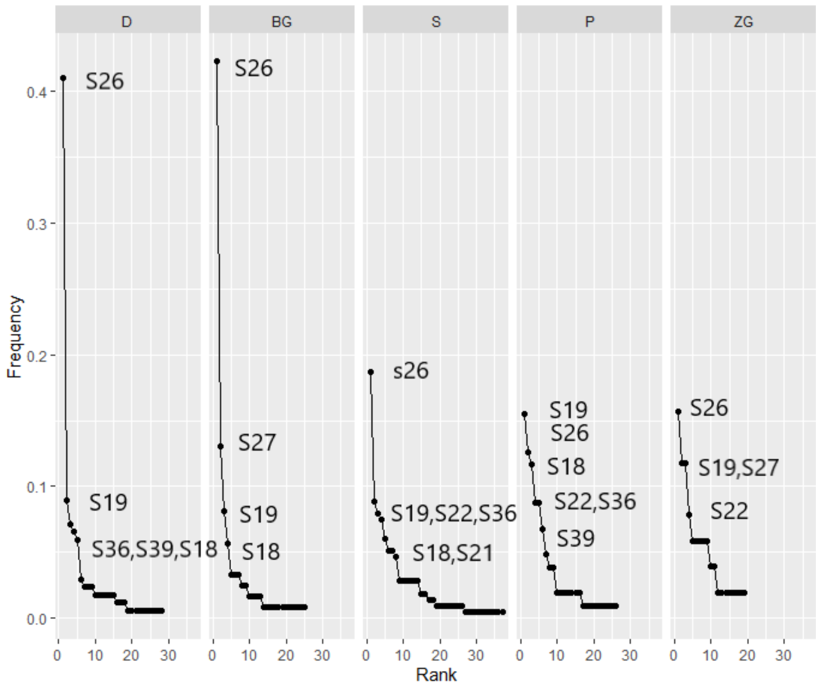
	Gatunki Species N	Razem – Total		Rodzaj pasożytnictwa Kind of parasitism	Żywiciel Host
		N	D		
S45	*Tromatobia ovivora* (Boheman, 1821)	15	2.28%	Ec, E	Ar.
S46	*Tromatobia variabilis* (Holmgren, 1856)	1	0.15%	Ec, E	Ar.
S47	*Zaglyptus multicolor* (Gravenhorst, 1826)	8	1.21%	Ec, A	Ar.
S48	*Zaglyptus varipes* (Gravenhorst, 1829)	8	1.21%	Ec, A	Ar.
S49	*Zatypota albicoxa* (Walker, 1874)	2	0.30%	Ec, A	Ar.
S50	*Zatypota discolor* (Holmgren, 1860)	6	0.91%	Ec, A	Ar.
S51	*Zatypota percontatoria* (Mueller, 1776)	2	0.30%	Ec, A	Ar.
Ogólna liczba osobników – Total number of specimens		659	100%	–	–

Ec – ektoparazytoid – ectoparasitoid, En – endoparazytoid – endoparasitoid, A – parazytoid dorosłych osobników – adult parasitoid, L – parasitoid larw – larvae parasitoid, P – parazytoid poczwarek – pupae parasitoid, E – parazytoid jaj – egg parasitoid, Ar – Araneae, Lep. – Lepidoptera, Col. – Coleoptera, Hym. – Hymenoptera, Pol. – polifag – polyphagus



Rys. 1. Lokalizacja stanowisk badań w zieleni miejskiej Poznania (D – Dębina, BG – Ogród Botaniczny, S – Serbska, P – Piątkowska, ZG – Ogród Zoologiczny)

Fig. 1. The location of the research sites in the green areas in Poznań (D – Dębina, BG – Botanical Garden, S – Serbska, P – Piątkowska, ZG – Zoological Garden)



Rys. 2. Krzywe różnorodności dominacji oparte na liczbie gatunków (liczebność logarytmiczna 10) w zieleni miejskiej Poznania w latach 2014–2016 (D – Dębina, BG – Ogród Botaniczny, S – Serbska, P – Piątkowska, ZG – Ogród Zoologiczny; numery licznych gatunków: S18 – *Itoplectis alternans*, S19 – *Itoplectis maculator*, S21 – *Liotrypphon caudatus*, S22 – *Liotryphon crassiseta*, S26 – *Pimpla contemplator*, S27 – *Pimpla flavicoxis*, S36 – *Scambus inanis*, S39 – *Scambus pomorum*)

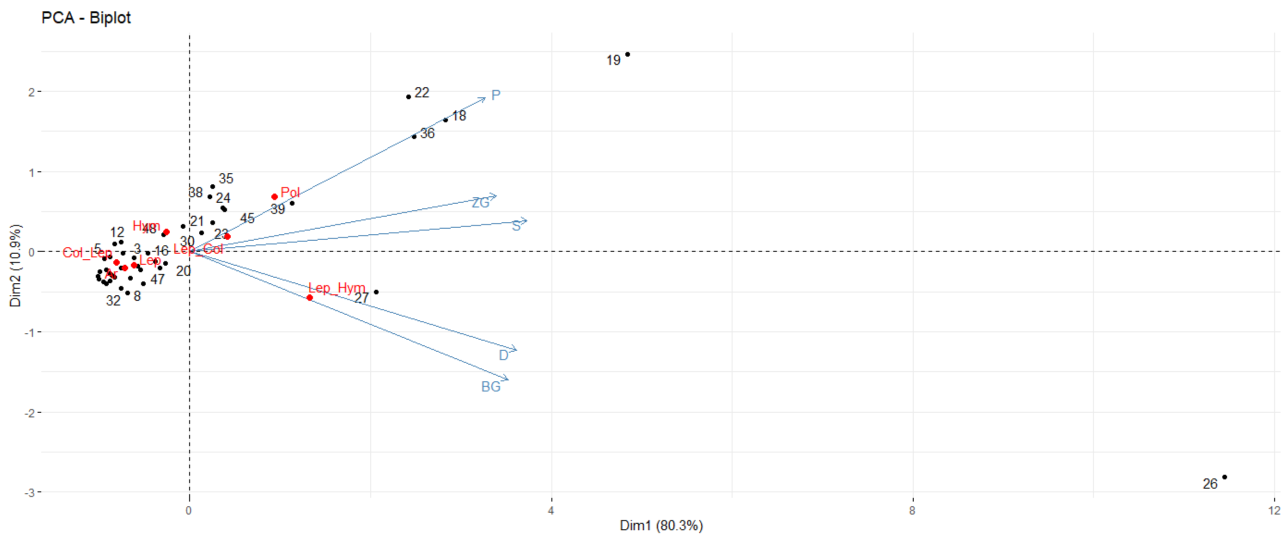
Fig. 2. The dominance diversity-curves based on the number of species (log 10 abundance) in green areas in Poznań between 2014 and 2016 (D – Dębina, BG – Botanical Garden, S – Serbska, P – Piątkowska, ZG – Zoological Garden; order of species significance: S18 – *Itoplectis alternans*, S19 – *Itoplectis maculator*, S21 – *Liotrypphon caudatus*, S22 – *Liotryphon crassiseta*, S26 – *Pimpla contemplator*, S27 – *Pimpla flavicoxis*, S36 – *Scambus inanis*, S39 – *Scambus pomorum*)

vidual sites (fig. 2): *Itoplectis alternans* (S18), *Itoplectis maculator* (S19), *Liotryphon caudatus* (S21), *Liotryphon crassiseta* (S22), *Pimpla contemplator* (S26), *Pimpla flavicoxis* (S27), *Scambus inanis* (S36), and *Scambus pomorum* (S39). *Pimpla contemplator* (S26) was the species with the highest frequency of occurrence at most of the sites. *Itoplectis maculator* (S19) was the species with the highest frequency of occurrence at the Piątkowska site (P) only. There were significant differences in the frequency of species occurrence at the Dębina (D) and Botanical Garden sites (BG), which were exposed to low anthropogenic pressure. At both sites there were two species with the highest frequency of occurrence. There were smaller differences in the frequency of occurrence of species at the Serbska (S) site, which was exposed to medium anthropogenic pressure. On the other hand, at the Piątkowska (P) and Zoological Garden sites (ZG), which were under high anthropogenic pressure, the frequencies of occurrence of individual species were similar.

PCA was used to analyse the qualitative and quantitative structure of the Pimplinae communities at individual sites, including parasitoid hosts (fig. 3). This method is used to examine the number of individual parasitoid species and thus determine the relationship between a particular species and the site. Only the sites exposed to low and high anthropogenic pressure had the communities of parasitoids with species related to the site through their hosts. In the communities of parasitoids at the Dębina (D) and Botanical Garden sites (BG), which were exposed to low anthropogenic pressure, the Lepidoptera and Hymenoptera parasitoids (Lep_Hym) exhibited the strongest relation with the site. In the parasitoid communities exposed to high anthropogenic pressure, i.e. at the Piątkowska (P) and Zoological Garden sites (ZG), polyphagic parasitoids (P) and Lepidoptera and Coleoptera parasitoids (Lep_Col) exhibited the strongest relation with the site.

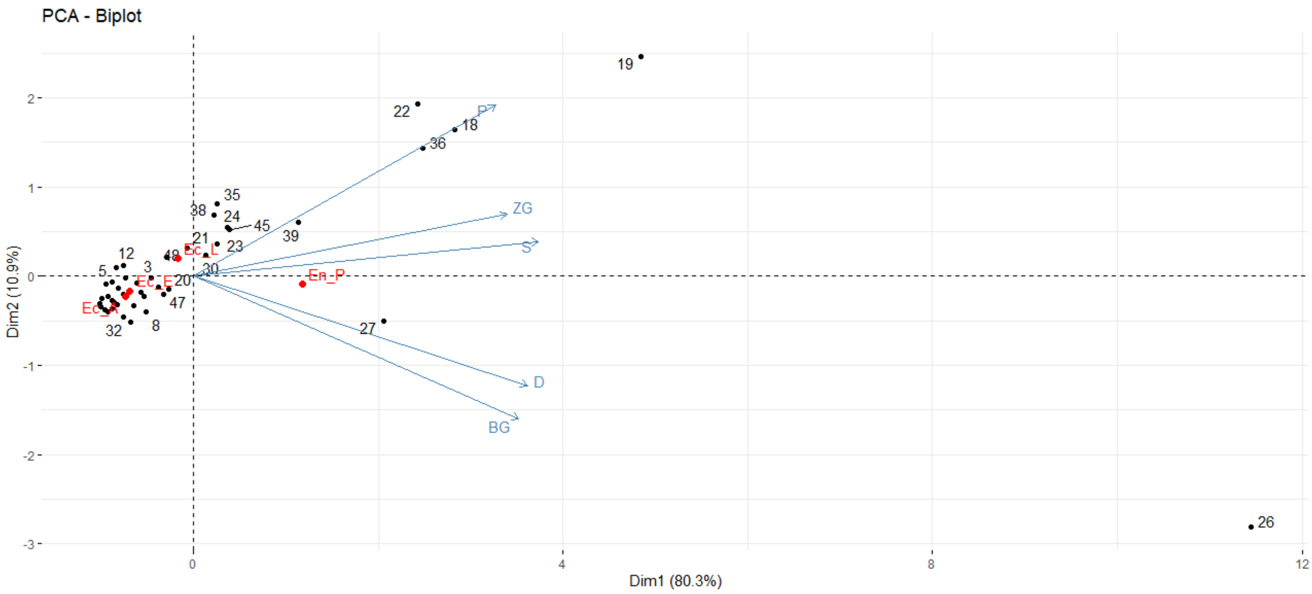
PCA was also used to analyse the qualitative and quantitative structure of the Pimplinae communities at individual sites, taking the type of parasitism into account (fig. 4). It was possible to clearly determine the species which were strongly related with the site through their hosts only in the parasitoid communities found at the of Serbska (S) (medium anthropogenic pressure) and Piątkowska sites (P) (high anthropogenic pressure). These were ectoparasitoids of larvae (Ec, L) at the Serbska site (S) and endoparasitoids of pupae (En, P) at the Piątkowska site (P).

The influence of anthropogenic pressure on the total catchability of parasitoids into individual Moericke traps at the sites during three years of the research was analysed



Rys. 3. Analiza składowych głównych (PCA) zgrupowań Pimplinae, z uwzględnieniem żywicieli parazytoidów, w zieleni miejskiej Poznania w latach 2014–2016 (D – Dębina, BG – Ogród Botaniczny, S – Serbska, P – Piątkowska, ZG – Ogród Zoologiczny; czarny punkt – gatunek parazytoida, czerwony punkt – żywiciel parazytoida)

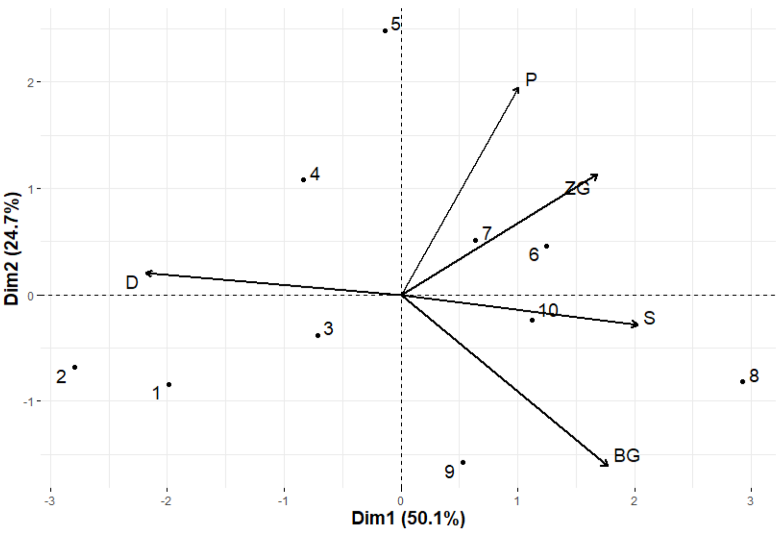
Fig. 3. Principal Component Analysis (PCA) of the Pimplinae communities, including the hosts of parasitoids in green areas in Poznań between 2014 and 2016 (D – Dębina, BG – Botanical Garden, S – Serbska, P – Piątkowska, ZG – Zoological Garden; black spot – parasitoid species, red spot – parasitoid's host)



Rys. 4. Analiza składowych głównych (PCA) zgrupowań Pimplinae, z uwzględnieniem rodzaju pasożytnictwa, w zieleni miejskiej Poznania w latach 2014–2016 (D – Dębina, BG – Ogród Botaniczny, S – Serbska, P – Piątkowska, ZG – Ogród Zoologiczny; czarny punkt – gatunek parazytoida, czerwony punkt – rodzaj pasożytnictwa)

Fig. 4. Principal Component Analysis (PCA) of the Pimplinae communities, including the type of parasitism in green areas in Poznań between 2014 and 2016 (D – Dębina, BG – Botanical Garden, S – Serbska, P – Piątkowska, ZG – Zoological Garden; black spot – parasitoid species, red spot – kind of parasitism)

with the χ^2 test. There were significant differences between the catchability of parasitoids into individual traps. Then, PCA was used to analyse the catchability of insects into individual Moericke traps (fig. 5). The results of the analysis of the influence of anthropogenic pressure on the catchability of parasitoids into individual traps were inconclusive. There was only a certain trend in the catchability observed. At the sites exposed to high and medium anthropogenic pressure



Rys. 5. Analiza składowych głównych (PCA) łowności parazytoidów z podrodziny Pimplinae w poszczególne pułapki Moericke'go w zieleni miejskiej Poznania w latach 2014–2016 (D – Dębina, BG – Ogród Botaniczny, S – Serbska, P – Piątkowska, ZG – Ogrod Zoologiczny; 1–10 – numer pułapki)

Fig. 5. Principal Component Analysis (PCA) of the catchability of parasitoids of the Pimplinae subfamily into individual Moericke traps in green areas in Poznań between 2014 and 2016 (D – Dębina, BG – Botanical Garden, S – Serbska, P – Piątkowska, ZG – Zoological Garden; 1–10 – trap number)

[Piątkowska (P), Zoological Garden (ZG), Serbska (S)], there were only one or two Moericke traps with high catchability of parasitoids. On the other hand, in the Dębina site (D), which was under low anthropogenic pressure, there were four Moericke traps which caught the most parasitoids (No. 1, 2, 3, 4).

During the three-year research 51 species of parasitoids of the Pimplinae subfamily were identified in the green areas in Poznań. The species diversity observed in our study was slightly lower than the diversity observed in the urban green space in Warsaw by Sawoniewicz (1982), who found 68 species in this environment. However, it was higher than the species diversity observed in earlier studies on these entomophages, which were conducted in Kórnik (Piekarska-Boniecka et al. 2009a) and in Poznań (Piekarska-Boniecka 2004). There were 31 species of parasitoids caught in the green areas in Kórnik and 38 species in Poznań.

The species diversity of the parasitoids found in the urban green areas in this study was slightly higher than the species diversity of these entomophages found in apple orchards near Poznań. Apple orchards are an environment exposed to anthropogenic pressure, but wild vegetation in the form of bushes as well as plants growing along roads and field margins are a favourable habitat for parasitoids. There were 51 species of parasitoids caught in the urban green areas and 48 species caught in the orchard environment (Piekarska-Boniecka et al. 2018). 80% of the species found in the orchards in this region were identified in the urban green areas. The analysis of species diversity showed that although urban greenery is exposed to heavy anthropogenic pressure, this environment is as attractive to parasitoids as apple orchards with adjacent wild vegetation.

The research results clearly showed that the intensity of anthropogenic pressure affected the qualitative and quantitative structure of the Pimplinae communities in urban green areas. The smallest parasitoid communities with the lowest species richness were found at the sites affected by high anthropogenic pressure. On the other hand, the sites exposed to medium and low anthropogenic pressure were characterised by larger parasitoid communities and higher species diversity. The research showed that the Serbska site (S), which was exposed to medium anthropogenic pressure, had the largest Pimplinae community with the highest species richness. This site was characterised by high abundance of vascular plants and the highest species richness of shrub plants, but the lowest share of woody plants. The Zoological Garden site (ZG), which was exposed to high anthropogenic pressure, had the smallest parasitoid community with the fewest species. The site was characterised by the lowest richness of flora as well as the lowest richness of herbaceous plants, ornamental flowering plants, and shrubs. Trojan and Winiarska (2001) observed in their study that highly urbanised areas with very poor environmental conditions were inhabited by small groups of animals with low species diversity as well as variable and very simplified dominant structure. The results of our study clearly indicated that the qualitative and quantitative structure of the Pimplinae communities inhabiting urban greenery was mainly influenced by the species richness of plants, and to a lesser extent by the size of the area, distance from the city centre or the amount of pollution.

The research results showed that there were individual species with the highest frequency of occurrence in the communities of parasitoids exposed to low anthropogenic pressure. On the other hand, the frequencies of the occurrence of individual species in the parasitoid communities exposed to high anthropogenic pressure were similar to each other.

Our research showed that as many as 6 (75%) out of 8 species of parasitoids with the highest frequency of occurrence in urban greenery were also the dominant species in the orchard environment. These were: *I. alternans* (S18), *I. maculator* (S19), *L. crassiseta* (S22), *P. contemplator* (S26), *S. inanis* (S36), and *S. pomorum* (S39). This means that the complexes of dominant species in both environments were very similar to each other. The other two species with the highest frequency of occurrence in the urban greenery were either caught sporadically in the orchard environment [*P. flavicoxis* (S27)] or they were not observed at all [*L. caudatus* (S21)] (Piekarska-Boniecka et al. 2018). Our research confirmed the dominance of *I. alternans* (S18), *I. maculator* (S19), and *P. contemplator* (S26) in the urban greenery. Earlier studies by Piekarska-Boniecka et al. (2009a), Rzańska et al. (2015), and Rzańska and Piekarska-Boniecka (2016) proved that these species were dominant in this environment.

Insect species of the *Itoplectis* genus are polyphagic endoparasitoids of pupae. Species of the *Liotryphon* genus are ectoparasitoids of Lepidoptera and Coleoptera larvae. Species of the *Pimpla* genus are endoparasitoids of Lepidoptera, Hymenoptera, and Coleoptera pupae. Species of the *Scambus* genus are ectoparasitoids of Lepidoptera, Hymenoptera, and Coleoptera larvae (Yu 2012). The trophic connections of the parasitoids with the highest frequency of occurrence clearly showed that these entomophages may regulate the populations of the larvae and pupae of pests feeding on ornamental shrubs and trees. The larvae of these phytophages gnaw leaves, buds, and fruit, thus reducing the decorative value of plants. The following economically-important pests of urban greenery occurring in Poland are parasitised by these entomophages: *Adoxophyes orana* (Fisch. v Röterst.), *Archips rosana* (L.), *Coleophora laricella* (Hbn.), *Euproctis chrysorrhoea* (L.), *Gracilaria syringella* (F.), *Hyphantria cunea* (Drury), *Leucoma salicis* (L.), *Lymantria dispar* (L.), *Lymantria monacha* (L.), *Malacosoma neustria* (L.), *Operophtera brumata* (L.), *Orygia antiqua* (L.), *Phyllonorycter blancardella* (F.), *Tortrix viridana* (L.), *Yponomeuta evonymella* (L.), *Yponomeuta malinella* Zell. (Lepidoptera); *Diprion pini* (L.), *Gilpinia frutetorum* (F.), *Neodiprion sertifer* (Geoffr.), *Tenthredo salicis* L. (Hymenoptera); *Anthonomus pomorum* (L.), *Saperda populnea* (L.), *Rhynchaenus fagi* (L.), and *Rhynchaenus quercus* (L.) (Coleoptera) (Yu 2012).

The results of our research confirmed the trophic relationship of parasitoids with the highest frequency of occurrence, because the study conducted by Sawoniewicz (1986) showed that parasitoids of gall-inducing phytophages, parasitoids of leaf miners and rollers phytophages as well as parasitoids of gnawing phytophages dominated in the Ichneumonidae complex in the urban greenery in Warsaw. Georgiev and Delkov (1997) and Georgiev (2000) also observed that parasitoids of the Ichneumonidae family effectively reduced the number of pests feeding in the urban green areas of the capital of Bulgaria. Minami et al. (1999) conducted research on the *L. dispar* (L.) parasitoid complex colonising plants in Osaka, Japan, and observed a considerable share of Ichneumonidae parasitoids among entomophages.

The results of our research clearly showed that the relationship between individual parasitoid species in the community and the site could be determined on the basis of their hosts only in the parasitoid communities exposed to low and high anthropogenic pressure. Lepidoptera and Hymenoptera parastoids were the most strongly related with the sites exposed to low anthropogenic pressure, whereas Lepidoptera and Coleoptera parasitoids exhibited the strongest relation with the sites exposed to high anthropogenic pressure.

The results of our research showed that the relationship between individual parasitoid species in the community and the site could be determined on the basis of the type of parasitism only at the sites exposed to medium anthropogenic pressure and at one site exposed to high anthropogenic pressure. Ectoparasitoids of larvae were the most closely related with the sites exposed to medium anthropogenic pressure, whereas ectoparasitoids of pupae were the most strongly related with the site exposed to high anthropogenic pressure.

The results of our research clearly showed that there were significant differences in the catchability of parasitoids in individual Moericke traps, but it was not possible to determine the relationship between the catchability and the intensity of anthropogenic pressure. Our research findings are in line with the results of the study by Hilszczański and Plewa (2009), who observed differences in the catchability of Cerambycidae (Coleoptera) in individual Moericke traps set in oak forests near Krotoszyn, Poland. Clair et al. (2020) conducted research on the occurrence of honey bees in soybean plantations in central Iowa, USA and observed differences in the catchability of these insects in Moericke traps.

Wnioski / Conclusions

1. Our research showed that the intensity of anthropogenic pressure influenced the qualitative and quantitative structure of the communities of parasitoids of the Pimplinae subfamily inhabiting urban green areas.

2. There were small Pimplinae communities with low species richness in urban green areas exposed to high anthropogenic pressure, whereas at the sites exposed to medium and low pressure there were more numerous communities with higher species diversity.
3. The richness of plant species was the main factor determining the qualitative and quantitative structure of the parasitoid communities.
4. Therefore, the flora in urban green space should be designed so as to ensure a good habitat for entomophages, which reduce the number of plant pests feeding in this environment.

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