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STRUCTURE OF *SPHECIDAE* (*HYMENOPTERA*) COMMUNITIES IN URBAN GREEN AREAS OF WARSAW

ABSTRACT

In green areas of Warsaw 70 *Sphecidae* species were recorded. The group of dominant species consisted of *Mellinus arvensis* (30%), *Passaloecus insignis* (7.5%), *Crossocerus elongatulus* (7.4%), and *C. annulipes* (7.3%). The highest species richness was noted in parks and neighbouring streetside green. Different parks had similar species composition but diverse abundance of *Sphecidae*. *Sphecidae* of streetside green near parks were similar to those in parks, especially in their dominance structure. As regards their dominance structure, the communities inhabiting urban parks were classified into two groups. One group comprised the communities living in the Łazienki Park and the Saxon Garden, which were similar to those occurring in rural parks. The other group occurred in the park at the Cemetery of Soviet Soldiers, and it was similar to the communities in suburban park, modified both pine and mixed forests, and a natural mixed forest. *Sphecidae* communities of other types of urban green areas (green of housing estates, allotments, isolated streetside green) showed a specific character, and in general they were not similar to each other, or to the communities from different types of green areas whether urban or non-urban. They all were poor in species and dominated by species with a high ecological tolerance and wide geographic range.

INTRODUCTION

In recent times all the habitats are subject to some kind of human pressure, directly or indirectly (Wodziczko 1947, Kornaś 1972).

Climax ecosystems, developed in a natural way, and effected by human activity to the extent not greater than by wild animals mostly searching them for food, are called primeval ecosystems. Nowadays they do not exist. The most similar to them contemporary ecosystems are called natural. Natural ecosystems are characterized by a consistency between the biocoenosis and site conditions, that is, a primeval system of relationships and processes is preserved in them (Kornaś 1972). Some natural ecosystems are indirectly subject to human pressure and others directly. The first group mostly includes the areas not colonized by man, or strict nature reserves. Most of natural ecosystems are under a direct influence of human activity.

The present paper is based on the studies made in different habitats subject to direct human pressure.

The natural habitats under study were represented by large forest complexes located far from urban habitats or from sources of industrial pollution. The next group consisted of habitats more affected by human pressure, which are called here modified habitats. They are represented, for example, by suburban forests. They suffer from a relatively heavy anthropogenic pressure because of their close vicinity to urban habitats. They are subject to planned management and are frequently visited by man, but their vegetation is not artificially developed, like for example in parks. The vegetation of modified habitats corresponds to site conditions, though it contains a large proportion of synanthropic species.

The habitats totally transformed as a result of direct human activity have been called restructured habitats. Urban habitats belong to those extremely transformed. Main components of their spatial structure are buildings, streets, and urban green areas. Habitat conditions in urban areas are a result of a total transformation of the primeval habitat (Andrzejewski 1975, Frankie, Ehler 1978).

An intense utilization of the habitat by man accounts for changes in a number of habitat factors both biotic and abiotic. A complex of habitat conditions characteristic of a town is called urban pressure. The intensity of urban pressure in green habitats is mostly determined by the density of buldings and inhabitants in neighbouring areas, the degree of habitat pollution, and the intensity of the utilization of green areas (Kotowski 1976). Thus, the urban pressure increases with growing pollution of green areas by combustion gas and other substances, with the decreasing size of green areas, and with the intensity of their management. Urban green (its type, species composition, and structure) is an effect of human management; it depends on the destination of different types of green areas and on the character of cultivation treatments.

Generally, the fauna of urban green areas is not planned by man. Although many animals cannot live in urban conditions, their species richness is unexpectedly high (Trojan, Pisarski 1976, Pisarski 1979, Czechowski, Pisarski 1981, Czechowski et al. 1981, 1982).

The development of interest in the fauna living in urban habitats began in early 1970s. At that time first papers were issued on the structure of animal communities, mostly birds and invertebrates. In Poland complex studies on the entomofauna of urban areas (exemplified by Warsaw) were started in 1974 by the Institute of Zoology PAS (Czechowski 1985).

The knowledge of *Sphecidae* inhabiting urban green areas both in Poland and in the world is very poor. The existing data are fragmentary, and

frequently limited to check-lists of species. Earlier faunal papers on *Aculeata* of urban habitats were most frequently based on materials collected from large green complexes such as parks and gardens. Such studies were conducted by Richards (1963) in the Garden of Buckingham Palace in London, Leclercq (1965, 1968) in Liége, Dathe (1969, 1971) in Berlin Zoological Garden. Among older publications Guichard and Yarrow (1947) provide interesting results based on the material collected from six gardens near Hampsted Heath in 1832—1947.

In the 1970s, first papers appeared on the species composition and community structure of *Aculeata* occurring in different types of urban green areas or in other restructured habitats. Haesler (1972) described the *Aculeata* fauna of such habitats as urban parks and gravel-pits; Tischler (1973) examined the fauna of embankments, Leclercq et al. (1976), the fauna (including *Aculeata*) of newly established belts of streetside green. Jacob-Remacle (1976), Jacob-Remacle and Leclercq (1980) studies *Aculeata* of urban gardens, and Gaspar and Thirion (1978) analysed *Sphecidae* of different anthropogenic habitats (streetside green, urban gardens, sand excavations, clumps of trees in crop fields).

One of the most important problems in the study on the fauna of urban habitats is the assessment of the effect of respective components of urban pressure. According to Davis (1978), four factors seem to be most important to urban fauna: distance to the centre of the town, age and size of a green area, and air temperature. Bones (1968) in his paper on *Sphecidae* of urban areas emphasized the adaptability of some *Sphecidae*, which he considered as non-synanthropic species, to urban conditions.

In Poland there were almost no data on *Sphecidae* in urban green areas until the 1970s. Among earlier publications there is a check-list of hymenopteran species, including *Sphecidae*, of Warsaw and its surroundings prepared by Głowacki (1953). In late 1970s, the first papers appeared on changes occurring in communities of different *Aculeata*, including *Sphecidae*, as a result of urban pressure (Czechowski 1985).

STUDY AREA

CRITERIA FOR HABITAT SELECTION

For designing artificial ecosystems, including the urban ones, both natural and economic factors are important. Site conditions of urban green areas determine the limits and directions of transformations, while the way of management and utilization accounts for the actual character of these areas. Most of the Warsaw area is on the site of *Tilio-Carpinetum* (linden-oak-

hornbeam forest). Other sites are poorly represented (Matuszkiewicz 1966). All study areas in Warsaw were located on the linden-oak-hornbeam site. Thus, their diversity reflects differences in the way of management. The type of urban green areas is determined by their role in the town, and the differentiation within a type depends on the way of utilization.

To determine the direction and the degree of transformation of *Sphecidae* communities in urban green areas, first of all the "original" community should be characterized. For this reason non-urban habitats homologous to the potential habitat of Warsaw were also studied. They included natural and modified linden-oak-hornbeam forests, and also linden-oak--hornbeam forests restructured in different ways but not subject to urban pressure.

According to the literature data, *Sphecidae* prefer light mixed forests, and they are likely to originate from such habitats (Tischler 1973). Hence, in natural linden-oak-hornbeam forests, where habitat conditions are not favourable to them, *Sphecidae* communities are poor. Many species occurring in modified and restructured linden-oak-hornbeam forests, that is, in the habitats usually dry and insolated, are absent from natural linden-oak-hornbeam forests. They occur, however, in other natural habitats, for example, in coniferous and mixed forests. For this reason coniferous and mixed forests (habitats more insolated and developed on podzolic soil, corresponding to a major part of soils in Warsaw) were also studied.

A comparison of *Sphecidae* communities from deciduous and coniferous forests of natural and modified habitats on homologous sites allows to assess the changes in these communities on different sites, and to follow the patterns of their transformation.

The study areas form a gradient of increasing anthropopressure from natural habitats, through suburban modified, to urban restructured habitats. A side branch of this gradient is represented by restructured non-urban habitats.

DESCRIPTION OF THE STUDY AREAS

Study areas were located in three zones forming a gradient of the distance from the town. These are the non-urban, suburban, and urban zones.

A. NON-URBAN ZONE

NATURAL HABITATS

Linden-oak-hornbeam forest (*Tilio-Carpinetum*) near Hamernia. The study area was located in a forest complex being a fragment of

the former Jaktorowska primeval forest. It supports a 40—75 years old tree stand dominated by *Quercus robur, Carpnus betulus*, and *Tilia cordata*. A shady forests, with dense canopy, in places contiguous (Garbarczyk, shady Pisarska 1981).

Mixed forest (*Pino-Quercetum*) near Łomna. The study area in the eastern part of the Kampinos Forest. Tree stand 65—75 years old consisted of *Quercus robur, Betula verrucosa, Betula pubescens*, and *Pinus silvestris*. Canopy density was loose (Garbarczyk, Pisarska 1981).

Pine forest (*Peucedano-Pinetum*) near Łomna. The study area in the eastern part of the Kampinos Forest, on dunes. Tree stand 70—80 years old, made up of *Pinus silvestris* with a sparse admixture of *Betula verrucosa*. Canopy density was loose (Garbarczyk, Pisarska 1981).

RESTRUCTURED HABITATS

A palace park at Radziejowice. Established early in the 16th century on a *Tilio-Carpinetum* site. Though located in a forested area, it directly adjoins meadows and fields. It used to be drained but now the canals are silted and filled up, and this area is very wet. A large part of the park is occupied by lawns and flower beds surrounded with clumps of trees and shrubs. Tree stand is diversified, predominated by native trees such as *Alnus glutinosa, Carpinus betulus, Quercus robur*, and *Tilia cordata*. Also many alien species grow there. The park is subject to intense cultivation treatment (Stefaniak, Orzeł, MS.).

A manor park at Młochów. Established in the first half of the 19th century on the *Tilio-Carpinetum* site. Młochów is a small settlement surrounded with fields. At a distance of 5 km from the settlement there are Młochów Woods. Nowadays the park is completely abandoned, not managed, not cultivated, but frequently visited by man and farm animals. The area is wet, even marshy in places. Trees are represented by native species such as *Quercus robur, Tilia cordata, Alnus glutinosa*, and also by alien species. Lawns are relatively small, most of the area being covered with trees and shrubs.

A rural garden at Mroków. Located near farm buildings and surrounded with crop fields. Most of its area supports flowers and vegetables. It si dotted with scarce young lindens (*Tilla cordata*) and many decorative shrubs. A meadow sawn with a mixture of fodder plants is close to it, and an orchard is several hundred metres away.

B. SUBURBAN ZONE

MODIFIED HABITATS

Linden-oak-hornbeam forest (*Tilio-Carpinetum*) at Białołęka Dworska, peripheral district of Warsaw. A wood of 0.4ha surrounded with fields. The canopy of low density, trees of different age with *Tilia cordata*, *Quercus robur*, and *Carpinus betulus* (Garbarczyk, Pisarska 1981).

Mixed forest (*Pino-Quercetum*) at Białołęka Dworska. Covers an area of about 3ha. Tree stand about 30 years old, dominated by *Pinus silvestris*, *Betula verrucosa*, and *Quercus robur*; 120—150 year old oaks at the edge. Birches grow in clumps. This study area was close to buildings and gardens (Garbarczyk, Pisarska 1981).

Pine forest (*Peucedano-Pinetum*) at Białołęka Dworska. Study area on a dune; in addition to *Pinus silvestris*, only a small admixture of *Betula verrucosa* and *Quercus robur*. Tree stand about 30 years old. It forms a belt 3km long and 1km wide (Garbarczyk, Pisarska 1981).

RESTRUCTURED HABITAT

Park at Ursynów. An old park of more than 5ha, located in southern part of Warsaw, surrounded with vast meadows, fields and orchards. The study area is characterized by a large proportion of open areas (lawns) with trees in double rows and clumps of shrubs (for more details see Kubicka et al. 1986).

C. URBAN ZONE (RESTRUCTURED HABITATS)

With respect to the way of management, the following types of urban green areas were distinguished: parks, green habitats of housing estates (adjoining loosely and densely built-up areas), streetside green (adjoining parks and isolated), and allotments.

PARKS

The Łazienki Park. An urban park occupying 86ha. Established in the first half of the 18th century in a forest. Bordering on a slightly different type of urban green, like sports and leisure Agrykola Park and Botanic Garden. The study plots were located on the lower terrace of the park.

Park at the Cemetery of Soviet Soldiers (plots I and II[1]),

[1] After Kubicka et al. (1986).

established in place of fields in 1949—1950. Covers an area of more than 20ha. Borders on allotments, leisure green area (Pole Mokotowskie) and fields. The joint area of this green complex is about 80ha.

The Saxon Garden (plots II and III). An urban park established early in the 18th century. During World War II devastated, and restored after the war. A very small park of about 16ha. Isolated from other types of green by streets and buildings.

GREEN AREAS OF LOOSELY BUILT-UP HOUSING ESTATES

Wierzbno (plot II). Constructed in 1960—1965 in place of fields and detached houses. Green areas account for about 40% of the whole area. With rather large lawns of 500—700m^2. Trees dominated by lindens (*Tilia cordata*).

Muranów (plot II), A housing estate developed in 1960—1965 on rubble. Green areas occupy about 40% of its area, but it is fragmented into patches most frequently of about 200m^2. Trees are domianted by maples (*Acer campestris*). The study plot was established on a lawn of about 200 m^2 with single lindens, bordering on an urban garden.

GREEN AREAS OF CLOSELY BUILT-UP HOUSING ESTATES

Wilcza Street. A courtyard lawn with single shrubs, covering an area of about 280m^2, with weeds and rarely mown. In the neighbourhood (on nearby courtyards) there are small lawns with single trees and shrubs, and also a garden with flowers and vegetables.

M D M (plot II). A courtyard lawn of about 300 m^2 with single lindens The courtyard is closely surrounded with buildings (the so-called well), so it is permanently shaded.

STREETSIDE GREEN

Streetside green bordering on parks

Ujazdowskie Avenue. A lawn 8m wide along the street near the Łazienki Park, with a row of lindens (*Tilia cordata*).

Żwirki i Wigury Avenue. A lawn 7m wide, along the street, bordering on the park at the Cemetery of Soviet Soldiers, with a row of lindens (*Tilia cordata*).

Marszałkowska Street. The plot at the edge of the Saxon Garden, along the street. It is an integral part of this small park, thus characterized by environmental conditions similar to those in the centre of the park.[2]

[2] In the introductory paper [Kubicka et al. (1986)] this plot is classified as a park plot (Saxon Garden I).

Isolated green

Konstytucji Square. A row of lindens (*Tilia cordata*) growing in the square in the centre of the town, on small patches of soil not covered with pavement. These trees are isolated from other green complexes by closely built-up area lining the square. In neighbouring courtyards there are small lawns and sigle trees.

A more detailed presentation of the study areas, with data on soil, vegetation, climate, pollution, etc., is given by Kubicka et al. 1985.

MATERIAL AND METHODS

In urban green areas the study was carried out in 1974—1978, and in suburban and non-urban areas in 1976—1978.

Insects were caught in Moericke's cups (Moericke 1951) located in tree canopy, mostly linden (*Tilia cordata*), each season. The materials were collected from mid-May to mid-October.

As the number of trees on which cups could be put was different on different plots, and also the number of cups per tree was different (some were destroyed), an index of relative number (Odum 1971) was used as the basis of the analysis. This index is the number of specimens caught in 10 cups over 10 days.

As a supplementary method the capture by entomological nets was used, but the material collected in this way was scarce in species as compared with that from Moericke's cups.

A total of about 10000 adult *Sphecidae* were caught.

To determine the diversity of *Sphecidae* communities, the index of similarity in species composition was calculated for communities on particular plots after Sörensen (1948). Four classes of the similarity index (S) were distinguished: I. $S \geqslant 63\%$, II. $63\% > S \geqslant 50\%$, III. $50\% > S \geqslant 37\%$, IV. $S < 37\%$. The results are set in Czekanowski's diagram (Figure 5).

Similarity in the dominance structure was determined using Morisita's (1959) index modified by Horn (1966). Five classes of the index of similarity in dominance structure of communities (S_d) were established: I. $S_d \geqslant 0.80$, II. $0.79 \geqslant S_d \geqslant 0.65$, III. $0.64 \geqslant S_d \geqslant 0.50$, IV. $0.49 \geqslant S_d \geqslant 0.20$. V $S_d < 0.20$. The results are given in Czekanowski's diagram (Fig. 6).

To determine the numerical similarity of *Sphecidae* communities, the method of establishing classes of abundance was used. This method is used when the data are largely scattered, and this was the case of *Sphecidae* communities from different study areas. It consists in establishing intervals for the analysed variables and their grouping within these intervals (Młynarczyk 1970). The difference (d) between the lowest and the highest values of

the abundance index, that is, the maximum difference, was taken as 100%. Four classes of the index value (Sn) were distinguished: I. $O \leqslant d < 20\%$, II. $20 \leqslant d < 40\%$, III. $40\% \leqslant d < 60\%$, IV. $60\% \leqslant d \leqslant 100\%$. The results are set in Czekanowski's diagram (Fig. 7).

The calculated indices of similarity in species composition (S), similarity in dominance structure (S_d) and numerical similarity (S_n) of *Sphecidae* communities are set using the point method (Młynarczyk 1970). Using this method different communities may be grouped on the basis of a few features. Respective features are quantified by means of points. A scale of the intensity of particular features is established, and after being classified these features are jointly expressed in a uniform way in points. Maximum values of the three similarity indices received three points each, and the successive lower values received 2, 1, and 0 points. In this way, the most similar communities received 9 points, and the least similar zero points. The results are presented in Czekanowski's diagram (Fig. 8).

To given a more complete interpretation of the results, different biocoenotic indices were used to characterize changes in species diversity and structure of the communities (Odum 1971): Shannon and Weaver's index of general diversity, species richness, Pielou's evenness index, and dominance index.

THE COMMUNITIES IN NON-URBAN AND SUBURBAN ZONES

COMMUNITIES OF NATURAL AND MODIFIED HABITATS

The fauna of *Sphecidae* of the natural linden-oak-hornbeam (*Tilio-Carpinetum*) forest under study (Hamernia) was poor. Only 23 species were recorded from this area. The abundance index of this community was the lowest of all the communities under study, and it was 1.5 (Tab. 8). The most abundant species consisted of *Mellinus arvensis, Crossocerus varius, Pemphredon lugubris*, and *Crossocerus megacephalus* (Tab. 1).

In the natural coniferous forest (Łomna) *Sphecidae* communities were much richer. Both the number of species and their abundance were higher. In the mixed forest (*Pino-Quercetum*), 46 species were recorded, in the pine forest (*Peucedano-Pinetum*), 36 species. The communities occurring in the coniferous forests were 7 times as abundant as the community in the linden-oak-hornbeam forest (Tab. 1). In the pine forest *Entomognathus brevis* was the dominant species. Except for this species, which was abundant only in the pine forest, the other most abundant species were common to the two coniferous forests. These were *Pemphredon lugubris, Mellinus arvensis*, and *Passaloecus insignis* (Fig. 1).

Table 1. Occurrence and abundance of *Sphecidae* in natural habitats; n — abundance index, + — scarce abundance

No.	Habitat / Species	Linden-oak--hornbeam forest		Mixed forest		Pine forest		Average	
		n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10
1	*Ammophila sabulosa* L.	—	—	+	0.3	0.1	0.9	+	0.5
2	*Pemphredon lugubris* Fabr.	0.1	8.9	3.5	33.3	1.1	9.9	1.6	20.9
3	*Pemphredon montanus* Dahlb.	—	—	0.2	2.2	0.2	1.4	1.1	1.7
4	*Pemphredon lugens* Dahlb.	—	—	—	—	0.2	1.5	0.1	0.7
5	*Pemphredon austriacus* Kohl.	0.1	4.8	—	—	—	—	+	0.3
6	*Pemphredon inornatus* Say	+	1.4	0.1	1.3	+	0.3	0.1	0.8
	Pemphredon lethifer Shuck.	—	—	0.1	0.8	0.2	1.6	0.1	1.2
8	*Ceratophorus clypealis* Thoms.	—	—	0.1	0.6	—	—	+	0.3
9	*Diodontus minutus* Fabr.	—	—	+	0.3	0.2	1.5	0.1	0.8
10	*Diodontus luperus* Schuck.	—	—	0.1	0.6	—	—	+	0.3
11	*Diodontus tristis* Van. Lind.	—	—	0.1	0.6	—	—	+	0.3
12	*Passaloecus singularis* Dahlb.	—	—	0.1	0.7	0.1	1.2	0.1	0.9
13	*Passaloecus eremita* Kohl.	—	—	—	—	+	0.3	+	0.1
14	*Passaloecus corniger* Shuck.	—	—	+	0.3	0.1	1.1	0.1	0.7
15	*Passaloecus gracilis* Curt.	+	1.4	0.3	2.7	0.5	4.3	0.3	3.4
16	*Passaloecus insignis* Van. Lind.	0.1	4.8	0.5	5.0	1.8	17.2	0.8	10.6
17	*Stigmus solskyi* A. Mor.	0.1	3.4	0.2	2.2	—	—	0.1	1.2
18	*Stigmus pendulus* Panz.	+	2.7	0.1	0.6	—	—	+	0.4
19	*Spilomena differens* Blüthg.	0.1	3.4	—	—	—	—	+	0.3
20	*Spilomena curruca* Dahlb.	—	—	—	—	0.1	0.8	+	0.4
21	*Spilomena enslini* Blüthg.	—	—	—	—	+	0.3	+	0.1
22	*Spilomena beata* Blüthg.	—	—	0.1	0.8	—	—	+	0.4
23	*Spilomena vagans* Blüthg.	—	—	+	0.3	+	0.3	+	0.3
24	*Psenulus concolor* Dahlb.	—	—	+	0.4	—	—	+	0.1
25	*Psenulus laevigatus* Schenck.	+	1.4	0.1	1.3	+	0.3	0.1	0.8
26	*Psenulus pallipes* Panz.	—	—	+	0.3	0.2	2.1	0.1	1.0
27	*Mellinus arvensis* L.	0.4	25.2	1.6	15.3	1.1	10.4	1.0	13.7
28	*Mellinus crabroneus* Thunb.	—	—	0.1	0.6	—	—	+	0.3

1	2	3	4	5	6	7	8	9	10
29	*Trypoxylon clavicerum* Lep.	+	1.4	0.4	3.6	0.3	2.5	0.2	2.9
30	*Trypoxylon attenuatum* Smith	—	—	0.3	2.6	—	—	0.1	1.2
31	*Trypoxylon figulus* L.	—	—	+	0.3	+	0.3	+	0.3
32	*Oxybelus dissectus* Dahlb.	—	—	0.1	0.6	—	—	+	0.3
33	*Oxybelus mandibularis* Dahlb.	—	—	0.1	0.8	—	—	+	0.4
34	*Oxybelus bipunctatus* Oliv.	—	—	—	—	+	0.4	+	0.1
35	*Crabro cribrarius* L.	—	—	0.1	0.8	—	—	+	0.4
36	*Crabro peltarius* Schreb.	+	1.4	0.1	0.8	—	—	+	0.4
37	*Crabro scutellatus* Schev.	—	—	0.1	1.0	—	—	+	0.5
38	*Ectemnius sexcinctus* Fabr.	—	—	0.2	1.6	0.1	0.8	0.1	1.0
39	*Ectemnius cavifrons* Thoms.	—	—	0.2	1.8	0.2	1.4	0.1	1.5
40	*Ectemnius ruficornis* Zett.	+	1.4	+	0.3	0.1	0.9	0.1	0.7
41	*Ectemnius continuus* Fabr.	—	—	0.1	0.5	0.1	0.8	+	0.5
42	*Entomognatus brevis* Van. Lind.	—	—	0.2	2.2	2.5	23.8	0.9	12.1
43	*Lindenius albilabris* Fabr.	—	—	0.1	0.8	—	—	+	0.4
44	*Lindenius pygmaeus armatus* Van. Lind.	+	1.4	—	—	—	—	+	0.1
45	*Rhopalum clavipes* L.	—	—	0.2	2.2	0.4	3.9	0.2	2.8
46	*Rhopalum coarctatum* Scop.	+	2.7	0.1	1.3	—	—	0.1	1.2
47	*Crossocerus quadrimaculatus* Fabr.	0.1	3.4	—	—	0.1	0.9	0.1	0.7
48	*Crossocerus ovalis* Lep. et Brul.	+	1.4	—	—	—	—	+	0.1
49	*Crossocerus elongatulus* Van. Lind.	—	—	0.1	0.6	+	0.3	+	0.4
50	*Crossocerus wesmaeli* Van. Lind.	—	—	—	—	+	0.3	+	0.1
51	*Crossocerus palmipes* L.	+	1.4	—	—	—	—	+	0.1
52	*Crossocerus assimilis* Smith	—	—	+	0.3	—	—	+	0.1
53	*Crossocerus walkeri* Shuck.	+	1.4	—	—	0.2	1.6	0.1	0.9
54	*Crossocerus annulipes* Lep. et Brul.	—	—	—	—	0.3	2.4	0.1	1.0
55	*Crossocerus styrius* Kohl.	0.1	7.5	—	—	—	—	0.4	0.5
56	*Crossocerus pubescens* Shuck.	—	—	+	0.3	+	0.3	+	0.3
57	*Crossocerus megacephalus* Rossi	0.1	7.5	0.5	4.3	0.3	2.8	0.3	3.8
58	*Crossocerus vagabundus* Panz.	—	—	0.1	0.6	—	—	+	0.3
59	*Crossocerus dimidiatus* Fabr.	+	1.4	0.1	0.8	—	—	+	0.5
60	*Crossocerus binotatus* Lep. et Brul.	—	—	0.1	0.6	+	0.2	+	0.4
61	*Crossocerus varius* Lep. et Brul.	0.2	10.3	0.1	0.8	0.1	1.0	0.1	1.5
	Total	1.5		10.6		10.5		7.6	

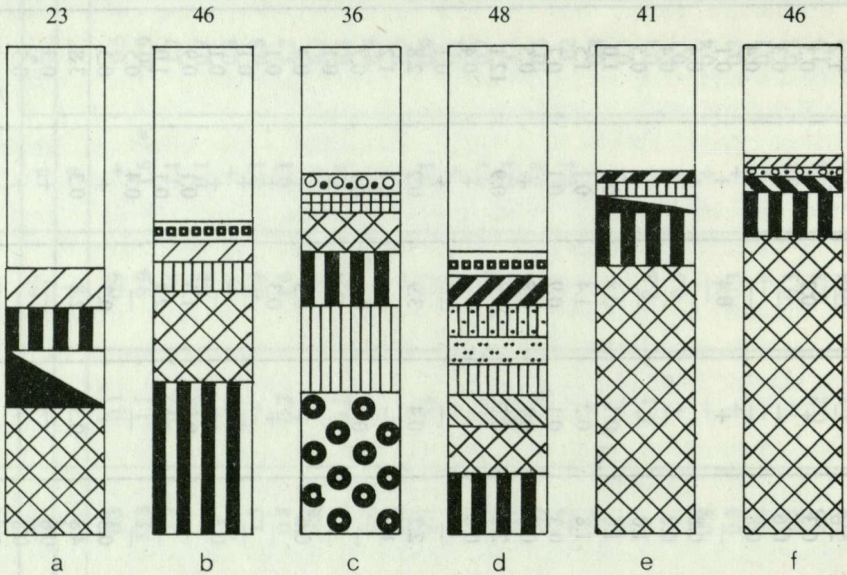


Fig. 1. Dominance structure of *Sphecidae* communities in natural and modified habitats. a—c — natural habitats (a — linden-oak-hornbeam forest, b — mixed forest, c — pine forest), d—f — modified habitats (d — linden-oak-hornbeam forest, e — mixed forest, f — pine forest); figures denote the number of species in a community; for graphical symbols see page 154

A comparative analysis of *Sphecidae* communities occurring in natural and modified habitats on homologous sites makes it possible to determine the character of their response to habitat modification. The greatest differences were found between communities occurring in the linden-oak-hornbeam forests compared (Hamernia and Białołęka Dworska), and the lowest in mixed forest (Łomna and Białołęka Dworska). The *Sphecidae* community of the modified linden-oak-hornbeam forest consisted of 48 species. The abundance index of this community (8.4) was lower than in the other modified habitats, but over 5 times higher than in the natural linden-oak-hornbeam forest. The dominant species in the modified linden-oak-hornbeam forest comprised *Pemphredon lugubris, Mellinus arvensis*, and *Passaloecus insignis*. Also *Crabro peltarius* and *Psenulus pallipes* were abundant (Tab. 2).

In the modified pine forest, the *Sphecidae* community consisted of 46 species, and the abundance index (20.2) was almost twice as high as in the natural pine forest. In the modified mixed forest, 41 species were recorded, and the abundance index was 11.4. The community occurring in the modified mixed forest was dominated by the same species as in the natural mixed forest. *Entomognathus brevis* was dominant in the natural pine forest but not in the modified pine forest.

Table 2. Occurrence and abundance of *Sphecidae* in modified habitats; n — abundance index, + — scarce abundance

No.	Habitat / Species	Linden-oak--hornbeam forest		Mixed forest		Pine forest		Average	
		n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10
1	*Podalonia affinis* Kirby	–	–	+	0.3	+	0.2	+	0.1
2	*Podalonia luffi* Saund.	–	–	+	0.3	–	–	+	0.1
3	*Ammophila sabulosa* L.	+	0.3	–	–	0.2	0.7	0.1	0.4
4	*Pemphredon lugubris* Fabr.	1.2	14.2	1.4	12.5	1.7	8.4	1.4	10.9
5	*Pemphredon montanus* Dahlb.	–	–	0.2	1.8	0.1	0.3	0.1	0.7
6	*Pemphredon lugens* Dahlb.	–	–	0.1	0.9	–	–	+	0.2
7	*Pemphredon austriacus* Kohl.	–	–	–	–	0.1	0.5	+	0.2
8	*Pemphredon wesmaeli* A. Mor.	+	0.2	–	–	–	–	+	0.1
9	*Pemphredon inornatus* Say	0.2	2.1	0.1	0.7	–	–	0.1	0.7
10	*Pemphredon lethifer* Shuck.	–	–	–	–	0.1	0.5	+	0.2
11	*Pemphredon morio* Van. Lind.	+	0.3	–	–	–	–	+	0.1
12	*Ceratophorus clypealis* Thoms.	+	0.2	–	–	–	–	+	0.1
13	*Diodontus minutus* Fabr.	+	0.3	–	–	–	–	+	0.1
14	*Diodontus luperus* Shuck.	+	0.3	–	–	–	–	+	0.1
15	*Diodontus tristis* Van. Lind.	–	–	–	–	0.2	0.8	0.1	0.4
16	*Passaloecus singularis* Dahlb.	0.2	2.6	0.2	1.8	0.4	2.0	0.3	2.2
17	*Passaloecus eremita* Kohl.	–	–	–	–	+	0.1	+	0.1
18	*Passaloecus gracilis* Curt.	0.1	0.8	0.1	1.2	0.6	2.9	0.3	2.2
19	*Passaloecus insignis* Van Lind	0.5	6.3	0.4	3.4	0.2	1.1	0.4	2.8
20	*Stigmus solskyi* A. Mor.	0.6	6.6	0.3	2.6	0.2	0.8	0.3	2.5
21	*Stigmus pendulus* Panz.	0.5	5.8	0.1	1.1	+	0.2	0.2	1.5
22	*Spilomena vagans* Blüthg.	+	0.2	0.1	0.4	–	–	+	0.1
23	*Spilomena mocsaryi* Kohl.	–	–	–	–	+	0.1	+	0.1
24	*Mimumesa dahlbomi* Wesm.	–	–	–	–	+	0.2	+	0.1
25	*Psenulus fuscipennis* Dahlb.	+	0.2	–	–	–	–	+	0.1
26	*Psenulus pallipes* Panz.	0.6	7.1	+	0.3	0.1	0.3	0.2	1.7
27	*Psenulus laevigatus* Schenck.	0.3	3.1	0.1	1.0	0.1	0.2	0.1	1.0

1	2	3	4	5	6	7	8	9	10
28	*Psenulus concolor* Dahlb.	0.1	1.3	–	–	–	–	+	0.3
29	*Cerceris quadrifasciata* Panz.	–	–	+	0.3	–	–	+	0.1
30	*Bembecinus tridens* Fabr.	–	–	+	0.3	–	–	+	0.1
31	*Didineis lunicornis* Fabr.	–	–	+	0.3	–	–	+	0.1
32	*Alyson spinosus* Panz.	0.1	1.1	–	–	0.1	0.3	0.1	0.4
33	*Mellinus arvensis* L.	0.7	8.5	5.6	48.7	12.1	59.9	6.1	46.0
34	*Tachysphex panzeri* Van. Lind.	–	–	–	–	+	0.2	+	0.1
35	*Trypoxylon clavicerum* Lep.	0.4	5.2	0.1	0.8	+	0.2	0.2	1.4
36	*Trypoxylon attenuatum* Smith.	0.1	1.2	0.1	0.5	–	–	0.1	0.4
37	*Trypoxylon figulus* L.	0.1	1.3	0.1	0.5	0.1	0.2	0.1	0.5
38	*Oxybelus dissectus* Dahlb.	–	–	–	–	0.1	0.6	+	0.3
39	*Oxybelus mandibularis* Dahlb.	–	–	–	–	0.1	0.3	+	0.1
40	*Oxybelus bipunctatus* Oliv.	–	–	–	–	0.3	1.5	0.1	0.7
41	*Crabro cribrarius* L.	0.1	1.2	0.2	1.8	–	–	0.1	0.7
42	*Crabro peltarius* Schreb.	0.4	4.5	–	–	0.3	1.5	0.2	1.7
43	*Ectemnius cephalotes* Olivier	+	0.3	0.1	1.1	0.2	0.9	0.1	0.7
44	*Ectemnius lituratus* Panz.	–	–	0.1	0.7	–	–	+	0.2
45	*Ectemnius sexcinctus* Fabr.	0.1	0.9	–	–	–	–	+	0.2
46	*Ectemnius cavifrons* Thoms.	0.3	4.0	0.1	1.2	0.3	1.3	0.3	1.9
47	*Ectemnius ruficornis* Zett.	0.1	1.4	0.1	0.8	0.1	0.5	0.1	0.7
48	*Ectemnius continuus* Fabr.	0.1	0.9	0.2	1.8	0.2	1.2	0.2	1.3
49	*Ectemnius dives* Lep. et Brul.	–	–	–	–	+	0.2	+	0.1
50	*Ectemnius guttatus* Van. Lind.	–	–	–	–	+	0.2	+	0.1
51	*Entomognatus brevis* Van. Lind.	0.1	0.9	+	0.3	0.1	0.5	0.1	0.5
52	*Lindenius albilabris* Fabr.	+	0.2	0.1	1.0	0.4	1.8	0.2	1.2
53	*Lindenius panzeri* Van. Lind.	0.2	1.8	+	0.3	0.6	2.9	0.3	1.9
54	*Lindenius pygmeaus armatus* Van. Lind.	0.1	0.6	–	–	0.1	0.3	+	0.3
55	*Rhopalum clavipes* L.	–	–	0.1	0.8	0.1	0.6	0.1	0.5
56	*Rhopalum coarctatum* Scop.	+	0.2	+	0.3	–	–	+	0.1
57	*Crossocerus quadrimaculatus* Fabr.	0.2	2.4	0.1	0.4	0.4	1.8	0.2	1.6
58	*Crossocerus ovalis* Lep. et Brul.	+	0.2	0.1	0.5	+	0.2	+	0.3
59	*Crossocerus elongatulus* Van. Lind.	0.1	0.9	–	–	–	–	+	0.2

1	2	3	4	5	6	7	8	9	10
60	*Crossocerus wesmaeli* Van. Lind.	0.1	0.6	+	0.3	0.3	1.4	0.1	0.9
61	*Crossocerus distinguendus* A. Mor.	–	–	+	0.3	–	–	+	0.1
62	*Crossocerus palmipes* L.	+	0.3	–	–	+	0.2	+	0.1
63	*Crossocerus assimilis* Smith	–	–	0.1	0.5	–	–	+	0.1
64	*Crossocerus annulipes* Lep. et Brul.	0.1	1.4	0.1	0.6	+	0.2	0.1	0.5
65	*Crossocerus cetratus* Shuck.	+	0.2	–	–	–	–	+	0.1
66	*Crossocerus nigritus* Lep. et Brul.	0.1	1.3	0.3	2.6	0.3	1.2	0.2	1.6
67	*Crossocerus megacephalus* Rossi	0.2	1.8	0.3	2.3	+	0.2	0.2	1.1
68	*Crossocerus vagabundus* Panz.	+	0.2	–	–	+	0.2	+	0.1
69	*Crossocerus binotatus* Lep. et Brul.	+	0.2	–	–	–	–	+	0.1
70	*Crossocerus varius* Lep. et Brul.	0.3	3.4	0.3	2.7	+	0.2	0.2	1.6
71	*Crossocerus dimidiatus* Fabr.	0.1	0.9	–	–	–	–	+	0.2
	Total	8.4		11.4		20.2		13.4	

Changes in the dominance structure of *Sphecidae* communities in linden-oak-hornbeam forests followed a different pattern than in coniferous forests. In the communities occurring in the modified linden-oak-hornbeam forest, the proportion of most abundant species was reduced, thus the dominance structure was more uniform, as compared with that of the community in the natural linden-oak-hornbeam forest. In the communities in modified coniferous forests the proportion of the dominant species increased by a factor of 3 in the mixed forest and by a factor of 7 in the pine forest.

Differences in the number of species, abundance, and dominance structure of *Sphecidae* communities between natural and modified habitats are reflected in the values of biocenotic indices (Tab. 8). The values of the indices of general diversity, evenness, and species richness of the communities from the two modified coniferous forests were smaller as compared with those for the communities occurring in natural coniferous forests, while the values of the dominance index were higher. The index of general diversity for communities occurring in deciduous forests was higher in the modified linden-oak-hornbeam forests, while the dominance index was lower there. This was mainly caused by the decrease in the proportion of dominant species. The habitat conditions in the modified linden-oak-hornbeam forests were much more favourable to these insects than in the natural linden-oak-hornbeam forests. This accounted for the occurrence of many species rather absent from natural linden-oak-hornbeam forests. But the increase in the number of species was not proportional to the increase in the abundance of the community in the modified linden-oak-hornbeam forest, and this was reflected in a lowered value of the index of species richness.

COMMUNITIES OF RESTRUCTURED HABITATS

Sphecidae communities occurring on the site of linden-oak-hornbeam forests restructured and managed in different ways (that is, in rural parks, a suburban park, and a rural garden) showed considerable differences in the number of species, species composition, and abundance. These communities were more diverse than those occurring in modified habitats. These differences are even more important if we take into account that the modified habitats represented different site conditions (linden-oak-hornbeam forest, mixed forest, pine forest).

In rural parks (Radziejowice, Młochów), *Sphecidae* communities were characterized by very poor species composition, but they were abundant than the communities from the natural linden-oak-hornbeam forest. In each of these parks merely 14 species were recorded (Tab. 3). The abundance index showed considerable differences between these two communities. It was 4.9 at Radziejowice and 31.9 at Młochów. Dominant spesies were

Table 3. Occurrence and abundance of *Sphecidae* in rural and suburban parks; n — abundance index, + — scarce abundance

No.	Habitat, locality / Species	Rural parks				Average		Suburban park	
		Młochów		Radziejowice				Ursynów	
		n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10
1	*Pemphredon lugubris* Fabr.	0.6	1.8	—	—	0.3	1.6	2.9	5.0
2	*Pemphredon inornatus* Say	—	—	—	—	—	—	0.5	0.8
3	*Pemphredon lethifer* Fabr.	—	—	0.1	2.2	0.1	0.3	0.3	0.6
4	*Diodontus minutus* Fabr.	—	—	0.1	1.8	+	0.2	—	—
5	*Diodontus tristis* Van. Lind.	—	—	—	—	—	—	0.4	0.6
6	*Passaloecus singularis* Dahlb.	—	—	—	—	—	—	0.8	1.3
7	*Passaloecus corniger* Shuck.	—	—	0.2	4.2	0.1	0.5	—	—
8	*Passaloecus insignis* Van. Lind.	16.8	52.7	0.6	12.5	8.7	47.5	0.4	0.7
9	*Stigmus solskyi* A. Mor.	—	—	—	—	—	—	0.1	0.1
10	*Stigmus pendulus* Panz.	7.0	21.8	0.5	9.9	3.7	20.3	0.1	0.1
11	*Spilomena beata* Blüthg.	0.9	2.8	—	—	0.5	2.5	—	—
12	*Mimesa lutaria* Fabr.	—	—	—	—	—	—	0.6	0.1
13	*Psenulus concolor* Dahlb.	—	—	0.9	18.8	0.4	2.4	0.3	0.5
14	*Psenulus fuscipennis* Dahlb.	—	—	—	—	—	—	0.2	0.3
15	*Psenulus pallipes* Panz.	—	—	—	—	—	—	0.4	0.6
16	*Psenulus laevigatus* Schenck.	2.3	7.3	0.7	15.2	1.5	8.3	0.3	0.5
17	*Psenulus schencki* Tourn.	—	—	—	—	—	—	0.5	0.8
18	*Gorytes bicinctus* Rossi	—	—	—	—	—	—	0.2	0.3
19	*Gorytes laticinctus* Lep.	—	—	—	—	—	—	0.1	0.1
20	*Nysson trimaculatus* Rossi	—	—	—	—	—	—	0.3	0.5
21	*Nysson maculosus* Gmelin	—	—	—	—	—	—	0.1	0.2
22	*Argogorytes fargei* Shuck.	—	—	—	—	—	—	0.1	0.1
23	*Alyson spinosus* Panz.	—	—	—	—	—	—	0.2	0.3
24	*Mallinus arvensis* L.	—	—	—	—	—	—	41.0	69.9
25	*Mellinus crabroneus* Thunb.	—	—	—	—	—	—	0.3	0.4
26	*Trypoxylon attenuatum* Smith	—	—	0.3	5.9	0.1	0.8	—	—
27	*Trypoxylon clavicerum* Lep.	—	—	0.1	1.8	+	0.2	—	—

1	2	3	4	5	6	7	8	9	10
28	*Oxybelus mandibularis* Dahlb.	—	—	—	—	—	—	0.1	0.2
29	*Crabro cribrarius* L.	—	—	—	—	—	—	0.3	0.4
30	*Crabro peltarius* Schreb.	—	—	—	—	—	—	0.2	0.3
31	*Ectemnius cephalotes* Olivier	—	—	—	—	—	—	0.9	1.6
32	*Ectemnius literatus* Panz.	—	—	—	—	—	—	0.4	0.7
33	*Ectamnius cavifrons* Thomas.	—	—	—	—	—	—	0.6	1.0
34	*Ectemnius ruficornis* Zett.	—	—	—	—	—	—	0.8	1.3
35	*Ectemnius continuus* Fabr.	—	—	—	—	—	—	0.5	0.9
36	*Lindenius panzeri* Van. Lind.	—	—	—	—	—	—	0.6	1.0
37	*Lindenius pygmaeus armatus* Van. Lind.	—	—	—	—	—	—	0.2	0.4
38	*Rhopalum clavipes* L.	0.1	0.4	0.2	2.2	0.1	0.7	—	—
39	*Rhopalum coarctatum* Scop.	0.3	0.8	0.8	17.4	0.5	2.8	0.5	0.8
40	*Crossocerus quadrimaculatus* Fabr.	0.4	1.4	—	—	0.2	1.2	0.3	0.5
41	*Crossocerus ovalis* Lep. et Brul.	—	—	—	—	—	—	0.3	0.5
42	*Crossocerus elongatulus* Van. Lind.	—	—	—	—	—	—	0.2	0.4
43	*Crossocerus wesmaeli* Van. Lind.	—	—	—	—	—	—	0.3	0.5
44	*Crossocerus distinguendus* A. Mor.	—	—	0.1	2.2	0.1	0.3	—	—
45	*Crossocerus assimilis* Smith	0.4	1.4	—	—	0.2	1.2	0.1	0.1
46	*Crossocerus annulipes* Lep. et Brul.	0.4	1.4	—	—	0.2	1.2	—	—
47	*Crossocerus styrius* Kohl.	0.3	0.8	—	—	0.1	0.8	—	—
48	*Crossocerus nigritus* Lep. et Brul.	0.1	0.4	—	—	0.1	0.4	—	—
49	*Crossocerus cetratus* Shuck.	—	—	—	—	—	—	0.2	0.3
50	*Crossocerus leucostomus* L.	—	—	—	—	—	—	0.1	0.2
51	*Crossocerus megacephalus* Rossi	—	—	—	—	—	—	1.3	2.3
52	*Crossocerus capitosus* Shuck.	0.1	0.4	0.2	3.7	0.2	0.8	—	—
53	*Crossocerus varius* Lep. et Brul.	2.1	6.6	0.1	2.2	1.1	6.0	1.0	1.8
	Total	31.8		4.9		18.2		59.0	

the same in the two communities: *Passaloecus insignis*, *Psenulus concolor*, and *Stigmus pendulus* (Fig. 2). Humid and shady rural parks are not suitable for most *Sphecidae* species.

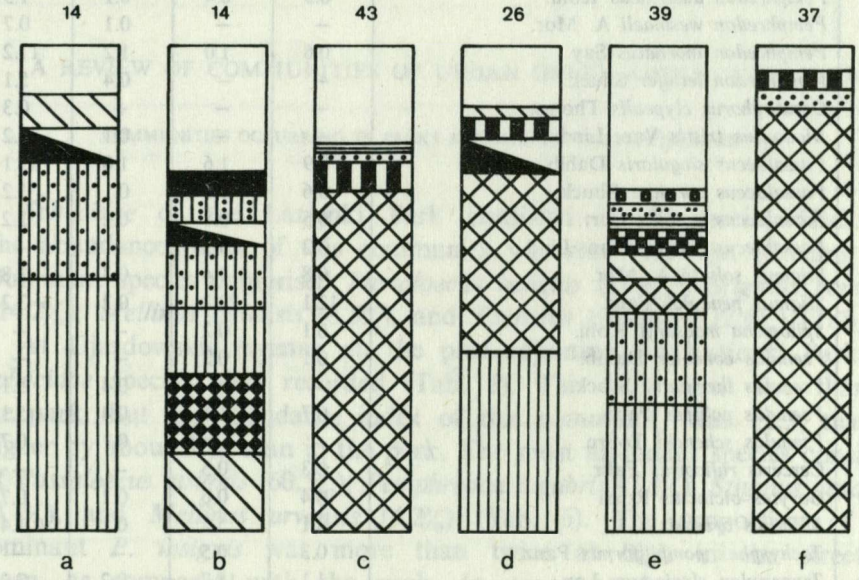


Fig. 2. Dominance structure of *Sphecidae* communities occuring in parks. a — rural park at Młochów, b — rural park at Radziejowice, c — suburban park at Ursynów, d — urban park Saxon Garden, e — urban park Łazienki, f — urban park at the Cemetery of Soviet Soldiers; other symbols see page 175

In the suburban park (Ursynów), habitat conditions were different, though it was also established on the site of a linden-oak-hornbeam forest. It was much more insolated and dry. *Sphecidae* community of this park comprised 43 species. Abundance index was high, reaching 59.0. The dominance structure was characterized by a large disproportion between the dominant and the other species. *Mellinus arvensis* accounted for almost 70% of the community abundance, while in rural parks the proportion of particular species was more uniform. Differences in the dominance structure between communities occurring in rural and suburban parks were reflected in the values of the evenness and dominance indices (Tab. 3).

Sphecidae community of the non-urban garden (Mroków) was most abundant of all the communities under study (Tab. 8). Then abundance index was 59.4. The community consisted of 39 species. This number of species was much higher than in the natural linden-oak-hornbeam forest and also in other homologous restructured habitats of the non urban zone, but lower than in homologous suburban habitats. The community was dominated

Table 4. Occurrence and abundance of *Sphecidae* in rural garden and urban allotment gardens; *n* — abundance index

No.	Species \ Habitat	Rural garden		Allotments	
		n	%	n	%
1	*Pemphredon lugubris* Fabr.	1.9	3.2	0.5	7.5
2	*Pemphredon austriacus* Kohl.	0.3	0.4	0.1	1.3
3	*Pemphredon wesmaeli* A. Mor.	–	–	0.1	0.7
4	*Pemphredon inornatus* Say	0.6	1.0	1.2	17.2
5	*Pemphredon lethifer* Shuck.	–	–	0.4	5.1
6	*Ceratophorus clypealis* Thoms.	–	–	+	0.3
7	*Diodontus tristis* Van. Lind.	–	–	0.1	1.2
8	*Passaloecus singularis* Dahlb.	0.9	1.6	1.0	15.1
9	*Passaloecus corniger* Shuck.	0.6	1.0	0.1	1.2
10	*Passaloecus gracilis* Curt.	0.5	0.8	0.2	2.2
11	*Passaloecus insignis* Van. Lind.	0.2	0.3	–	–
12	*Stigmus solskyi* A. Mor.	0.8	1.4	0.3	3.8
13	*Stigmus pendulus* Panz.	12.1	20.2	0.2	3.2
14	*Spilomena mocsaryi* Kohl.	0.1	0.2	–	–
15	*Psenulus concolor* Dahlb.	0.1	0.2	–	–
16	*Psenulus laevigatus* Schck.	–	–	0.4	5.1
17	*Psenulus pallipes* Panz.	0.7	1.1	0.4	5.1
18	*Psenulus schencki* Tourn.	–	–	0.1	0.7
19	*Cerceris ruficornis* Fabr.	0.3	0.5	–	–
20	*Gorytes bicinctus* Rossi	0.4	0.6	0.1	0.7
21	*Mellinus arvensis* L.	3.1	5.2	0.1	1.4
22	*Tachysphex pompiliformis* Panz.	0.3	0.5	–	–
23	*Trypoxylon clavicerum* Lep.	11.1	18.7	0.2	2.9
24	*Trypoxylon attenuatum* Smith.	1.0	1.8	0.4	5.5
25	*Trypoxylon figulus* L.	1.0	1.9	0.3	3.8
26	*Oxybelus dissectus* Dahlb.	0.4	0.6	–	–
27	*Oxybelus mandibularis* Dahlb.	0.3	0.4	–	–
28	*Crabro peltarius* Schreb.	1.7	2.9	–	–
29	*Ectemnius cavifrons* Thoms.	0.2	0.3	0.2	2.3
30	*Ectemnius ruficornis* Zett.	–	–	0.1	0.7
31	*Lindenius pygmaeus armatus* Van. Lind.	0.2	0.3	–	–
32	*Rhopalum clavipes* L.	0.3	0.5	0.1	0.9
33	*Rhopalum coarctatum* Scop.	1.7	2.7	–	–
34	*Crossocerus quadrimaculatus* Fabr.	0.7	1.2	–	–
35	*Crossocerus ovalis* Lep. et Brul.	1.0	1.7	–	–
36	*Crossocerus tarsatus* Shuck.	0.3	0.4	–	–
37	*Crossocerus elongatulus* Van. Lind.	4.1	7.0	0.1	1.0
38	*Crossocerus wesmaeli* Van. Lind.	1.8	3.1	–	–
39	*Crossocerus distinguendus* A. Mor.	0.1	0.2	–	–
40	*Crossocerus palmipes* L.	0.6	0.9	–	–
41	*Crossocerus varius* Lep. et Brul.	1.3	2.0	–	–
42	*Crossocerus annulipes* Lep. et Brul.	6.2	10.5	0.8	11.1
43	*Crossocerus nigritus* Lep. et Brul.	0.4	0.7	–	–
44	*Crossocerus megacephalus* Rossi	1.3	2.2	–	–
45	*Crossocerus vagabundus* Panz.	0.9	1.6	–	–
46	*Crossocerus dimidiatus* Fabr.	0.1	0.2	–	–
	Total	59.4		6.9	

by *Trypoxylon clavicerum*, *Stigmus pendulus*, *Crossocerus annulipes*, and *C. elongatulus* (Tab. 4). *Stigmus pendulus* was the only species abundant also in other communities of non-urban and suburban habitats.

A REVIEW OF COMMUNITIES OF URBAN GREEN AREAS OF WARSAW

COMMUNITIES OCCURRING IN PARKS AND ADJOINING STREETSIDE GREEN[3]

Sphecidae of the Łazienki Park consisted of 39 species (Tab. 5). The abundance index of this community was relatively low, reaching 7.9. Dominant species comprised *Passaloecus insignis* (19.8%), *Stigmus pendulus* (14.2%), *Mellinus arvensis* (8.5%), and *Psenulus concolor* (12.6%) (Tab. 5).

At Ujazdowskie Avenue on the plot adjoining the Łazienki Park, 23 *Sphecidae* species were recorded (Tab. 6). This was much less than in the park. But the abundance index of this community was 11.3, that is, higher by about 30% than in the park. The most abundant species consisted of *Passaloecus insignis* (60.5%), *Pemphredon lugubris* (7.1%), *Stigmus pendulus* (4.1%), and *Mellinus arvensis* (4.2%) (Tab. 6). The proportion of the dominant *P. insignis* was more than twice as high in the streetside green, as compared with the park. In contrast, the proportion of *S. pendulus* was higher in the park. *P. lugubris* was not dominant inside the park, but it was relatively abundant at the street.

In the Saxon Garden, 26 species were recorded. Their abundance, like in the Łazienki Park, was low, the index being 10.0. The dominant species consisted of *Passaloecus insignis* (37.5%), *Mellinus arvensis* (34.5%), and *Crossocerus varius* (9.7%) (Tab. 5).

At Marszałkowska Street bordering on the Saxon Garden, 34 species were recorded, that is, 8 species more than within the park (Tab. 6). Also the abundance of the community occurring in this study area was higher than within the park; the index of abundance was 20.4 (Tab. 8). This seems to be related to differences in vegetation structure. A higher insolation of the streetside edge of the Saxon Garden may be the most important factor. The dominance structure of this community was similar to that within the park. The dominant species comprised *Mellinus arvensis* (25.5%), *Passaloecus insignis* (31.4%) and *Pemphredon lugubris* (6.1%).

In the park at the Cemetery of Soviet Soldiers, 37 species were recorded (Tab. 5). The number of species in this community was similar to that in the Łazienki Park, but its abundance was higher by a factor of more than 6. The index of abundance was high, and it amounted

[3] Because individual *Sphecidae* searched large areas, these study areas are discussed jointly.

Table 5. Occurrence and abundance of *Sphecidae* in urban parks of Warsaw; n — abundance index, + — scarce abundance

No.	Study area / Species	Łazienki		Saxon Garden		Cemetery of Soviet Soldiers		Average	
		n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10
1	*Pemphredon lugubris* Fabr.	0.3	3.7	0.5	5.1	1.4	2.8	0.7	3.3
2	*Pemphredon inornatus* Say	0.1	1.1	–	–	+	0.1	+	0.1
3	*Diodontus minutus* Fabr.	+	0.1	–	–	–	–	+	0.1
4	*Diodontus luperus* Shuck.	+	0.1	–	–	–	–	+	0.1
5	*Passaloecus singularis* Dahlb.	0.1	1.8	0.2	1.7	+	0.1	0.1	0.5
6	*Passaloecus corniger* Shuck.	+	0.1	–	–	+	0.1	+	0.1
7	*Passaloecus gracilis* Curt.	+	0.1	+	0.2	+	0.1	+	0.1
8	*Passaloecus insignis* Van. Lind.	1.6	19.8	3.7	37.5	0.2	0.4	1.8	8.3
9	*Stigmus solskyi* A. Mor.	+	0.5	–	–	+	0.1	+	0.1
10	*Stigmus pendulus* Panz.	1.1	14.2	0.1	1.0	–	–	0.4	1.8
11	*Spilomena differens* Blüthg.	0.3	3.4	–	–	–	–	0.1	0.5
12	*Spilomena curruca* Dahlb.	+	0.3	–	–	–	–	+	0.1
13	*Spilomena troglodytes* Van. Lind.	+	0.4	–	–	–	–	+	0.1
14	*Spilomena beata* Blüthg.	+	0.3	–	–	–	–	+	0.1
15	*Mimesa lutaria* Fabr.	–	–	–	–	0.1	0.1	+	0.1
16	*Psenulus concolor* Dahlb.	1.0	12.6	0.2	1.5	0.1	0.2	0.4	1.8
17	*Psenulus laevigatus* Schenck.	0.3	3.5	+	0.2	0.1	0.2	0.1	0.6
18	*Psenulus pallipes* Panz.	0.4	4.7	0.1	0.9	–	–	0.2	0.6
19	*Psenulus schencki* Tourn.	0.1	1.4	–	–	+	0.1	+	0.2
20	*Gorytes bicinctus* Rossi	–	–	+	0.2	0.1	0.1	+	0.1
21	*Gorytes quinquecinctus* Fabr.	–	–	–	–	+	0.1	+	0.1
22	*Nysson trimaculatus* Rossi	–	–	–	–	0.1	0.1	+	0.1
23	*Mellinus arvensis* L.	0.7	8.5	3.4	34.5	41.9	86.3	15.3	69.1
24	*Trypoxylon clavicerum* Lep.	+	0.4	0.1	0.6	+	0.1	+	0.2
25	*Trypoxylon attenuatum* Smith	0.1	1.4	–	–	–	–	+	0.2
26	*Oxybelus mandibularis* Dahlb.	–	–	–	–	0.3	0.6	0.1	0.4
27	*Oxybelus latidens* Cerst.	–	–	+	0.1	+	0.1	+	0.1

1	2	3	4	5	6	7	8	9	10
28	*Crabro cribrarius* L.	–	–	–	–	+	0.1	+	0.1
29	*Crabro peltarius* Schreb.	–	–	+	0.3	–	–	+	0.1
30	*Crabro scutellatus* Shev.	–	–	–	–	+	0.1	+	0.1
31	*Ectemnis cephalotes* Oliver	+	0.1	+	0.4	2.0	4.0	0.7	3.1
32	*Ectemnius literatus* Panz.	–	–	+	0.3	0.1	0.1	+	0.1
33	*Ectemnius sexcinctus* Fabr.	0.1	0.9	0.1	0.6	0.1	0.3	0.1	0.4
34	*Ectemnius cavifrons* Thoms.	0.1	0.9	0.2	1.6	0.3	0.7	0.2	0.8
35	*Ectemnius ruficornis* Zett.	0.1	1.8	0.1	1.0	0.1	0.2	0.1	0.5
36	*Lindenius albilabris* Fabr.	+	0.1	–	–	+	0.1	+	0.1
37	*Lindenius panzeri* Van. Lind.	+	0.5	–	–	+	0.1	+	0.1
38	*Lindenius pygmaeus armatus* Van. Lind.	–	–	0.1	0.7	0.1	0.1	+	0.2
39	*Rhopalum clavipes* L.	0.1	0.6	–	–	–	–	+	0.2
40	*Rhopalum coarctatum* Scop.	0.1	1.0	–	–	+	0.1	+	0.2
41	*Crossocerus quadrimaculatus* Fabr.	0.2	2.5	+	0.3	+	0.1	0.1	0.4
42	*Crossocerus ovalis* Lep. et Brul.	0.2	1.4	+	0.3	+	0.1	0.1	0.3
43	*Crossocerus elongatulus* Van. Lind.	0.2	2.9	–	–	+	0.1	0.1	0.4
44	*Crossocerus wesmaeli* Van. Lind.	+	0.4	+	0.2	+	0.1	+	0.1
45	*Crossocerus distinguendus* A. Mor.	0.2	1.9	0.1	0.5	+	0.1	+	0.1
46	*Crossocerus podagricus* Van. Lind.	0.1	1.6	–	–	–	–	+	0.2
47	*Crossocerus annulipes* Lep. et Brul.	0.2	2.0	+	0.3	0.1	0.1	0.1	0.5
48	*Crossocerus nigritus* Lep. et Brul.	0.1	1.1	–	–	–	–	+	0.1
49	*Crossocerus megacephalus* Rossi	–	–	–	–	0.1	0.1	0.1	0.3
50	*Crossocerus capitosus* Shuck.	–	–	+	0.3	–	–	+	0.1
51	*Crossocerus vagabundus* Panz.	0.1	1.4	–	–	–	–	+	0.2
52	*Crossocerus varius* Lep. et Brul.	+	0.5	1.0	9.7	0.9	1.7	0.6	2.8
	Total	7.9		10.0		48.4		22.1	

Table 6. Occurrence and abundance of *Sphecidae* in streetside green of Warsaw; n — abundance index, + — scarce abundance

No.	Study area / Species	Adjacent to park								Isolated	
		Ujazdowskie Ave.		Marszałkowska St.		Żwirki i Wigury Ave.		Average		Konstytucji Sq.	
		n	%	n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10	11	12
1	*Pemphredon lugubris* Fabr.	0.8	7.1	1.3	6.1	0.4	2.1	0.8	4.7	0.1	0.8
2	*Pemphredon inornatus* Say	+	0.3	0.9	4.4	–	–	0.3	1.8	–	–
3	*Ceratophorus morio* Van. Lind.	0.1	1.2	–	–	–	–	+	0.2	–	–
4	*Diodontus luperus* Shuck.	0.1	0.4	–	–	–	–	+	0.1	–	–
5	*Diodontus tristis* Van. Lind.	0.1	0.6	0.1	0.3	–	–	0.1	0.3	0.2	1.3
6	*Passaloecus singularis* Dahlb.	0.4	3.7	0.8	4.1	0.1	0.2	0.4	2.5	0.2	1.7
7	*Passaloecus corniger* Shuck.	0.2	1.7	–	–	–	–	0.1	0.3	0.1	1.2
8	*Passaloecus gracilis* Curt.	–	–	+	0.2	–	–	+	0.1	–	–
9	*Passaloecus insignis* Van. Lind.	6.8	60.5	6.4	31.4	0.1	0.4	4.4	25.4	0.1	0.8
10	*Spilomena beata* Blüthg.	–	–	0.4	2.0	–	–	0.1	0.7	0.2	1.7
11	*Stigmus solskyi* A. Mor.	–	–	0.3	1.5	0.1	0.2	0.1	0.7	–	–
12	*Stigmus pendulus* Panz.	0.5	4.1	0.9	4.5	–	–	0.5	2.6	0.6	5.0
13	*Mimesa lutaria* Fabr.	–	–	0.2	1.2	–	–	0.1	0.5	–	–
14	*Psen dahlbomi* Wesm.	–	–	–	–	–	–	–	–	0.1	1.2
15	*Psenulus concolor* Dahlb.	0.2	2.0	0.1	0.6	–	–	0.1	0.6	0.3	2.3
16	*Psenulus fuscipennis* Dahlb.	–	–	+	0.2	–	–	+	0.1	–	–
17	*Psenulus laevigatus* Schenck.	0.1	0.8	–	–	0.1	0.6	0.1	0.4	0.1	0.5
18	*Psenulus schencki* Tourn.	–	–	–	–	–	–	–	–	0.4	3.7
19	*Psenulus pallipes* Panz.	0.3	2.7	0.1	0.3	–	–	0.1	0.7	1.0	8.7
20	*Gorytes bicinctus* Rossi	–	–	0.1	0.4	–	–	+	0.2	+	0.2
21	*Nysson trimaculatus* Fabr.	–	–	+	0.2	–	–	+	0.1	–	–
22	*Mellinus arvensis* L.	0.5	4.2	5.2	25.5	16.9	82.0	7.5	43.0	0.1	0.5
23	*Nitela spinolae* Latr.	0.1	0.5	–	–	–	–	–	–	–	–
24	*Trypoxylon clavicerum* Lep.	0.3	2.5	0.3	1.2	–	–	0.2	1.0	+	0.3
25	*Trypoxylon attenuatum* Smith	–	–	–	–	–	–	–	–	0.1	1.0
26	*Trypoxylon figulus* L.		–	0.1	0.6	–	–	+	0.2	–	–

1	2	3	4	5	6	7	8	9	10	11	12
27	*Oxybelus mandibularis* Dahlb.	+	0.3	–	–	–	–	+	0.1	–	–
28	*Crabro cribrarius* L.	+	0.3	–	–	–	–	+	0.1	–	–
29	*Ectemnius cephaloptes* Olivier	0.2	1.5	0.3	1.6	0.8	4.0	0.4	2.4	+	0.2
30	*Ectemnius lituratus* Panz.	–	–	–	–	0.1	0.2	+	0.1	+	0.2
31	*Ectemnius sexcinctus* Fabr.	–	–	0.1	0.6	0.5	2.2	0.2	1.1	1.9	15.9
32	*Ectemnius rugifer* Dahlb.	–	–	–	–	–	–	–	–	–	0.1
33	*Ectemnius cavifrons* Thoms.	–	–	0.2	1.1	0.3	1.3	0.2	1.0	–	–
34	*Ectemnius ruficornis* Zett.	–	–	0.4	1.8	0.3	1.7	0.2	1.4	0.8	6.5
35	*Ectemnius lapidarius* Panz.	–	–	–	–	0.1	0.2	+	0.1	–	–
36	*Ectemnius continuus* Fabr.	–	–	+	0.1	–	–	+	0.1	–	–
37	*Entomagnatus brevis* Van. Lind.	–	–	–	–	–	–	–	–	0.4	3.7
38	*Lindenius panzeri* Van. Lind.	–	–	+	0.2	0.1	0.2	+	0.2	–	–
39	*Lindenius pygmaeus armatus* Van. Lind.	–	–	0.1	0.3	–	–	+	0.1	–	–
40	*Rhopalum clavipes* L.	0.3	2.4	0.4	1.8	0.3	1.4	0.3	1.8	+	0.2
41	*Rhopalum coarctatum* Scop.	–	–	–	–	0.1	0.2	+	0.1	+	0.2
42	*Crossocerus ovalis* Lep. et Brul.	–	–	+	0.2	–	–	+	0.1	–	–
43	*Crossocerus quadrimaculatus* Fabr.	0.1	0.6	0.3	1.3	–	–	0.1	0.6	–	–
44	*Crossocerus elongatulus* Van. Lind.	–	–	0.2	0.8	0.2	0.9	0.1	0.7	2.2	18.8
45	*Crossocerus wesmaeli* Van. Lind.	–	–	–	–	–	–	–	–	1.3	11.1
46	*Crossocerus distinguendus* A. Mor.	–	–	0.1	0.3	0.1	0.3	0.1	0.3	+	0.3
47	*Crossocerus exiguus* Van. Lind.	+	0.4	–	–	–	–	+	0.1	–	–
48	*Crossocerus podagricus* Van. Lind.	–	–	0.1	0.2	–	–	+	0.1	–	–
49	*Crossocerus varius* Lep. et Brul.	0.1	1.2	0.6	3.1	0.3	1.7	0.4	2.1	–	–
50	*Crossocerus assimilis* Smith	–	–	–	–	–	–	–	–	0.1	1.2
51	*Crossocerus nigritus* Lep. et Brul.	–	–	–	–	–	–	–	–	+	0.2
52	*Crossocerus annulipes*	0.1	1.0	0.3	1.5	–	–	0.1	0.8	1.3	10.6
53	*Crossocerus megacephalus* Rossi	–	–	0.1	0.4	0.1	0.2	0.1	0.3	–	–
	Total	11.3		20.4		21.0		17.1		11.6	

to 48.4. This was the most abundant urban *Sphecidae* community. The dominant species, *Mellinus arvensis* accounted for 86.3%.

At Żwirki i Wigury Avenue adjoining the park at the Cemetery of Soviet Soldiers, only 19 species were recorded. The abundance index of this community was 21.0, thus lower by half than in the park. Like in the park, the dominant species was *M. arvensis,* which accounted for more than 80% of the community.

The proportions of most abundant species were similar in the park at the Cemetery of Soviet Soldiers and at Żwirki i Wigury Avenue, though in the park the number of species was two times higher and the abundance of the community was much higher (Fig. 3). Because of the

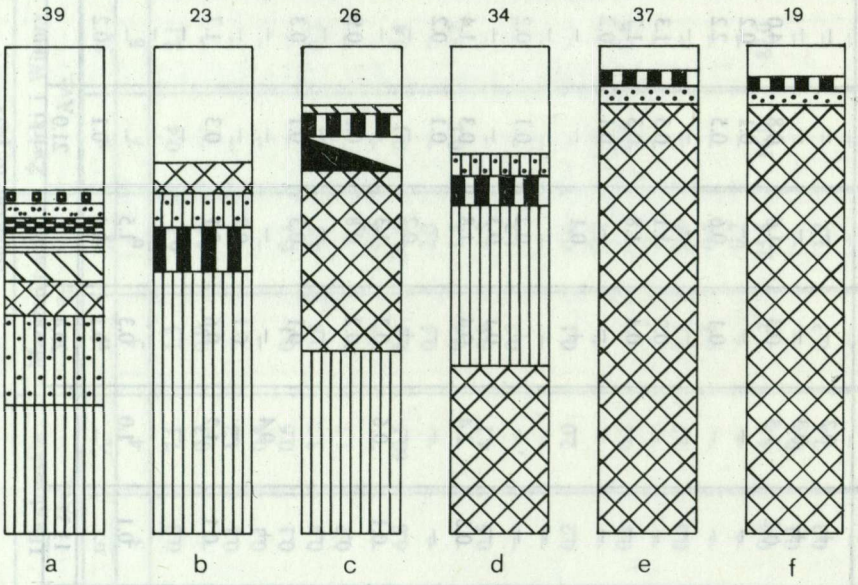


Fig. 3. Dominance structure of *Sphecidae* communities occurring in urban parks and adjoining streetside green. a — Łazienki Park, b — Ujazdowskie Avenue, c — Saxon Garden, d — Marszałkowska Street, e — park at the Cemetery of Soviet Soldiers, f — Żwirki i Wigury Avenue; other symbols see page 158

differences in the number of species and in the abundance of these communities, the index of species richness of the streetside community was lower than of the park community, while the evenness index reached a higher value. Similarly, the index of general diversity was higher for the streetside community than for the park community (Tab. 8).

COMMUNITIES OF HOUSING ESTATES

In Wierzbno, 17 species of *Sphecidae* were recorded. The abundance of this community was relatively high, the index being 22.3 (Tab. 8).

The dominant species were *Mellinus arvensis* (24.3%), *Crossocerus elongatulus* (24.7%), *C. wesmaeli* (10.8%), *C. annulipes* (8.2%), and *Pemphredon lugubris* (6.3%).

In Muranów, 20 *Sphecidae* species were recorded. The abundance index of this community was 10.1, lower by half than in Wierzbno (Tab. 8). The most abundant species consisted of *Mellinus arvensis* (21.8%), *Passaloecus singularis* (21.8%), *Pemhredon lugubris* (6.9%), *Crossocerus distinguendus* (6.9%), *C. elongatulus* (5.9%) (Tab. 7).

The *Sphecidae* communities of the two study areas in green habitats of loosely built-up housing estates had three dominant species in common: *Mellinus arvensis, Pemphredon lugubris, Crossocerus elongatulus* (Fig. 4).

In green of the courtyard of closely built-up area (MDM II), merely 11 *Sphecidae* species were recorded. The community abundance on this plot was very low. The index of abundance was 6.3 (Tab. 8). It was lower by a factor of 3.5 than the Wierzbno community and by a factor of 2 than the Muranów community. The species most abundant on this plot consisted of *Stigmus pendulus* (47.7%), *Nitela spinolae* (9.5%), and *Crossocerus annulipes* (7.9%) (Tab. 7). The dominant species in this community was not dominant in the other communities, though it was rather abundant in many study areas.

In green of the courtyard at Wilcza Street, 22 *Sphecidae* species were recorded. The community abundance was relatively high. The index of abundance reached 24.0 (Tab. 8). This community was characterized by an even distribution of numbers of particular species. The most abundant species comprised *Crossocerus annulipes* (22.5%), *Psenulus pallipes* (15.8%), *Psenulus schencki* (10.0%), *Crossocerus elongatulus* (6.3%), *Psenulus concolor* (7.1%), *Passaloecus singularis* (5.4%), *Stigmus pendulus* (6.7%), and *Mellinus arvensis* (8.3%) (Tab. 7).

COMMUNITY OF ISOLATED STREETSIDE GREEN

In green of the Konstytucji Square, 30 species of *Sphecidae* were recorded (Tab. 8). The community abundance in this study area was almost twice as high as on the nearby plot (MDM II). Over a four-year study period, only three species permanently occurred there. These were *Crossocerus elongatulus, C. wesmaeli*, and *Psenulus pallipes*. At the same time. these were the most abundant species. The occurrence of 16 species was limited to single seasons. Ten species were represented only by males. In this group there was *Ectemnius ruficornis*, the dominant species in 1975 at Konstytucji Square. It occurred there again in 1978. Because of this faunal instability it was not possible to determine the dominance structure

Table 7. Occurrence and abundance of *Sphecidae* in green areas of housing estates in Warsaw; n — abundance index, + — scarce abundance

No.	Study area / Species	Housing estates											
		Loosely built-up						Closely built-up					
		Wierzbno		Muranów		Average		Wilcza St		MDM II		Average	
		n	%	n	%	n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	*Pemphredon lugubris* Fabr.	1.4	6.3	0.7	6.9	1.0	6.4	1.1	4.6	–	–	0.6	3.9
2	*Pemphredon inornatus* Say	0.1	0.4	–	–	0.1	0.4	–	–	–	–	–	–
3	*Pemphredon lethifer* Shuck.	–	–	0.1	1.0	0.1	0.4	–	–	–	–	–	–
4	*Pemphredon austriacus* Kohl.	–	–	0.3	3.0	0.2	0.9	0.1	0.4	–	–	0.1	0.6
5	*Diodontus tristis* Van. Lind.	–	–	–	–	–	–	0.1	0.4	–	–	0.1	0.6
6	*Passaloecus singularis* Dahlb.	0.4	1.8	2.2	21.8	1.3	8.1	1.3	5.4	–	–	0.6	3.9
7	*Passaloecus corniger* Shuck.	–	–	–	–	–	–	–	–	0.3	4.8	0.2	1.3
8	*Passaloecus gracilis* Curt.	–	–	0.4	3.9	0.2	1.2	0.1	0.4	–	–	0.1	0.6
9	*Passaloecus insignis* Van. Lind.	–	–	0.3	3.0	0.2	0.9	0.1	0.4	–	–	0.1	0.6
10	*Stigmus solskyi* A. Mor.	0.3	1.3	–	–	0.2	0.9	–	–	–	–	–	–
11	*Stigmus pendulus* Panz.	–	–	0.2	2.0	0.1	0.6	1.6	6.7	3.0	47.7	2.3	14.9
12	*Spilomena differens* Blüthg.	–	–	–	–	–	–	0.1	0.4	–	–	0.1	0.6
13	*Psenulus concolor* Dahlb.	–	–	–	–	–	–	1.7	7.1	–	–	0.9	5.9
14	*Psenulus pallipes* Panz.	–	–	0.2	2.0	0.1	0.6	3.8	15.8	0.6	9.5	2.2	14.2
15	*Psenulus schencki* Tourn.	–	–	–	–	–	–	2.4	10.0	–	–	1.2	7.8
16	*Psenulus laevigatus* Schenck.	0.4	1.8	0.4	3.9	0.4	2.4	–	–	0.3	4.8	0.2	1.3
17	*Gorytes quadrifasciatus* Fabr.	–	–	–	–	–	–	0.1	0.4	–	–	0.1	0.6
18	*Mellinus arvensis* L.	5.4	24.3	2.2	21.8	3.8	23.2	2.0	8.3	0.1	1.6	1.0	6.5
19	*Nitela spinolae* Latr.	–	–	–	–	–	–	–	–	0.6	9.5	0.3	1.9
20	*Trypoxylon clavicerum* Lep.	1.3	5.7	–	–	0.6	3.9	0.4	1.7	–	–	0.2	1.3
21	*Trypoxylon attenuatum* Smith	–	–	0.3	3.0	0.2	0.9	0.4	1.7	–	–	0.2	1.3
22	*Trypoxylon figulus* L.	0.7	3.2	–	–	0.4	2.1	0.3	1.2	0.3	4.8	0.3	1.9
23	*Crabro peltarius* Schreb.	0.1	0.4	–	–	0.1	0.4	–	–	–	–	–	–
24	*Ectemnius cephalotes* Olivier	0.7	3.1	0.3	3.0	0.5	3.0	–	–	–	–	–	–
25	*Ectemnius ruficornis* Zett.	0.8	3.6	0.1	1.0	0.5	3.0	0.4	1.7	–	–	0.2	1.3
26	*Ectemnius continuus* Fabr.	0.6	2.7	–	–	0.3	1.8	–	–	–	–	–	–

1	2	3	4	5	6	7	8	9	10	11	12	13	14
27	*Entomognatus brevis* Van. Lind.	–	–	–	–	–	–	–	–	0.2	3.2	0.1	0.6
28	*Lindenius pygmaeus* armatus Van. Lind.	0.3	1.3	–	–	0.3	1.8	–	–	–	–	–	–
29	*Crossocerus quadrimaculatus* Fabr.	–	–	0.2	2.0	0.1	0.4	–	–	–	–	–	–
30	*Crossocerus varius* Lep. et Brul.	–	–	0.1	1.0	+	0.2	0.1	0.4	0.1	1.6	0.1	0.6
31	*Crossocerus elongatulus* Van. Lind.	5.5	24.7	0.6	5.9	3.0	18.7	1.5	6.3	0.3	4.8	0.9	5.9
32	*Crossocerus wesmaeli* Van. Lind.	2.4	10.8	0.1	1.0	1.2	7.6	0.6	2.5	–	–	0.3	1.9
33	*Crossocerus exiguus* Van. Lind.	0.1	0.4	0.2	2.0	0.2	0.9	–	–	–	–	–	–
34	*Crossocerus annulipes* Lep. et Brul.	1.8	8.2	0.5	4.9	1.1	7.2	5.4	22.5	0.5	7.9	2.9	18.7
35	*Crossocerus distinguendus* A. Mor.	–	–	0.7	6.9	0.3	2.1	0.4	1.7	–	–	0.2	1.3
	Total	22.3		1.01		16.5		24.0		6.3		15.5	

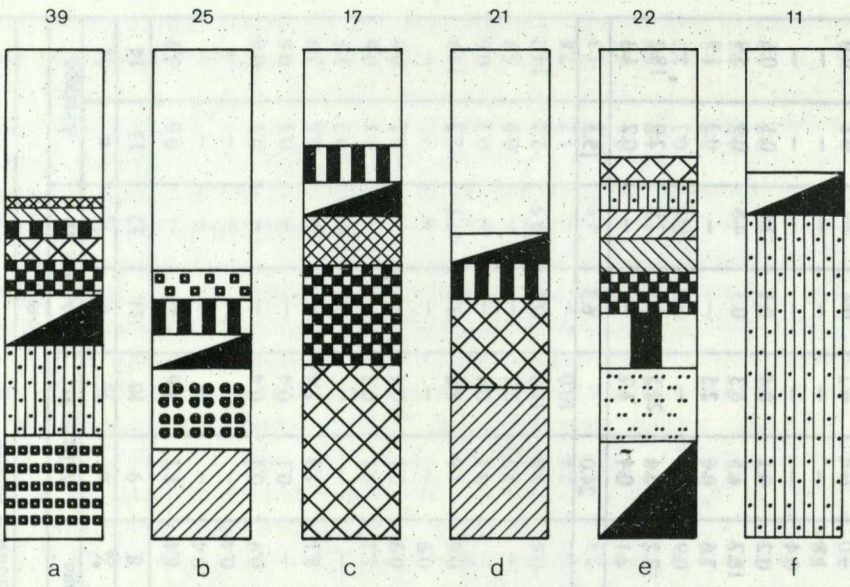


Fig. 4. Dominance structure of *Sphecidae* communities occurring in restructured habitats under different types of anthropogenic pressure. a — rural garden (Mroków), b — urban allotment gardens, c—f — green of housing estates (c — Wierzbno, d — Muranów, e — Wilcza Street, f — MDM); other symbols see page 155

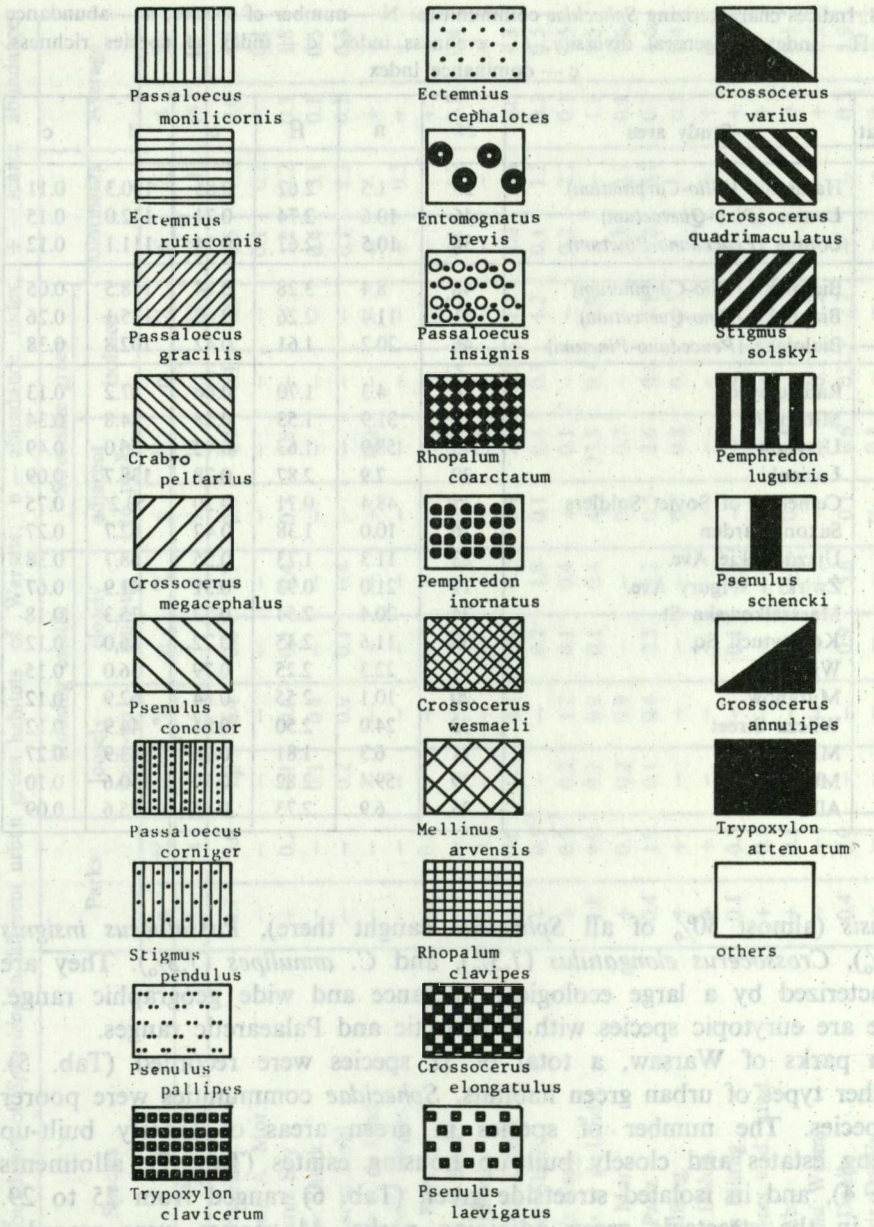
of the community; most of the species recorded in this study area were likely to be accidental species.

COMMUNITY OF URBAN ALLOTMENTS

Sphecidae of urban allotments were represented by an unexpectedly low number of 25 species, and their abundance was relatively low (6.9) (Tab. 8). Their abundance was lower than in urban parks and even in green areas of housing estates. The dominance structure of the community was characterized by a relatively uniform distribution of numbers of particular species. This was reflected in a high value of the evenness index. The most abundant species consisted of *Passaloecus singularis* (15.1%), *Pemphredon inornatus* (17.2), *Crossocerus annulipes* (11.1%), and *Pemphredon lugubris* (7.5% (Tab. 4).

DESCRIPTION OF COMMUNITIES IN URBAN GREEN HABITATS

A total of 70 *Sphecidae* species were recorded from urban green habitats of Warsaw (Tab. 9). The most abundant species consisted of *Mellinus*



Explanations for graphical symbols in Figures 1—4

Table 8. Indices characterizing *Sphecidae* communities: N — number of species, n — abundance index, H — index of general diversity, e — evenness index, d — index of species richness, c — dominance index

Habitat	Study area	N	n	H	e	d	c
Natural	Hamernia (*Tilio-Carpinetum*)	23	1.5	2.67	0.85	190.3	0.11
	Łomna (*Pino-Quercetum*)	46	10.6	2.74	0.71	142.0	0.15
	Łomna (*Peucedano-Pinetum*)	36	10.5	2.67	0.74	111.1	0.12
Modified	Białołęka (*Tilio-Carpinetum*)	48	8.4	3.28	0.84	168.5	0.05
	Białołęka (*Pino-Quercetum*)	41	11.4	2.26	0.60	125.1	0.26
	Białołęka (*Peucedano-Pinetum*)	46	20.2	1.61	0.42	102.8	0.38
Restructured	Radziejowice	14	4.3	1.70	0.66	67.2	0.13
	Młochów	14	31.9	1.53	0.58	24.8	0.34
	Ursynów	43	58.9	1.63	0.43	56.0	0.49
	Łazienki	39	7.9	2.87	0.78	138.7	0.09
	Cemetery of Soviet Soldiers	37	48.4	0.71	0.20	53.2	0.75
	Saxon Garden	26	10.0	1.38	0.42	82.7	0.27
	Ujazdowskie Ave.	23	11.3	1.73	0.55	68.7	0.38
	Żwirki i Wigury Ave.	19	21.0	0.93	0.31	41.9	0.67
	Marszałkowska St.	34	20.4	2.54	0.72	75.3	0.18
	Konstytucji Sq.	30	11.6	2.45	0.72	86.0	0.12
	Wierzbno	17	22.3	2.25	0.79	36.0	0.15
	Muranów	20	10.1	2.55	0.84	62.9	0.12
	Wilcza Street	22	24.0	2.50	0.81	44.9	0.12
	MDM II	11	6.3	1.81	0.76	43.9	0.27
	Mroków	39	59.4	2.82	0.77	50.6	0.10
	Allotments	25	6.9	2.73	0.85	95.6	0.09

arvensis (almost 30% of all *Sphecidae* caught there), *Passaloecus insignis* (7.5%), *Crossocerus elongatulus* (7.3%), and *C. annulipes* (7.3%). They are characterized by a large ecological tolerance and wide geographic range. These are eurytopic species with Holoarctic and Palaearctic ranges.

In parks of Warsaw, a total of 52 species were recorded (Tab. 5). In other types of urban green habitats, *Sphecidae* communities were poorer in species. The number of species in green areas of loosely built-up housing estates and closely built-up housing estates (Tab. 7), allotments (Tab. 4), and in isolated streetside green (Tab. 6) ranged from 25 to 29. Only in the streetside green adjoining parks, 44 species were recorded (Tab. 6).

Parks are established for the same purpose, and, consequently, they are utilized in the same way. But they differ from each other in a number of factors such as age, size vegetation structure, thus also in the degree of insolation and humidity, type of surrounding habitats, etc. This differentiation

Table 9. Occurrence and abundance of *Sphecidae* in different urban green habitats of Warsaw; n — abundance index, + — scarce abundance

No.	Species	Parks		Housing estates				Streetside green				Allotments		Average	
				loosely built-up		closely built-up		adjacent to parks		isolated					
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	*Pemphredon lugubris* Fabr.	0.7	3.6	1.0	6.4	0.6	3.7	0.8	4.7	0.1	0.9	0.5	7.5	0.6	4.3
2	*Pemphredon wesmaeli* A. Mor.	–	–	–	–	–	–	–	–	–	–	0.1	0.7	+	0.1
3	*Pemphredon inornatus* Say	+	0.2	0.1	0.4	0.1	0.4	0.3	1.8	–	–	1.2	17.2	0.3	1.8
4	*Pemphredon lethifer* Shuck.	–	–	0.1	0.4	–	–	–	–	–	–	0.4	5.1	0.1	0.5
5	*Pemphredon austriacus* Kohl	–	–	0.2	0.9	0.1	0.4	–	–	–	–	0.1	1.3	0.1	0.3
6	*Ceratophorus morio* v. d. Lind.	–	–	–	–	–	–	+	0.2	–	–	–	–	+	+
7	*Ceratophorus clypealis* Thoms.	–	–	–	–	–	–	–	–	–	–	+	0.3	+	+
8	*Diodontus minutus* Fabr.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
9	*Diodontus tristis* v. d. Lind.	–	–	–	–	0.1	0.5	0.1	0.3	0.2	1.3	0.1	1.2	0.1	0.4
10	*Diodontus luperus* Shuck.	+	0.1	–	–	–	–	+	0.1	–	–	–	–	+	+
11	*Passaloecus singularis* Dahlb.	0.1	0.6	1.3	8.1	0.6	4.2	0.4	2.5	0.2	1.7	1.0	15.1	0.6	4.3
12	*Passaloecus corniger* Shuck.	+	0.1	–	–	0.2	1.0	0.1	0.4	0.1	1.2	0.1	1.2	0.1	0.5
13	*Passaloecus gracilis* Curt.	+	0.1	0.2	1.2	0.1	0.4	+	0.1	–	–	0.2	2.2	0.1	0.5
14	*Passaloecus insignis* v. d. Lind.	1.8	9.0	0.2	0.9	0.1	0.4	4.4	25.5	0.1	0.9	–	–	1.1	7.5
15	*Stigmus solskyi* A. Mor.	+	0.1	0.2	0.9	–	–	0.1	0.7	–	–	0.3	3.7	0.1	0.6
16	*Stigmus pendulus* Panz.	0.4	1.9	0.1	0.6	2.3	15.2	0.5	2.6	0.6	5.1	0.2	3.2	0.7	4.6
17	*Spilomena beata* Blüthg.	+	+	–	–	–	–	0.1	0.8	0.2	1.7	–	–	0.1	0.4
18	*Spilomena curruca* Dahlb.	+	+	–	–	–	–	–	–	–	–	–	–	+	+
19	*Spilomena differens* Blüthg.	0.1	0.5	–	–	0.1	0.4	–	–	–	–	–	–	+	0.2
20	*Spilomena troglodytes* v. d. Lind.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
21	*Mimesa lutaria* Fabr.	+	0.1	–	–	–	–	0.1	0.5	–	–	–	–	+	0.1
22	*Mimumesa dahlbomi* Wesm.	–	–	–	–	–	–	–	–	0.1	1.2	–	–	+	0.2
23	*Psenulus concolor* Dahlb.	0.4	2.0	–	–	0.9	5.6	0.1	0.6	0.3	2.2	–	–	0.3	1.9
24	*Psenulus fuscipennis* Dahlb.	–	–	–	–	–	–	+	0.1	–	–	–	–	+	+
25	*Psenulus laevigatus* Schenck.	0.1	0.7	0.4	2.4	0.2	1.0	0.1	0.4	0.1	0.5	0.4	5.1	0.2	1.3
26	*Psenulus pallipes* Panz.	0.2	0.8	0.1	0.6	2.2	14.5	0.1	0.7	1.0	8.6	0.4	5.0	0.7	4.5

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
27	*Psenulus schencki* Tourn.	+	0.2	–	–	1.2	8.0	–	–	0.4	3.6	0.1	0.7	0.3	2.0
28	*Gorytes bicinctus* Rossi	+	0.1	–	–	–	–	+	0.2	+	0.3	0.1	0.7	+	0.1
29	*Gorytes quinquecinctus* Fabr.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
30	*Gorytes quadrifasciatus* Fabr.	–	–	–	–	0.1	0.4	–	–	–	–	–	–	0.1	0.1
31	*Nysson trimaculatus* Rossi	+	0.1	–	–	–	–	+	0.1	–	–	–	–	+	+
32	*Mellinus arvensis* L.	13.3	66.0	3.8	23.1	1.0	6.9	7.5	43.4	0.1	0.5	0.1	1.5	4.3	29.5
33	*Nitela spinolae* Latr.	–	–	–	–	0.3	2.0	+	0.1	–	–	–	–	0.1	0.4
34	*Trypoxylon clavicerum* Lep. et Serv.	+	0.2	0.6	3.9	0.2	1.2	0.2	1.0	+	0.3	0.2	2.9	0.2	1.4
35	*Trypoxylon attenuatum* Smith	+	0.2	0.2	0.9	0.2	1.2	–	–	0.1	1.0	0.4	5.5	0.1	1.0
36	*Trypoxylon figulus* L.	–	–	0.4	2.2	0.3	1.9	+	0.2	–	–	0.3	3.8	0.2	1.1
37	*Oxybelus mandibularis* Dahlb.	0.1	0.5	–	–	–	–	+	0.1	–	–	–	–	+	0.1
38	*Oxybelus latidens* Gerst.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
39	*Crabro cribrarius* L.	+	0.1	–	–	–	–	+	0.1	–	–	–	–	+	+
40	*Crabro peltarius* Schreb.	–	–	0.1	0.4	–	–	–	–	–	–	–	–	+	0.1
41	*Crabro loevi* Dahlb.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
42	*Crabro scutellatus* Scheven	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
43	*Ectemnius cephalotes* Oliv.	0.7	3.3	0.5	3.1	–	–	0.4	2.4	+	0.3	–	–	0.3	1.9
44	*Ectemnius lituratus* Panz.	+	0.2	–	–	–	–	+	0.1	+	0.3	–	–	+	0.1
45	*Ectemnius sexcinctus* Fabr.	0.1	0.5	–	–	–	–	0.2	1.0	1.9	16.1	–	–	0.4	2.5
46	*Ectemnius cavifrons* Thoms.	0.2	0.9	–	–	–	–	0.2	1.0	–	–	0.2	2.3	0.1	0.6
47	*Ectemnius ruficornis* Zett.	0.1	0.6	0.5	2.8	0.2	1.2	0.2	1.4	0.8	6.6	0.1	0.7	0.3	2.1
48	*Ectemnius lapidarius* Panz.	–	–	–	–	–	–	+	0.1	–	–	–	–	+	+
49	*Ectemnius continuus* Fabr.	–	–	0.3	1.9	–	–	+	0.1	–	–	–	–	0.1	0.3
50	*Ectemnius rugifer* Dahlb.	–	–	–	–	–	–	–	–	+	0.1	–	–	+	+
51	*Entomagnatus brevis* v. d. Lind.	–	–	–	–	0.1	0.7	–	–	0.4	3.7	–	–	0.1	0.6
52	*Lindenius albilabris* Fabr.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
53	*Lindenius panzeri* v. d. Lind.	+	0.2	–	–	–	–	+	0.2	–	–	–	–	+	0.1
54	*Lindenius pygmaeus armatus* v. d. Lind.	+	0.2	0.3	1.9	–	–	+	0.1	–	–	–	–	0.1	0.4
55	*Rhopalum clavipes* L.	+	0.1	–	–	–	–	0.3	1.8	+	0.3	0.1	0.9	0.1	0.5
56	*Rhopalum coarctatum* Scop.	+	0.2	–	–	–	–	+	0.1	+	0.3	–	–	+	0.1
57	*Crossocerus quadrimaculatus* Fabr.	0.1	0.5	0.1	0.4	–	–	–	–	–	–	–	–	+	0.2
58	*Crossocerus ovalis* Lep. et Brul.	0.1	0.3	–	–	–	–	+	0.1	–	–	–	–	+	0.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
59	*Crossocerus elongatulus* v. d. Lind.	0.1	0.5	3.0	18.6	0.9	6.1	0.1	0.7	2.2	18.8	0.1	1.0	1.1	7.4
60	*Crossocerus wesmaeli* v. d. Lind.	+	0.1	1.2		0.3	2.1	–	–	1.3	11.1	–	–	0.5	3.3
61	*Crossocerus distinguendus* A. Mor.	+	0.1	0.3	2.1	0.2	1.4	0.1	0.3	+	0.3	–	–	0.1	0.7
62	*Crossocerus exiguus* v. d. Lind.	–	–	0.2	0.9	–	–	+	0.1	–	–	–	–	+	0.2
63	*Crossocerus podagricus* v. d. Lind.	+	0.2	–	–	–	–	+	0.1	–	–	–	–	+	0.1
64	*Crossocerus assimilis* Smith	–	–	–	–	–	–	–	–	+	0.3	–	–	+	+
65	*Crossocerus annulipes* Lep. et Brul.	0.1	0.5	1.2	7.2	2.9	19.5	0.1	0.8	1.3	10.6	0.8	11.2	1.1	7.3
66	*Crossocerus varius* Lep. et Brul.	0.6	3.1	+	0.2	0.1	0.8	0.4	2.1	–	–	–	–	0.2	1.3
67	*Crossocerus nigritus* Lep. et Brul.	+	0.2	–	–	–	–	–	–	+	0.2	–	–	+	0.1
68	*Crossocerus megacephalus* Rossi	+	0.1	–	–	–	–	0.1	0.3	–	–	–	–	+	0.1
69	*Crossocerus capitosus* Shuck.	+	0.1	–	–	–	–	–	–	–	–	–	–	+	+
70	*Crossocerus vagabundus* Panz.	+	0.2	–	–	–	–	–	–	–	–	–	–	+	+
	Total	20.0		17.3		16.6		15.5		11.8		7.5		15.0	

of parks accounts for the diversity of *Sphecidae* communities occurring there. As the differentiation of the study areas goes in many different directions, it was not possible to distinguish the factors responsible for particular features of the communities. Based on the studies carried out so far, it is possible to provide a detailed description of *Sphecidae* communities but not to explain their structure.

The species composition of *Sphecidae* occurring in urban parks was relatively rich and largely similar.

The Sörensen index (S) ranged from 62 to 70% (Fig. 5). The species

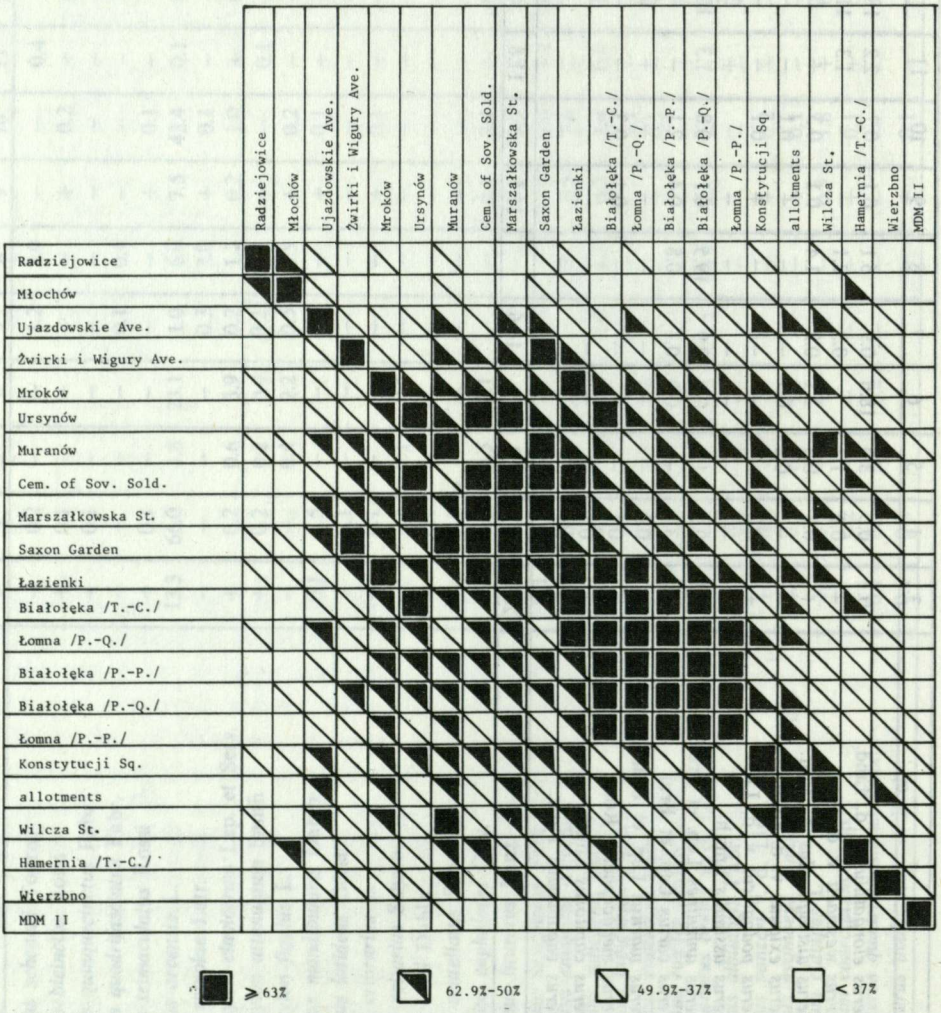


Fig. 5. Diagram of similarity in the species composition of *Sphecidae* communities occurring in non-urban, suburban, and urban (Warsaw) study areas (T.-C. — *Tilio-Carpinetum*, P.-Q. — *Pino-Quercetum*, P.-P. — *Peucedano-Pinetum*)

composition of the *Sphecidae* community occurring in the park at the Cemetery of Soviet Soldiers was similar to those in the Saxon Garden (S=70%) and the Łazienki Park (S=68%). But the communities from the Saxon Garden and the Łazienki Park were less similar to each other (S=62%).

The *Sphecidae* communities living in parks were similar to those in adjoining streetside green. *Sphecidae* are well flying insects, so one should expect they their species composition will be most similar in adjoining areas, that is in parks and the bordering streetside green. But this was not the case. The similarity between *Sphecidae* communities from the Łazienki Park and the adjoining Ujazdowskie Avenue was only 45%. The community from the park at the Cemetery of Soviet Soldiers was similar to that from the adjoining Żwirki i Wigury Avenue in 61%. The highest similarity of 67% was found between the communities from the Saxon Garden and Marszałkowska Street. Though this is a relatively high value, it should be noted that the *Sphecidae* community from the Saxon Garden was more similar to that from Żwirki i Wigury Avenue at the park at the Cemetery od Soviet Soldiers (S=69%).

The species composition of *Sphecidae* communities occurring in parks was distinct from that in study areas of other types. The similarity of park communities to them was generally lower, particularly to the communities living in green areas of housing estates, isolated streetside green and allotments. The only exception was a relatively high similarity between the communities from the Saxon Garden and green areas of Muranów housing estate.

Park communities of *Sphecidae* formed a complex only with respect to their species composition, while they differed in their dominance structure and abundance. The community from the park at the Cemetery of Soviet Soldiers was much more abundant that those from the Saxon Garden and Łazienki Park.

Sphecidae communities from the park at the Cemetery of Soviet Soldiers differed from that occurring in the Łazienki Park with respect to the dominance structure (Fig. 2). The index of similarity in dominance structure (S_d) was very low, reaching 0.15. The dominance structure of the *Sphecidae* community from the Saxon Garden was of an intermediate character, and it was similar to the structure of the community from the Łazienki Park (S_d=0.65) and from the park at the Cemetery of Soviet Soldiers (S_d=0.61).

A very similar dominance structure was noted for the communities occurring in parks and the adjoining streetside green (Fig. 3). The similarity in the structure of *Sphecidae* communities was the highest for the park at the Cemetery of Soviet Soldiers and Żwirki i Wigury Avenue,

the similarity index being more than 0.99. For the communities from the Saxon Garden and Marszałkowska Street this index was 0.98, and for the Łazienki Park and Ujazdowskie Avenue 0.76.

In the case of the group of communities occurring in streetside green adjoining parks the situation was similar as in the case of the group of communities living in parks. *Sphecidae* communities from green adjoining the Łazienki Park (Ujazdowskie Avenue) and from green adjoining the park at the Cemetery of Soviet Soldiers (Żwirki i Wigury Avenue) had different dominance structures (S_d=0.14), like these parks, while the community from Ujazdowskie Avenue had a similar structure to that of the community from Marszałkowska Street (S_d=0.77).

Sphecidae communities from streetside green adjoining parks were simplified continuations of the communities from respective parks. This is indicated by relatively high values of their indices of similarity, at higher values of the indices of species richness for park communities. The similarity of these communities increased with the decreasing of the size of the park, as the habitat conditions in the park became more similar to those in the streetside green areas. Under similar and unfavourable conditions, like for example on streetside plots, *Sphecidae* communities tend to produce similar dominance structures. The communities from Ujazdowskie Avenue and Marszałkowska Street were dominated by the same species, and the index of similarity in their dominance structure (S_d) was 0.77. *Sphecidae* communities in parks, that is, in the Łazienki Park and the Saxon Garden, showed more differences, and the similarity index of their dominance structure was 0.65.

Thus, *Sphecidae* communities occurring in urban parks and in neighbouring streetside green areas qualitatively represent one type, though in two variants of the dominance structure.

The communities from other types of urban green areas were much more diversified. The green of housing estates both loosely and closely built-up is of such an individual character that the *Sphecidae* communities occurring there markedly differed in their species composition, numbers, and dominance structure (Tab. 7). The similarity in species composition (S) for communities living in loosely built-up housing estates (Wierzbno and Muranów) was 59% and for the communities in closely built-up housing estates (Wilcza Street and MDM II) it was 42%. Among *Sphecidae* communities from housing estates, the most similar species composition was found between those from Muranów and the courtyard at Wilcza Street. The similarity index in the species composition (S) of these communities was as high as 70%. Both these study areas were close to urban gardens, and this probably largely determined the composition of *Sphecidae* communities. The communities from Muranów and Wilcza Street were also similar to

the community occurring in allotments (S=57% and S=63%, respectively).

The diversity of *Sphecidae* communities from different green habitats of housing estates was even more clear-cut with respect to their dominance structure (Fig. 4). The index of similarity (S_d) for communities occurring in loosely built-up housing estates (Wierzbno and Muranów) was 0.57, and for those occurring in closely built-up areas (Wilcza Street and M.D.M. II) it was 0.23. The dominance structure of the community from Wierzbno was most similar to that from the park at the Cemetery of Soviet Soldiers and from Żwirki i Wigury Avenue adjoining this park. The dominance structure of the community from Muranów was most similar to that from the allotments. The values of S_d were 0.65 in all these cases. *Sphecidae* communities from green areas of closely built-up housing estates were characterized by a distinct dominance structure. The index of their similarity to other communities did not reach 0.50 in any case.

The analysis of the species composition, dominance structure, and abundance of *Sphecidae* communities occurring in green areas of housing estates shows that they shared such features as a relatively low number of species, and generally rather uniform distribution of the abundance of particular species, this being reflected in relatively high values of the evenness index (Tab. 8). The only exception was the community from a small, dark courtyard in M.D.M II. This community was clearly dominated by only one species, which was reflected in more than two times higher values of the dominance index than for other communities from housing estates. The communities from housing estates had a specific dominance structure, not occurring in other *Sphecidae* communities. Their distinct character was related to their higher numbers, and also to the proportion of such species as *Crossocerus annulipes, C. elongatulus, Passaloecus singularis,* and *Psenulus pallipes* (Fig. 9); for example, the proportion of *C. annulipes* was about 7% of the community in loosely built-up housing estates, and about 19% in closely built-up housing estates, while from 0.1 to 2.0% in urban parks, 1.4% in the modified linden-oak-hornbeam forest (Białołęka Dworska), and zero in the natural linden-oak-hornbeam forest (Hamernia).

In the isolated streetside green, the number of *Sphecidae* species was relatively high, but they probably did not form communities there, or they formed extremely simplified communities. This was indicated by differences in the local fauna recorded in particular years; the number of species, species composition, and dominance structure were variable. Of 30 species recorded there only three were present permanently. Nests with developmental stages of two of them (*Crossocerus elongatulus* and *Psenulus pallipes*) were found in dry branches at the Konstytucji Square. Thus, it is absolutely sure that these two species nest in isolated streetside green. But the great

majority of *Sphecidae* immigrated there from other areas as accidental species.

COMMUNITIES OF URBAN GREEN HABITATS IN RELATION TO THOSE FROM OTHER HABITATS

In the natural habitats under study, *Sphecidae* were relatively little abundant. In modified habitats, their numbers were generally several times higher than in homologous natural habitats. This was the case of all the communities under study, that is, in both linden-oak-hornbeam forests and coniferous forests. In restructured habitats on the sites of linden-oak-hornbeam forests, the abundance of respective communities was much more diversified. It was always higher than in the natural linden-oak-hornbeam forest, and differences in numbers could range from several times to 40 times.

At the present stage of investigations it can be stated that the number of species in *Sphecidae* communities depends, at least to some degree, on the way of management and utilization of the green area. No such relationship was found for their numbers.

The highest numbers of *Sphecidae* were noted in green of restructured habitats adjoining agrocoenoses. It should be remembered that the habitats under study differed in the way of management. They included a rural garden (Mroków) and parks, including a rural park (Młochów), a suburban park (Ursynów), and an urban park at the Cemetery of Soviet Soldiers. The communities occurring in the other parks under study, that is, in the rural park at Radziejowice and in urban parks (Łazienki and Saxon Garden), also in urban allotments, were characterized by a low abundance.

The number of species in modified habitats and also in restructured park habitats (urban and suburban parks) was high. Only in rural parks the number of species was low. These study areas were characterized by a high humidity and low insolation, thus they were not suitable for *Sphecidae*. *Sphecidae* communities occurring in green areas of housing estates comprised clearly less species than those occurring in parks. Thus, different habitat conditions, for example, such as in rural parks and in green areas of housing estates, produce the same effect — *Sphecidae* communities poor in species.

Among the restructed habitats, only parks and gardens were represented by study areas located within and outside the town. The other types of urban green areas under study had no corresponding habitats outside the town. There were considerable differences between the rural garden and urban allotment gardens due to the character of neighbouring areas

and the way of their management (allotment gardens were much more heterogeneous). There were also differences in *Sphecidae* communities between these two study areas. These differences concerned species composition, abundance, and dominance structure (Fig. 4). Thus, differences in the character of cultivation treatments and in the location of the site accounted for the development of different *Sphecidae* communities. Despite these differences in the number of species, community abundance, and abundance of individual species, the indices of evenness, dominance, and general diversity were rather similar for these communities, while the index of species richness was much higher for the community occurring in allotments. Though the *Sphecidae* community in the rural garden contained 14 species more, its abundance was higher by a factor of more than 8. Consequently the number of species in relation to their abundance was higher for the community from urban allotment gardens, accounting for a significant difference in the value of the index of species richness.

Sphecidae communities from all the parks under study differed from each other in the number of species and abundance (Tab. 8). With respect to the character of the dominance structure, the *Sphecidae* communities occurring in parks can be classified into two groups. One group consists of the communities from the two rural parks and the Łazienki, which is on old, large, urban park. The other group comprises the communities from the suburban park (Ursynów) and from the urban park at the Cemetery of Soviet Soldiers (Fig. 6). The communities of the first group are characterized by a lower abundance and more even distribution of the proportions of particular species, as compared with the communities of the second group. This is reflected in the values of the dominance index and the evenness index. The evenness index for *Sphecidae* communities in rural parks and the Łazienki Park ranged from 0.58 to 0.78, and the dominance index from 0.09 to 0.34. For the *Sphecidae* communities from the suburban park and from the park at the Cemetery of Soviet Soldiers the evenness index was 0.43 and 0.20, and the dominance index was 0.49 and 0.75, respectively.

The *Sphecidae* communities of the first group shared three dominant species: *Passaloecus insignis, Stigmus pendulus,* and *Psenulus concolor* (Fig. 2). The values of the index of similarity in dominance structure were 0.81 for the communities in Młochów and the Łazienki Park, and 0.67 for the communities in Radziejowice and the Łazienki Park (Fig. 6).

The *Sphecidae* communities of the second group also shared three dominant species. These were *Mellinus arvensis, Pemphredon lugubris*, and *Ectemnius cephalotes*. The proportions of these species in the communities compared were very similar. The index of similarity in dominance structure was as high as 0.97.

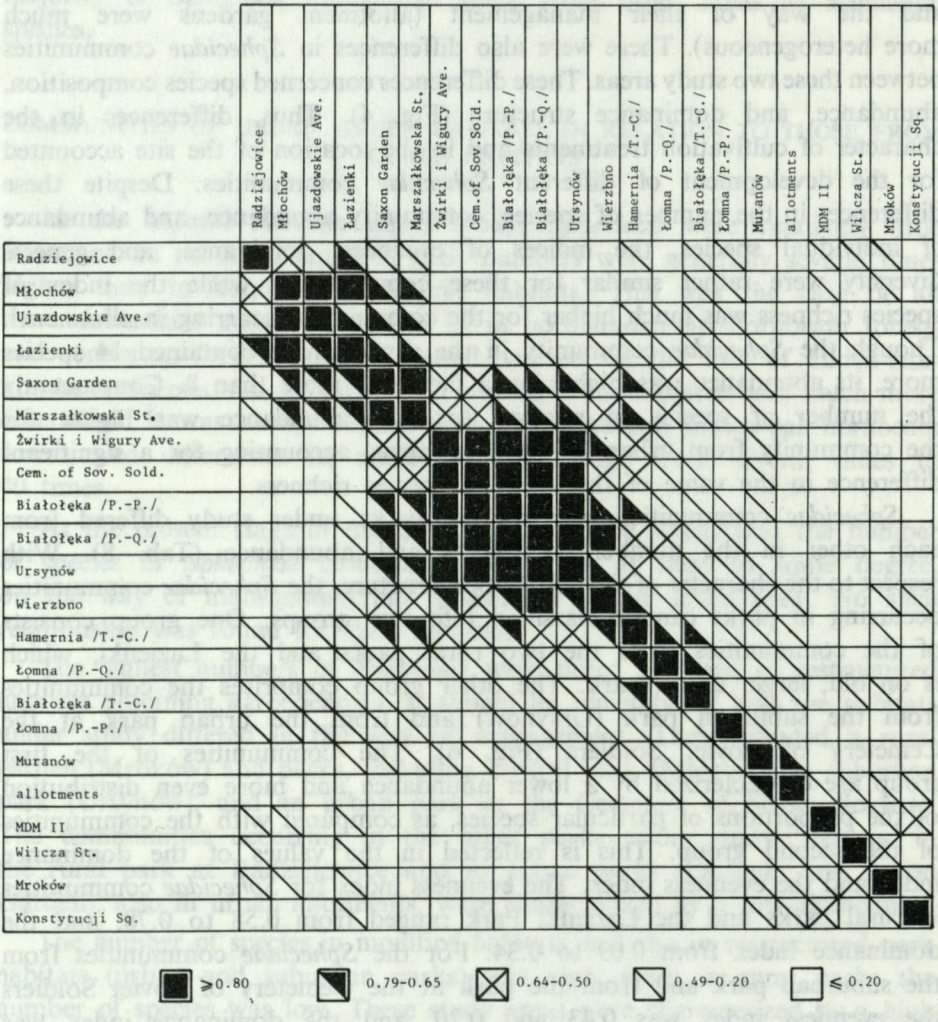


Fig. 6. Diagram of similarity in the dominance structure of *Sphecidae* communities occurring in non-urban, suburban, and urban (Warsaw) study areas. Symbols for study areas as in Fig. 5

The *Sphecidae* community occurring in the Saxon Garden is of an intermediate character between these two types. Its evenness index was 0.42 and dominance index 0.27. The index of similarity in the dominance structure between the community from the Saxon Garden and the communities from other parks under study ranged from 0.61 to 0.67. An exception was the community from the rural park at Radziejowice (S_d=0.31). The group of dominant species in the community from the Saxon Garden

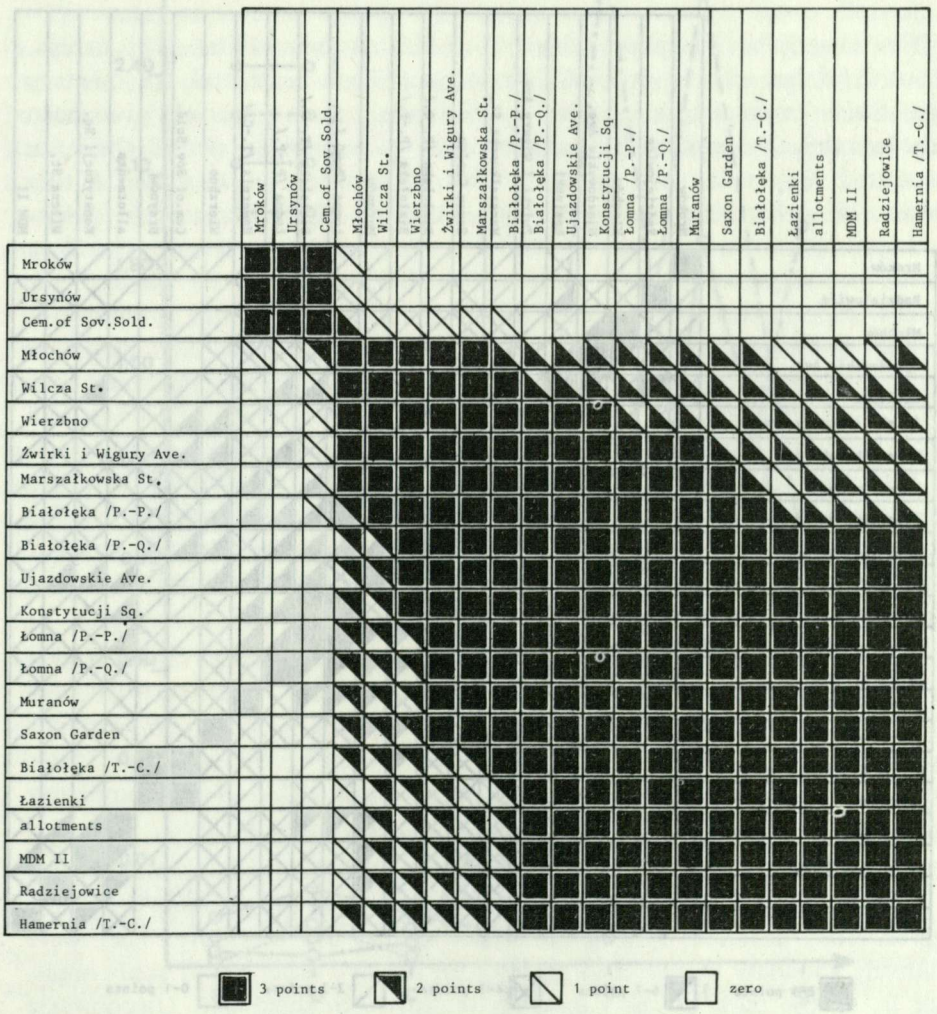


Fig. 7. Diagram of quantitative similarity between *Sphecidae* communities occurring in non-urban, suburban, and urban (Warsaw) study areas. Symbols for study areas as in Fig. 5

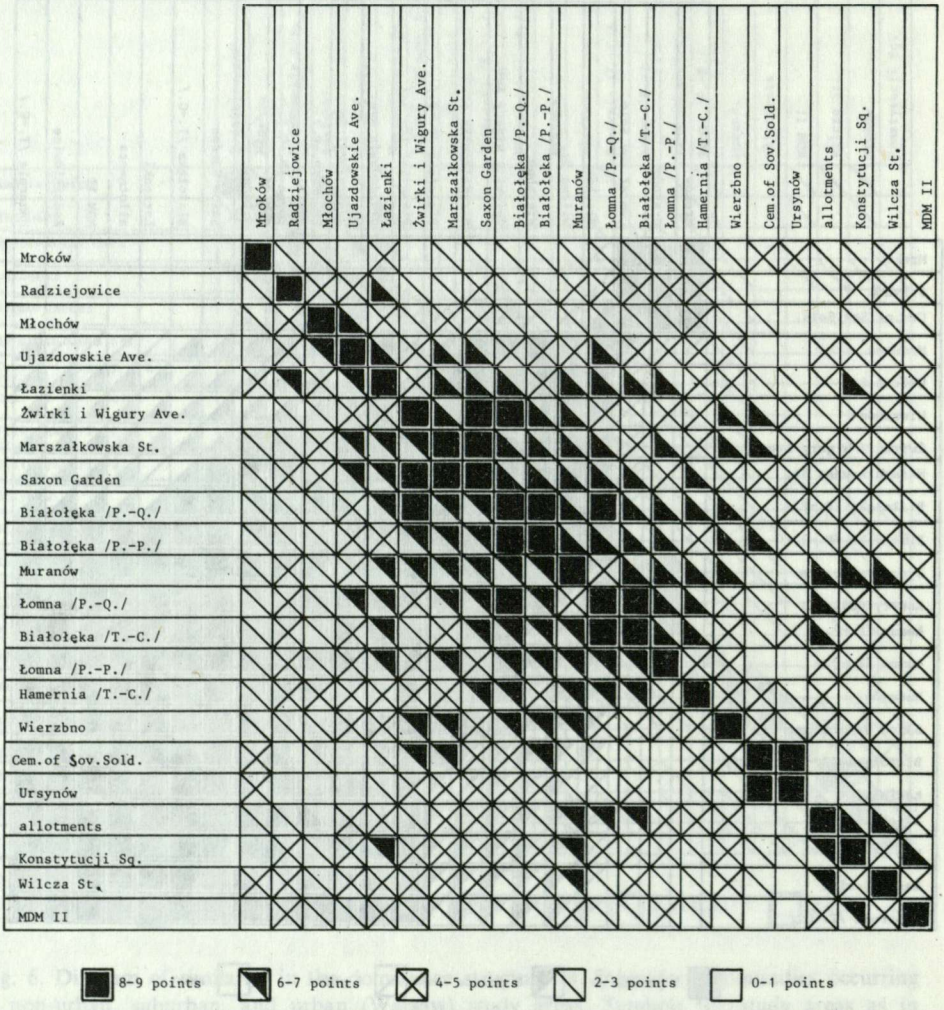


Fig. 8. Diagram of cumulative similarity between *Sphecidae* communities in non-urban, suburban, and urban (Warsaw) study areas. Symbols for study areas as in Fig. 5.

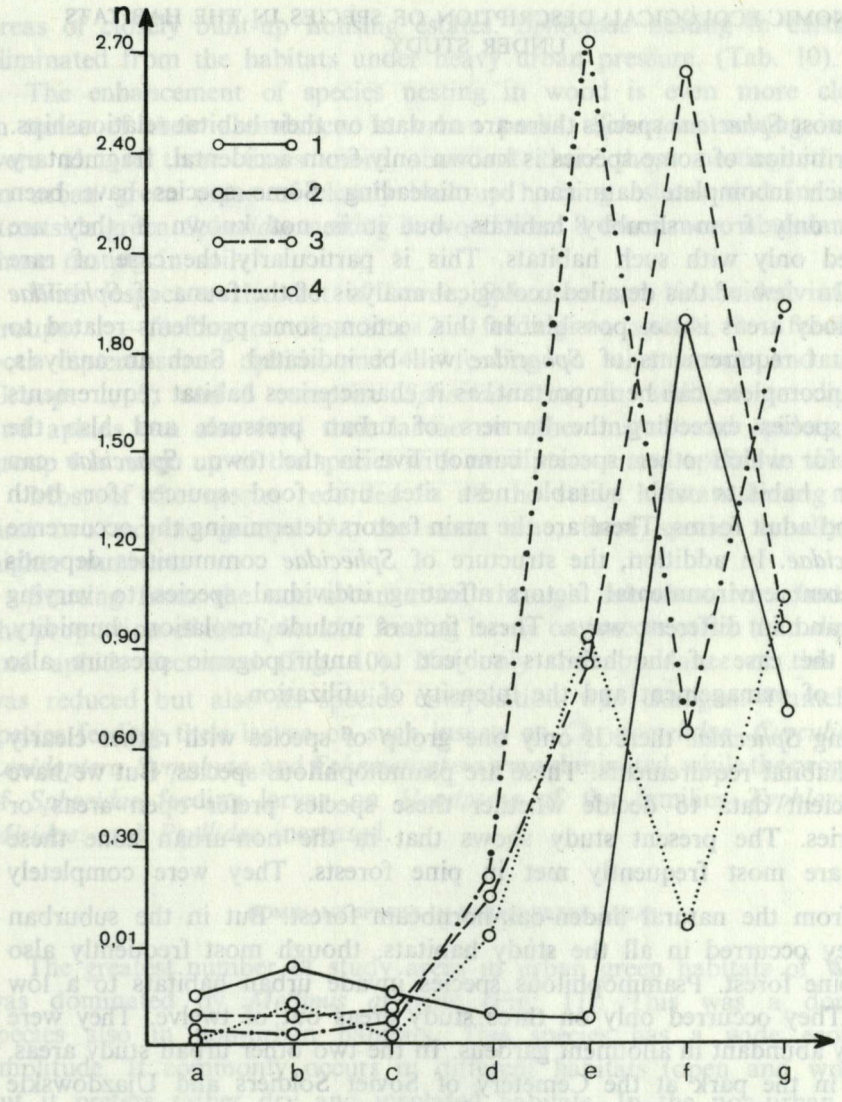


Fig. 9. Relationship between the abundance of some *Sphecidae* species and urban pressure. n — abundance index, 1 — *Crossocerus wesmaeli*, 2 — *C. annulipes*, 3 — *C. elongatulus*, 4 — *Psenulus pallipes*, a — natural habitats, b — modified habitats, c — urban parks, d — streetside green adjoining parks, e — green of housing estates loosely built-up, f — green of housing estates closely built — up, g — isolated streetside green

includes some dominant species of the communities from rural parks and the Łazienki Park as well as some dominant species from the suburban park and the park at the Cemetery of Soviet Soldiers.

BIONOMIC-ECOLOGICAL DESCRIPTION OF SPECIES IN THE HABITATS UNDER STUDY

For most *Sphecidae* species there are no data on their habitat relationships. The distribution of some species is known only from accidental, fragmentary data. Such incomplete data can be misleading. Some species have been recorded only from shrubby habitats, but it is not known if they are associated only with such habitats. This is particularly the case of rare species. In view of this detailed ecological analysis of the fauna of *Sphecidae* in the study areas is not possible. In this section, some problems related to the habitat requirements of *Sphecidae* will be indicated. Such an analysis, though incomplete, can be important, as it characterizes habitat requirements of the species exceeding the barriers of urban pressure, and also the reasons for which other species cannot live in the town. *Sphecidae* can occur in habitats with suitable nest sites and food sources for both larval and adult forms. These are the main factors determining the occurrence of *Sphecidae*. In addition, the structure of *Sphecidae* communities depends on different environmental factors affecting individual species to varying degrees and in different ways. These factors include insolation, humidity, and in the case of the habitats subject to anthropogenic pressure also the way of management and the intensity of utilization.

Among *Sphecidae* there is only one group of species with rather clearly defined habitat requirements. These are psammophilous species. But we have no sufficient data to decide whether these species prefer open areas or shrubberies. The present study shows that in the non-urban zone these species are most frequently met in pine forests. They were completely absent from the natural linden-oak-hornbeam forest. But in the suburban zone they occurred in all the study habitats, though most frequently also in the pine forest. Psammophilous species invade urban habitats to a low degree. They occurred only on three study areas out of twelve. They were relatively abundant in allotment gardens. In the two other urban study areas, that is, in the park at the Cemetery of Soviet Soldiers and Ujazdowskie Avenue, only single individuals were recorded.

With respect to their nesting habits, three groups of *Sphecidae* can be distinguished: 1) constructing earth nests, 2) constructing nests in wood, in corridors of xylophages, in branches of trees and shrubs, and in wooden stems of herbaceous plants, and 3) constructing nests in both earth and wood. In *Sphecidae* communities occurring in the habitats arranged in the gradient of increasing urban pressure, the proportion of species nesting in wood increases. Their proportion was about 56% in the communities from urban parks, and more than 73% in the communities from green

areas of closely built-up housing estates. *Sphecidae* nesting in earth were eliminated from the habitats under heavy urban pressure. (Tab. 10).

The enhancement of species nesting in wood is even more clear-cut in terms of their abundance. In urban parks, *Sphecidae* nesting in earth were almost three times more abundant than those nesting in wood. In urban green areas of closely built-up housing estates and in isolated streetside green *Sphecidae* nesting in wood were 8 times more abundant than those nesting in soil.

With respect to the diet of larvae, *Sphecidae* can be divided into four groups: 1 — feeding on dipterans, 2 — feeding on aphids, 3 — feeding on both dipterans and aphids, and 4 — feeding on other insects and spiders. Groups 1, 2, and 3 comprise *Sphecidae* that in addition to dipterans and aphids can also feed their larvae on other insects and spiders, while group 4 is made up of the species with no dipterans and aphids in their diet.

Most of the species recorded in all the study habitats belong to the first two trophic groups. At the same time, these species usually reach higher numbers.

Starting from the non-urban zone, through suburban to urban zone, the proportion of the *Sphecidae* feeding larvae on insects other than dipterans and aphids decreased (Fig. 10). Not only the abundance of this group was reduced but also its species composition was changed. Namely, the species feeding their larvae on such insects as *Chrysomelidae, Curculionidae, Lepidoptera, Symphyta,* and *Ephemeroptera* were eliminated, while the proportion of *Sphecidae* feeding larvae on *Hemiptera* of the families *Typhlocybidae, Miridae,* and *Psyllidae* increased.

DOMINANT SPECIES IN URBAN GREEN AREAS

The greatest number of study areas in urban green habitats of Warsaw was dominated by *Mellinus arvensis* (Fig. 11). This was a dominant species also in non-urban habitats. This species has a wide ecological amplitude. It commonly occurs in different habitats (open and wooded), but it prefers rather dry and insolated habitats. In the non-urban study habitats its abundance was much higher in coniferous as compared with linden-oak-hornbeam forests. It was not recorded from humid rural parks at all. *M. arvensis* build their nests in earth, usually in sandy loam soils. They feed offspring on various dipterans, most of which are common in the town. These are dipterans of the genera *Calliphora R.-D., Sarcophaga Meig., Lucilia R.-D., Stomoxys Geoffr.,* and *Pollenia R.-D.* (Draber-Mońko 1982, Górska 1982). It follows from the data on the biology of *M. arvensis* that both their diet and habitat requirements predispose this species for invading urban habitats. Under favourable habitat conditions this species

Table 10. The number of species and abundance of *Sphecidae* differing in their nesting habits in urban green of Warsaw: N — number of species, %N — percentage of species, n — abundance index, %n — percentage of individuals

Type of greenery / Nesting sites	Parks				Housing estates								Street sides							
					Loosely built				Closely built				Adjacent to park				Isolated			
	N	%N	n	%n	N	%N	n	%n	N	%N	n	%n	N	%N	n	%n	N	%N	n	%n
Earth	16	30.8	15.8	71.7	6	22.2	5.8	36.3	4	15.4	1.6	10.7	11	24.4	6.9	38.8	4	13.3	1.0	8.4
Branches	29	55.8	5.4	24.5	18	66.7	7.2	44.5	19	73.1	12.4	81.8	29	64.4	10.1	55.8	21	70.0	7.8	67.0
Earth and branches	5	9.6	0.8	3.4	3	11.1	3.1	19.3	3	11.5	1.1	7.5	4	8.9	1.0	5.4	3	10.0	2.7	23.2
Unknown	2	3.8	0.1	0.4	–	–	–	–	–	–	–	–	1	2.2	0.1	0.1	2	6.7	0.2	1.4

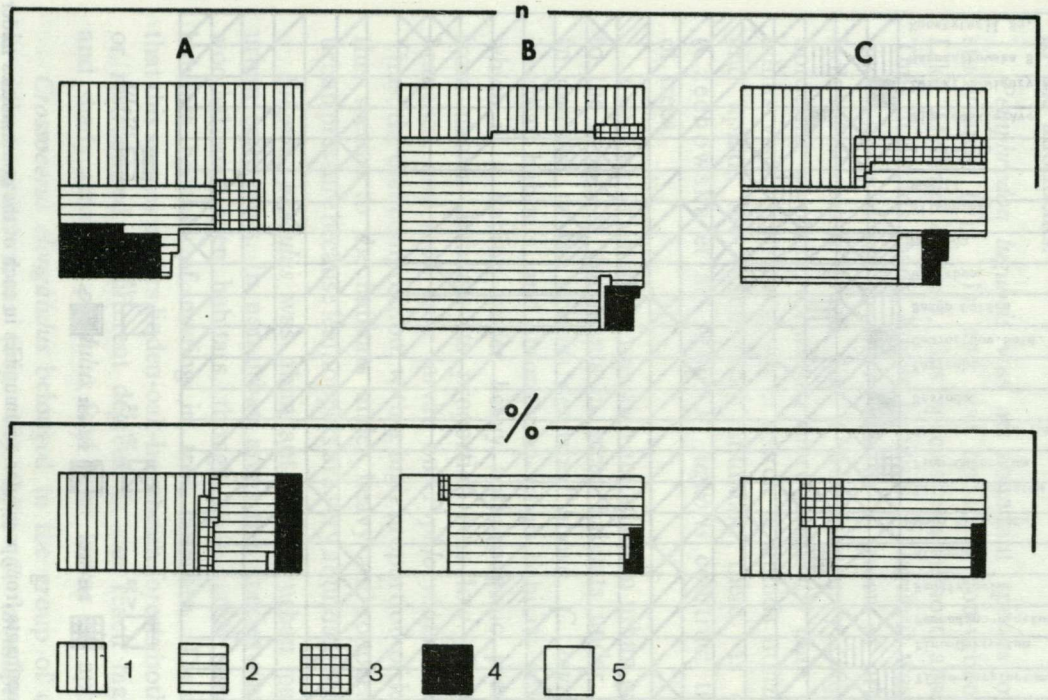


Fig. 10. Numbers (n) and proportion (%) of trophic groups in *Sphecidae* communities of the non-urban (A), suburban (B), and urban (C) zones. *Sphecidae* feeding on: 1 — aphids, 2 — dipterans, 3 — aphids and dipterans, 4 — other insects and spiders, 5 — diet unknown

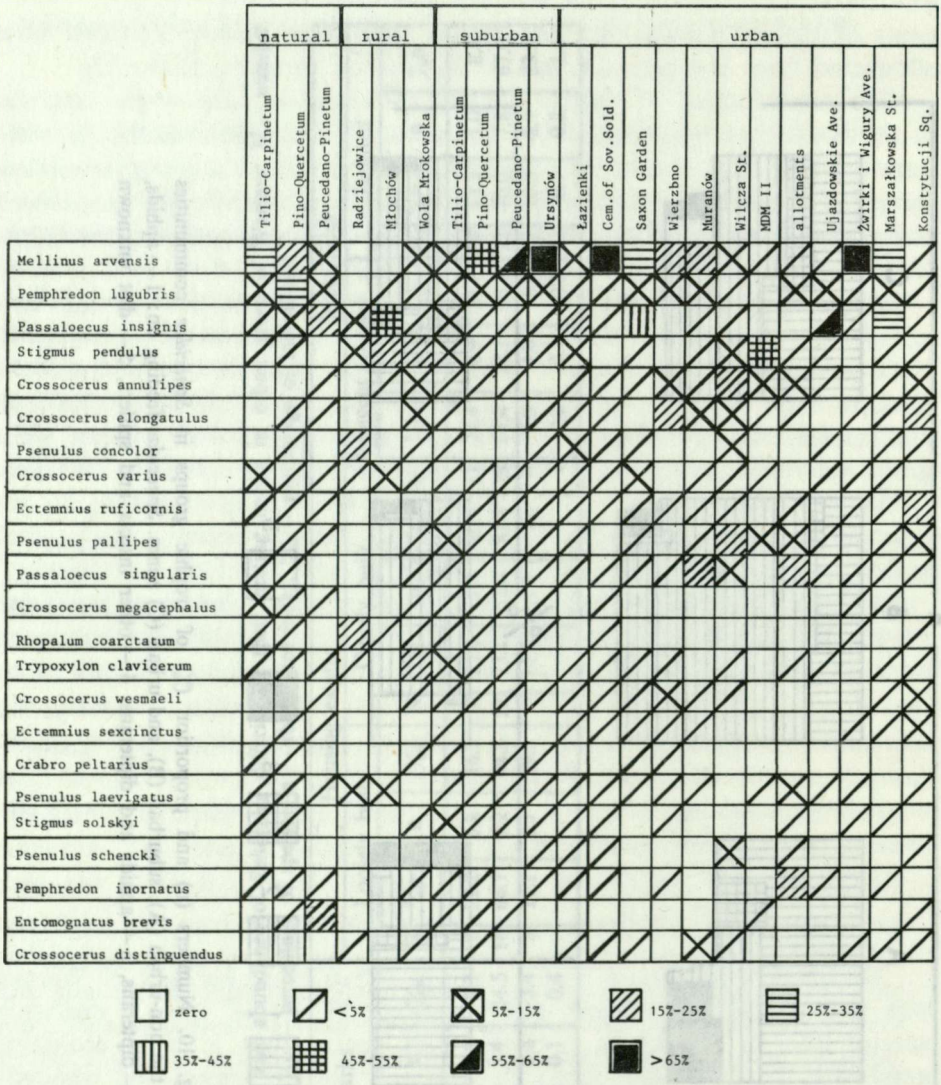


Fig. 11. Percentage of dominants from particular communities in each of the communities under study

can reach very high numbers, for example, in the park at the Cemetery of Soviet Soldiers. But it may happen that the way of utilization, or the type of management preclude its occurrence. And so *M. arvensis* was relatively scarce in the rural garden, in urban allotment gardens, and in streetside isolated green areas. The importance of the way of habitat utilization to the occurrence of this species is indicated by the fact that

it was dominant and accounted for more than 80% of the *Sphecidae* caught in the park at the Cemetery of Soviet Soldiers, located close to the allotments.

Pemphredon lugubris was an abundant species on most of the urban study areas (Fig. 11), and also on some non-urban and suburban areas. Like *Mellinus arvensis,* this species was almost absent from rural parks. Thus, it avoids shady, humid habitats. *P. lugubris* was scarce in the habitats under heavy urban pressure, that is, in green of urban courtyards and in isolated streetside green. But it was frequently caught in streetside green bordering on parks, sometimes more frequently than within parks. Probably adults visit streetside green in search of aphids utilized as food for larvae, and aphids are much more abundant there, as compared with parks (Czechowska et al. 1979). *P. lugubris* construct their nests in branches of trees.

Crossocerus annulipes was also abundant in urban green areas. It belonged to the group of dominants in green habitats under heavy urban pressure. In contrast to the species described above, *C. annulipes* dominated only in urban habitats, and among non-urban habitats only in the rural garden, which is a habitat under heavy anthropogenic pressure. In communities from natural habitats its proportion was low. *C. annulipes* nest in tree branches, and feed their larvae on *Typhlocybidae, Miridae,* and *Psyllidae.* Thus, the diet composition, with a high proportion of leafhoppers, predisposes this species to the habitats under heavy anthropogenic and, in particular, urban pressure because leafhoppers are very abundant there (Chudzicka 1979).

Stigmus pendulus was abundant in old urban parks and in green of urban courtyards. In non-urban areas this species was recorded from both wooded and open habitats, though it is rather associated with wooded habitats because of nesting in tree branches. The present study shows that this species prefers linden-oak-hornbeam forests both natural and modified or restructured to different degrees. It can reach high numbers in humid and shady areas. *S. pendulus* feed their larvae on aphids.

Crossocerus elongatulus belonged to the group of dominant species only in urban green areas (Fig. 11). Like *C. annulipes*, it did not reach high numbers in natural and modified habitats, where it accounted to less than 0.5% of the community, on the average. Nor in parks was it abundant (0.4%). But in streetside green bordering on parks its proportion was 0.7%, in closely built-up housing estates 5.9%, and in loosely built-up areas 18.7%. *C. elongatus* is characterized by a great ecological tolerance. It can nest in tree branches and also in earth. According to Bones (1968) it also nests in walls of buildings and in concrete balcony boards. It feeds larvae on aphids and small dipterans (*Drosophilidae, Phoridae, Agromyzi-*

dae, Chloropidae), but it also catches larger dipterans such as *Empididae, Syrphidae, Calliphoridae*, and *Larvevoridae* (Leclercq 1954).

Passaloecus insignis in urban habitats was most abundant in old parks. In non-urban habitats was abundant in coniferous forests, and also in modified and restructured linden-oak-hornbeam forests (Fig. 11). This species seems to be sensitive to different types of anthropogenic pressure, as indicated by its low numbers in intensely cultivated areas (e.g., the rural garden) and in urban habitats (e.g., allotments and housing estates). It nests in tree branches and feeds offspring on aphids.

Passaloecus singularis also nests in branches and feeds larvae on aphids but, unlike *P. insignis*, was one of the dominant species in green of loosely and closely built-up housing estates. It did not belong to the group of dominants in the non-urban zone.

The species of the genus *Psenulus* Kohl, such as *P. concolor, P. laevigatus*, and were dominant in non-urban habitats with higher humidity, such as rural parks. In natural habitats they were not abundant. They build nests in wood, and feed their larvae on aphids and other small insects, e.g., *Thysanoptera*. They occur in open and wooded areas, though because of their nesting habits they are rather associated with wooded habitats.

Two species of the genus *Ectemnius* Dahlb, *E. ruficornis* and *E. sexcinctus*, were abundant on single study areas in urban habitats. They were relatively abundant in isolated streetside green, though not in every study year. As compared to other *Sphecidae*, these are rather large insects, so it seems probable that they were not passively blown by the wind there, but activvely visited these habitats. They build nests in branches or in corridors of xylophages, and feed larvae on dipterans common in urban green, such as *Muscidae, Calliphoridae, Sarcophagidae*, and *Syrphidae*.

Pemphredon inornatus dominated only in urban allotment gardens. It feeds larvae on aphids and nests in branches.

This review of the species abundant in urban green habitats shows that they are characterized by a high ecological tolerance, and occupy different habitats. Most of them nest in branches. They feed their larvae either on dipterans common in urban habitats or on aphids. *Crossocerus annulipes* is the only species with a different diet, as it feeds on leafhoppers. Leafhoppers are very abundant in urban habitats, so this species has an abundant food supply as well.

SPECIES NOT OCCURRING IN URBAN HABITATS

Some members of the *Sphecidae* communities under study occurred only in the non-urban and suburban zones. A large part of this group was

represented by psammophilous species. These were *Alyson fuscatus*, *A. lunicornis*, *Ammophila sabulosa*, *A. affinis*, *A. luffi*, *Bembecinus tridens*, and *Oxybelus bipunctatus*. They were most abundant in the suburban zone. *Sphecidae* of the genera *Alyson* Panz. and *Bembecinus* Costa feed their larvae on leafhoppers, and those of the genus *Ammophila* Kirby on larvae of lepidopterans and *Symphyta*. *Oxybelus bipunctatus*, like other species of this genus, feed their larvae mostly on dipterans. Thus, most probably not the diet but the character of their nest sites is the factor limiting the occurrence of these insects in the town. Also *Cerceris quadrifasciata* and *Tachysphex panzeri* can be included to this group of species, as their habitat requirements are similar to those of psammophilous species. The literature data and the present observations suggest that these two species prefer mainly open habitats. *C. quadrifasciata* feed their larvae on beetles of the family *Curculionidae*, and *T. panzeri* on insects of the order *Orthoptera*.

The species preferring humid areas have not been recorded from urban green habitats of Warsaw. These are two species occurring only in the non-urban zone. *Crossocerus styrius* was recorded from the natural linden-oak-hornbeam forest, alder-ash carr, and from the abandoned rural park. The biology of this species is not known. *Crossocerus walkeri* was caught in the natural linden-oak-hornbeam forest and in the pine forest. If feeds offspring on insects of the order *Ephemeroptera*.

Also three species of the genus *Pemphredon* Latr., *P. montanus*, *P. lugens*, and *P. clypealis*, were absent from urban green habitats. Like other species of this genus, they feed their larvae on aphids, and nest in branches. Lack of detailed data on the biology of these species precludes the understanding why they do not occur in the town.

In urban green areas of Warsaw there were no rare species such as *Ectemnius dives*, *Crossocerus cetratus*, *C. guttatus*, and *Passaloecus eremita*, which occur in non-urban habitats.

This review of the species absent from urban habitats shows that urban green areas are not suitable for psammophilous species, on the one hand, and for hygrophilous species, on the other. With respect to their food preferences, only *Sphecidae* feeding on dipterans, leafhoppers, and aphids can find suitable conditions in urban green habitats.

ZOOGEOGRAPHICAL ANALYSIS

The *Sphecidae* collected in this study represent such zoogeographical elements as boreal, Holarctic, Palaearctic, Euro-Siberian, south-Euro-Siberian, subatlantic, and Submediterranean (Tab. 11). They are distinguished according to the criteria established by the Centre of Faunal Documentation of

Table 11. Percentage of zoogeographical elements in the fauna of *Sphecidae*, based on the number of individuals

Environment / Zoogeographical element	Rural			Suburban		Urban				
	natural	parks	garden	modyfied	park	parks	street sides	housing estates loosely built	housing estates closely built	allotments
Boreal	0.2	0.7	–	0.1	0.3	–	0.1	–	–	–
Holarctic	10.6	6.6	16.2	6.9	5.0	1.6	9.9	23.6	26.7	31.3
Palearctic	43.8	53.3	30.1	70.0	80.0	87.5	71.2	58.1	33.5	40.4
Eurosiberian	0.2	–	2.0	0.3	1.3	0.1	0.6	–	–	–
Southern-Eurosiberian	–	–	–	0.1	–	0.4	2.6	–	–	–
European	30.7	38.7	50.5	20.6	12.0	9.9	15.0	17.3	39.1	27.3
Subatlantic	0.7	0.7	–	–	–	–	–	–	–	–
Submediterranean	13.8	–	1.2	2.0	1.4	0.5	0.6	1.0	0.7	1.0

the Institute of Zoology, PAS (Czechowski, Mikołajczyk 1980). Individual *Sphecidae* species have been classified to these elements in an earlier paper (Skibińska 1982).

The members of the Holarctic, Palaearctic, and European elements occurred in all the study habitats and types of green. Also submediterranean species occurred in almost all study areas. They were absent only from a shady site in closely built-up area (M.D.M. II). At the same time, these four zoogeographical elements were most abundant in particular *Sphecidae* communities. The other elements were represented by single species with low abundance.

The diversity of zoogeographical elements occuring in particular habitats and types of urban green areas gives a picture of the effects of anthropogenic pressure on particular elements.

In urban parks and streetside habitats bordering on parks, almost all geographical elements occurring in non-urban habitats were recorded. In green areas of loosely and closely built-up housing estates, no Euro-Siberian, south-Euro-Siberian, and boreal elements were recorded.

Comparing *Sphecidae* communities from restructured habitats utilized in the same way but located in different zones (non-urban, suburban, and urban), a clear increase in the proportion of the Palaearctic element in urban habitats can be seen. For example, in the rural garden the proportion of this element was about 30%, while in urban allotment gardens more than 40%, in rural parks about 53%, in the suburban park about 80%, and in urban parks more than 87%.

An opposite situation was observed within the urban green habitats, in the gradient of increasing urban pressure. In the gradient of habitats

arranged from parks through streetside green adjoining parks, green areas of loosely built-up housing estates, to green areas of closely built-up housing estates, the proportion of the Palaerctic element declined and generally the proportion of Holarctic, European, and submediterranean elements increased.

In urban green areas more affected by urban pressure than parks, the proportions of different zoogeographical elements tended to be more uniform. It is possible, however, that this uniform distribution was randomly produced, which may be the case when the community abundance is low.

CONCLUSIONS

Sphecidae communities occurring in urban green areas markedly differ from those living in the "mother" habitats for Warsaw, that is, in natural linden-oak-hornbeam forests (*Tilio-Carpinetum*). The distinct character of these communities was determined by differences in habitat conditions between natural linden-oak-hornbeam forests and urban green areas. The linden-oak-hornbeam forest is humid and shady, while urban habitats are dry and insolated. The structure of the vegetation is different and, what is particularly important, trees and shrubs in urban green (even in parks) are much less dense. Also soil types are different. In Warsaw these are mostly podzolic soils, while brown in the natural linden-oak-hornbeam forest. Habitat conditions in natural linden-oak-hornbeam forests are not suitable for *Sphecidae*. They generally prefer dry and insolated areas. Among the study habitats, mixed forest (*Pino-Quercetum*) was most suitable to these insects. The literature data show that they also prefer insolated mixed forests (Tischler 1973).

The *Sphecidae* community occuring in the linden-oak-hornbeam forest was characterized by a very low abundance and also by a low number of species. Many species absent from the natural linden-oak-hornbeam forest were caught in the modified linden-oak-hornbeam forest and in restructured habitats on the sites of linden-oak-hornbeam forests both urban and non-urban. The dominance structure of the *Sphecidae* community occurring in the natural linden-oak-hornbeam forest was to some extent similar to the structure of poorer communities from urban green habitats of reduced suitability, such as streetside green (Marszałkowska Street) or green of housing estates (Wierzbno).

Sphecidae communities occurring in different types of green areas in Warsaw were represented by rather a high number of species. A total of 70 species were recorded in urban green. Within the town, the number of species dropped in the gradient of increasing urban pressure. The

communities from large parks comprised 37—39 species, thus not much less than relatively rich communities from different habitats of the suburban and non-urban zones. In other types of urban green the number of species was much lower (Tab. 8). Changes occurring in *Sphecidae* communities of urban green areas arranged in the gradient of increasing urban pressure were not limited to the simplification of their species composition. Also the abundance of these communities and their dominance structure were changed. All *Sphecidae* communities from modified habitats and almost all from restructured habitats had an increased abundance, as compared with those from natural habitats. The mean abundance of of *Sphecidae* communities from different habitats in urban areas was higher than in the natural habitats under study, but lower than in the habitats of the suburban zone. Their numbers in particular urban habitats were differentiated, although the differences were not so large as in habitats of the non-urban zone. For example, the abundance of *Sphecidae* communities in the natural linden-oak-hornbeam forest differed from that in the rural garden by a factor of about 40, while within urban habitats *Sphecidae* communities differed by a factor of about 8. In the town, the highest *Sphecidae* abundance was noted in one of the parks (at the Cemetery of Soviet Soldiers), and the lowest in a small, shady courtyard (M.D.M.).

With respect to the similarity in species composition and dominance structure of *Sphecidae* communities in urban green areas, the study areas can be classified into two groups. One group is made up of parks and adjoining streetside green. The other consists of green areas of housing estates, isolated streetside green and allotment gardens.

Although the urban parks under study differed in their age, size, and location (character of the neighbouring areas), they shared many features. Each park occupied a much larger area of continuous green than any other study areas. All parks were managed and utilized in a similar way. *Sphecidae* communities from urban parks showed a high similarity in their species composition, thus in this respect they formed one complex. With respect to the dominance structure of *Sphecidae* communities occurring in urban parks, two types of their communities have been distinguished. One comprises *Sphecidae* communities from old parks (Łazienki and the Saxon Garden), which are similar to the communities from rural parks. The other is made of the community from the park at the Cemetery of Soviet Soldiers, which is similar to the communities from the suburban park, modified coniferous and mixed forests, and natural mixed forest. The *Sphecidae* community from this park was similar to these communities not only its dominance structure. A high value of the cumulative similarity index shows that these communities are clearly related (Fig. 12).

Sphecidae communities occurring in streetside green adjoining parks were

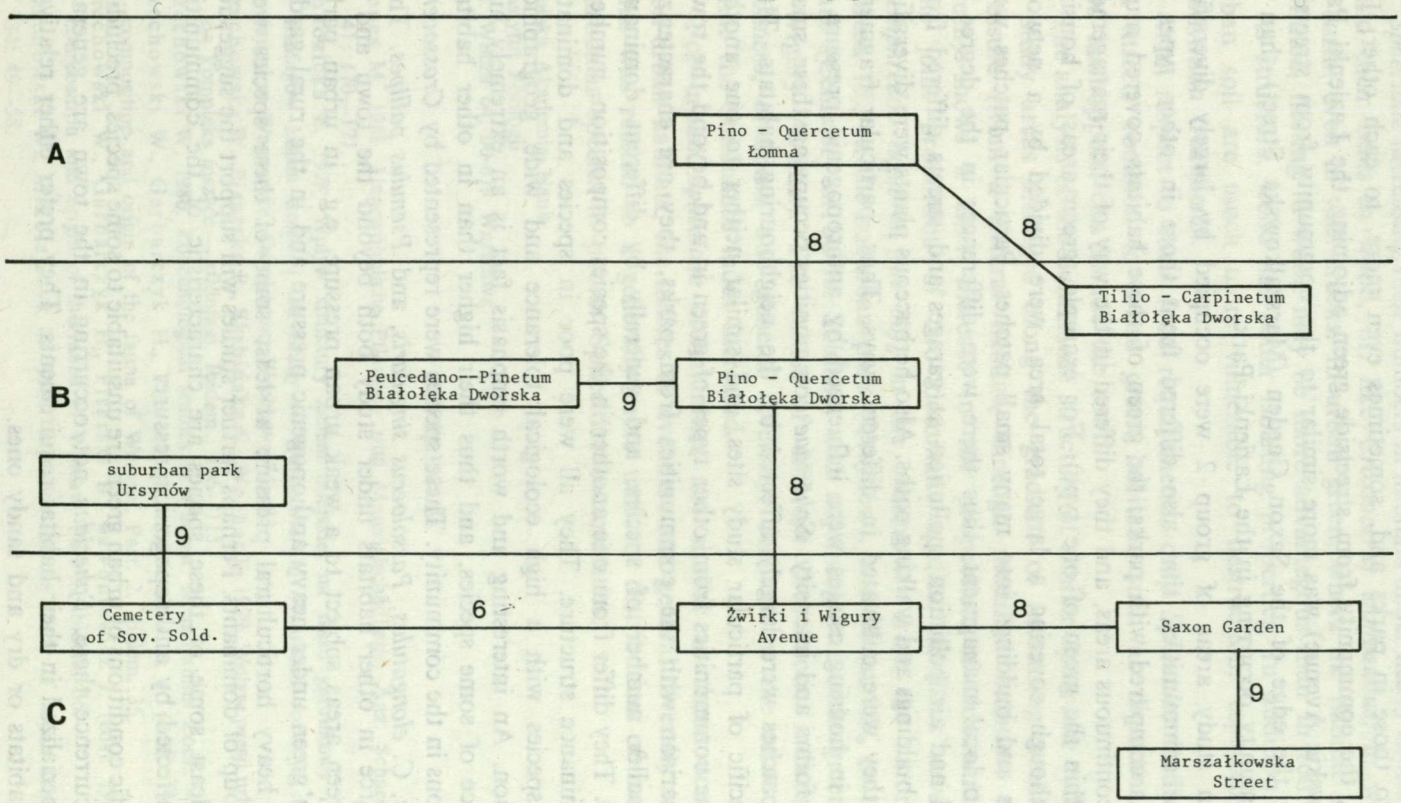


Fig. 12. Dendrogram of similarity between *Sphecidae* communities based on the cumulative similarity index. Figures denote the values of the index

similar to those in parks and, sometimes even more, to each other. For example, the community from streetside green adjoining the Łazienki Park (Ujazdowskie Avenue) was more similar to the community from streetside green at the edge of the Saxon Garden (Marszałkowska Street) than to the community occurring in the Łazienki Park.

Urban study areas of group 2 were occupied by largely diversified *Sphecidae* communities, that also differed from those in other types of green. As compared with parks, the green of these habitats covered much smaller continuous areas, and they differed in the way of their management (even within the green of one type). For example, green areas of housing estates, though covering a large total area, were divided by a network of streets and buildings into many small patches. Particular patches were subject to local managment, thus there were differences in the degree of their soil and air pollution; pollution at garages and streets differed from that near buildings and walking paths. Also herbaceous plants were diversified because they were cultivated in different ways. Thus, particular fragments of green in housing estates were influenced by anthropogenic pressure of different forms and intensity, *Sphecidae* communities occupying these small, mosaic patches were largely affected by the neighbouring habitats. They were specific of particular study sites, and similar neither to one another nor to the communities from other types of green in and beyond the town. In comparison with the communities from parks, they are characterized by a smaller number of species, and generally by different dominance structure. They differ from one another in the species composition, numbers, and dominance structure. They all were poor in species and dominated by the species with a high ecological tolerance and wide geographical distribution. An interesting and worth emphasis fact is an extremely high abundance of some species, and thus their higher than in other habitats proportions in the community. These species were represented by *Crossocerus annulipes, C. elongatulus, Passaloecus singularis*, and *Psenulus pallipes*. They were scarce in other habitats under study both beyond the town and in urban green areas subject to a weak urban pressure, e.g., in urban parks. In urban green under heavy anthopogenic pressure and in the rural garden under a heavy horticultural pressure at least some of these species were in the group of dominants. Perhaps further studies will support the suggestion that at least some of these species are characteristic of the communities heavily affected by anthropogenic pressure.

Specific conditions of urban green are unsuitable to some species, precluding their occurrence there. *Sphecidae* not occurring in the town are generally highly specialized in their habitat requirements. They prefer either relatively humid habitats or dry and sandy ones.

Sphecidae increasing their numbers in habitats under heavy urban pressure build their nests in wood, or, like *Crossocerus elongatulus*, in wood and in earth, even in wall cracks. In urban green, where the habitat is heavily polluted, nesting in wood may be more advantegous than in soil. Because of its structure, wood has better isolating properties. In addition, nests in urban soil are much more vulnerable to destruction, especially during cultivation treatments.

With respect to their food requirements, only *Sphecidae* feeding larvae on insects common in urban green habitats, such as dipterans, aphids, and leafhoppers, can invade the town.

The analysis of the dominance structure of similar *Sphecidae* communities in study areas arranged along the gradient of increasing anthropogenic pressure (from a natural habitat, through modified habitats, to urban green) shows a clear increase in the proportion of dominant species. The joint proportion of two dominant species, *Mellinus arvensis* and *Pemphredon lugubris* was 50% in the community from the natural mixed forest, 75% in the suburban park (Ursynów), and about 90% in the urban park (Cemetery of Soviet Soldiers) and adjoining streetside green (Żwirki i Wigury Avenue). The values of different biocoenotic indices (species richness, evenness, and general diversity) declined in the same gradient, while the dominance index increased.

For urban *Sphecidae* communities not similar to those occurring in non-urban habitats, the indices of evenness and general diversity were high. This was related to a generally more uniform distribution of numbers of particular species in poorer Sphecidae communities.

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STRUKTURA ZGRUPOWAŃ *SPHECIDAE* (*HYMENOPTERA*) W ZIELENI MIEJSKIEJ WARSZAWY

STRESZCZENIE

W zieleni Warszawy stwierdzono występowanie 70 gatunków *Sphecidae*. Dominantami są: *Mellinus arvensis* — 30%, *Passaloecus insignis* — 7,5%, *Crossocerus elongatulus* — 7,3%, *Crossocerus annulipes* — 7,3%.

Badania prowadzono w parkach i zieleni ulicznej sąsiadującej z nimi, w zieleni osiedlowej (w osiedlach o zabudowie luźnej i zwartej), w ogródkach działkowych oraz w izolowanej zieleni przyjezdniowej.

Najwyższą liczbę gatunków stwierdzono w zgrupowaniach z dużych parków (37—39 gatunków), najniższą — w zgrupowaniach z zieleni osiedlowej (11—22 gatunków).

Liczebność zgrupowań *Sphecidae* występujących w poszczególnych środowiskach miejskich jest zróżnicowana (maksymalna różnica liczebności jest około 8-krotna).

Liczba gatunków w zgrupowaniach uzależniona jest od sposobu zagospodarowania i użytkowania obiektu zieleni; w odniesieniu do liczebności zgrupowań takiej prawidłowości nie stwierdzono.

Ze względu na stopień podobieństwa składu gatunkowego i struktury dominacyjnej zgrupowań *Sphecidae* miejskie obiekty badawcze można zakwalifikować do dwóch grup. Do jednej należą parki i sąsiadująca z nimi zieleń uliczna, do drugiej obiekty reprezentujące pozostałe rodzaje zieleni miejskiej.

Zgrupowania *Sphecidae* z różnych parków miejskich mają podobny skład gatunkowy, natomiast różnią się liczebnością. Podobne (zwłaszcza pod względem struktury dominacyjnej) do zgrupowań parkowych są zgrupowania z zieleni ulicznej sąsiadującej z parkami. Ze względu na strukturę dominacyjną zgrupowań z parków miejskich, wyróżniono dwa ich typy. Do

pierwszego należą zgrupowania z Łazienek i Ogrodu Saskiego, które są podobne do zgrupowań z parków wiejskich. Do drugiego — zgrupowanie z parku przy Cmentarzu Żołnierzy Radzieckich, które jest podobne do zgrupowania z parku podmiejskiego oraz z borów odkształconych i naturalnego boru mieszanego. Zgrupowania *Sphecidae* z pozostałych rodzajów zieleni miejskiej (zieleń osiedli mieszkaniowych, ogródki działkowe, izolowana zieleń uliczna) mają swoisty charakter i w zasadzie nie wykazują podobieństwa ani między sobą, ani też do zgrupowań z innych rodzajów zieleni, tak w mieście jak i poza nim. Cechami wspólnymi zgrupowań z tych środowisk, jest ich ubóstwo gatunkowe oraz przewaga gatunków o dużej tolerancji ekologicznej i szerokim zasięgu geograficznym.

W zgrupowaniach *Sphecidae* występujących w zieleni poddanej silnej presji urbanizacyjnej stwierdzono wyraźny wzrost liczebności niektórych gatunków. Są to: *Crossocerus elongatulus, C. annulipes, Passaloecus singularis, Psenulus pallipes*. Gatunki te w innych badanych środowiskach, zarówno poza miastem, jak i w zieleni miejskiej poddanej wpływom słabej presji urbanizacyjnej, np. w parkach miejskich, są reprezentowane nielicznie. W zieleni miejskiej poddanej silnej presji urbanizacyjnej oraz w ogrodzie wiejskim (który poddany jest silnej presji antropogenicznej) należą one do grupy dominantów. Gatunki te gniazdują w drewnie, bądź jak *Crossocerus elongatulus*, także w ziemi i innych miejscach, np. w szczelinach murów.

СТРУКТУРА СООБЩЕСТВ РОЮЩИХ ОС (*HYMENOPTERA, SPHECIDAE*) ГОРОДСКИХ ЗЕЛЕНЫХ НАСАЖДЕНИЙ ВАРШАВЫ

РЕЗЮМЕ

В городской зелени Варшавы констатировали 70 видов роющих ос. Доминантами являются: *Mellinus arvensis*, составляющий около 30% фауны *Sphecidae* из исследованных насаждений, *Passaloecus insignis* — 7,5%, *Crossocerus elongatulus* — 7,3%, *Crossocerus annulipes* — также 7,3%. Наиболее богатым видовым составом характеризовались сообщества из парков и прилегающих к ним уличных насаждений. Сообщества из парков были сходны по своему видовому составу, но отличались по численноти отдельных видов. Сходными с парковыми сообществами (особенно по структуре доминации) были сообщества из соседних с парками уличных насаждений. С точки зрения структуры доминации в городских парках выделили два типа сообществ. К первому причислены сообщества *Sphecidae* из Лазенок и Сасского Огрода, которые сходны с сообществами из сельских парков. Ко второму — сообщество из парка при Мемориальном кладбище советских воинов, которое сходно с сообществами из пригородных парков, а также с сообществами из деформированных боров и природных смешанных боров. Сообщества *Sphecidae* из остальных родов городской зелени (зелень жилых районов, садово-огородные участки, изолированная уличная зелень) имеют специфический характер и в принципе не сходны ни между собой, ни с сообществами из иного рода насаждений как в городе, так и вне его. Общими чертами этих сообществ являются бедность видового состава и преимущество видов со значительной экологической толерантностью и широким географическим ареалом.