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STRUCTURE OF NEUROPTERAN (*NEUROPTEROIDEA*) COMMUNITIES IN URBAN GREEN AREAS OF WARSAW

ABSTRACT

Species composition and quantitative structure of neuropteran communities were examined in different types of urban green habitats of Warsaw. Changes in these communities caused by urban pressure are indicated. The study was conducted in three typical urban green habitats such as parks, green areas of housing estates, and streetside green.

INTRODUCTION

Urban green areas are under an extremely heavy pressure of human activity. As a result, natural habitat is largely transformed there, including hydrological, chemical, and thermal conditions. Also plant cover is changed, mostly intentionally shaped by man (Kubicka et al. 1986).

The set of physical and chemical factors that assume values deviating from their values in natural habitats, has been called the anthropogenic pressure. This pressure acts as a factor selecting the potential urban flora and fauna. Consequently, a specific urban ecosystem is formed, with its own plant and animal world.

The present paper is a part of zoocoenological studies carried out in Warsaw by the Institute of Zoology, PAS. An earlier paper discussed the species composition and origin of *Neuroptera* and *Mecoptera* of Warsaw (Czechowska 1982). The purpose of this paper is to assess the species composition and abundance of neuropteran communities in different types of urban green areas, and to show directions of changes resulting from urban pressure.

STUDY AREAS, METHODS, AND MATERIAL

The total surface of urban green habitats in Warsaw is a dozen or so thousand hectares. It comprises grassy habitats and different types of wooded areas

(Kowalska 1979). Three basic types of urban green areas can be distinguished with regard to their management, utilization, and structure: parks, green habitats of housing estates, and streetside green. A detailed presentation of urban green habitats, and a description of all the areas and plots where the Institute of Zoology carried out its study is given in the introductory paper (Kubicka et al. 1986).

Neuropterans were caught in four parks, three housing estates, and four streetside green habitats. The parks were represented by the Łazienki Park (II), the park at the Cemetery of Soviet Soldiers (I, II), the Saxon Garden (II, III), and the Praski Park (I, II).[1] Green habitats of housing estates were studied in Wierzbno (II), Muranów, and M.D.M. (II), and streetside green at Ujazdowskie Avenue, Żwirki i Wigury Avenue (I), Marszałkowska Street (=Saxon Garden I),[2] and Konstytucji Square. Comparative studies were conducted in homologous habitats to those of Warsaw, that is, in linden-oak-hornbeam forests *Tilio-Carpinetum*) situated near Warsaw at such villages as Klembów, Hamernia, Truskaw, and Marysin Wawerski.[3]

The material was collected in 1974—1980. In Warsaw the study was conducted in 1974—1978, and in the natural habitats compared in 1976—1981 (Tab. 1). Generally, respective plots were under study for two or three seasons, and only in the Praski Park this period was reduced to one season.

Moericke's cups were used to catch insects in tree canopy (Czechowski, Mikołajczyk 1981). Series of captures covered five-day periods at seven-day intervals from May to October.

The basic material was collected from linden (*Tilia* sp.) canopy, as these trees are common in Warsaw urban green areas of all types. Additional samples were taken from other tree species. In 1975, these were three maples (*Acer* sp.) and three horse-chestnuts (*Aesculus hippocastanum*) in the Saxon Garden; in 1976, an oak (*Quercus* sp.), hornbeam (*Carpinus betulus*), and an alder (*Alnus glutinosa*) in the Łazienki Park.

There were 8000 adult neuropterans collected, including 5990 specimens from urban green areas and 2010 from natural linden-oak-hornbeam habitats. In addition, 678 neuropteran larvae were shaken from lower parts of linden canopy.

To compare the data quantitatively, an abundance index (n) was calculated, characterizing the number of individuals caught per trap per day.

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[1] Figures in parentheses denote study plots according to Kubicka et al. 1986.

[2] Kubicka et al. 1986 consider this site to be a peripheral plot of the Saxon Garden. It is directly adjacent to a street and separated from the rest of the park by a sidewalk.

[3] A detailed analysis of the species composition and structure of neuropteran communities in natural linden-oak-hornbeam forests will be prepared spearately.

Table 1. Sampling years for urban green habitats of Warsaw and linden-oak-hornbeam forests (*Tilio-Carpinetum*) of Mazovia

Habitat		Study area (plot)	Study years							
			1974	1975	1976	1977	1978	1979	1980	1981
Urban green	Parks	Łazienki Park (II)		+	+		+			
		Cemetery of Soviet Soldiers (I, II)	+	+			+			
		Saxon Garden (II, III)	+	+			+			
		Praski Park		+						
	Housing estate green	Wierzbno (II)			+	+				
		Muranów (II)			+	+				
		M.D.M. (II)			+	+				
	Streetside green	Ujazdowskie Avenue		+	+		+			
		Żwirki i Wigury Avenue (I)		+		+	+			
		Marszałkowska Street		+			+			
		Konstytucji Square		+	+	+				
Tilio-Carpinetum					+	+		+	+	+

The check-list of species (Tab. 2) contains only those associated with broad-leaved trees. The species known to depend on the fauna associated with coniferous trees are excluded. They were occasionally caught on lindens adjoining spruces.

A complete list of species recorded from Warsaw is given in an earlier paper (Czechowska 1982). Systematic names are used after Aspöck, Aspöck, and Hölzel (1980).

COMMUNITIES IN LINDEN-OAK-HORNBEAM FORESTS

In linden canopy of the natural forests under study, 20 neuropteran species have been recorded (Tab. 2), representing four families: *Raphidiidae*, *Coniopterygidae*, *Hemerobiidae*, and *Chrysopidae*. The family *Chrysopidae* was dominant with respect to the number of species and abundance (8 species and 89% of the material collected). The family *Hemerobiidae* was represented by 6 species, and they accounted for only 8.7% of the material. Each of the remaining two families (*Coniopterygidae* and *Raphidiidae*) was represented by 3 species occurring in low numbers. They accounted for 2.3% of the material.

In shady, humid linden-oak-hornbeam forests, the most abundant populations were formed by *Chrysotropia ciliata* (31% of the community),

Table 2. Occurrence and abundance of neuropterans in linden-oak-hornbeam forests (*Tilio-Curpinetum*) of Mazovia and in urban green habitats of Warsaw (n — index of abundance, + — n < 0.001)

No.	Habitat / Species	*Tilio-Carpinetum*		Urban green							
				Parks		Housing estate green		Streetside green		Average	
		n	%	n	%	n	%	n	%	n	%
	Raphdiidae										
1	*Raphidia notata* Fabr.	+	+	–	–	–	–	–	–	–	–
2	*Raphidia major* Burm.	0.001	0.3	–	–	–	–	–	–	–	–
3	*Raphidia xanthostigma* Schumm.	+	+	–	–	–	–	–	–	–	–
	Coniopterygidae										
4	*Coniopteryx tineiformis* Curt.	0.004	1.3	+	+	0.001	0.3	+	+	+	+
5	*Coniopteryx esbenpeterseni* Tjed.	–	–	+	+	0.001	0.3	–	–	+	+
6	*Semidalis aleyrodiformis* (Steph.)	0.001	0.3	–	–	–	–	–	–	–	–
7	*Conventzia psociformis* (Curt.)	0.001	0.3	–	–	–	–	–	–	–	–
	Hemerobiidae										
8	*Drepanopteryx phalaenoides* (L.)	0.001	0.3	+	+	–	–	–	–	+	+
9	*Wesmaelius nervosus* (Fabr.)	+	+	0.006	1.0	–	–	0.003	2.6	0.003	0.9
10	*Wesmaelius subnebulosus* (Steph.)	–	–	0.018	3.1	0.013	4.5	0.021	18.4	0.017	5.2
11	*Hemerobius humulinus* L.	0.018	6.0	0.075	12.9	0.023	7.9	0.015	13.2	0.038	11.6
12	*Hemerobius micans* Oliv.	0.004	1.3	+	+	–	–	–	–	+	+
13	*Hemerobius lutescens* Fabr.	–	–	0.006	1.0	–	–	+	+	0.002	0.6
14	*Sympherobius pygmaeus* (Ramb.)	0.001	0.3	+	+	–	–	+	+	+	+
15	*Sympherobius elegans* (Steph.)	–	–	+	+	0.002	0.7	+	+	+	+
16	*Sympherobius klapaleki* Zel.	0.002	0.6	–	–	–	–	+	+	+	+
	Chrysopidae										
17	*Nineta flava* (Scop.)	0.056	18.7	0.258	44.3	0.077	26.4	0.017	14.9	0.117	35.8
18	*Nineta vittata* (Wesm.)	0.005	1.7	+	+	–	–	–	–	+	+
19	*Nineta inpunctata* (Reut.)	0.001	0.3	–	–	–	–	–	–	–	–

Table 2. Cont.

No.	Habitat / Species	*Tilio-Carpinetum*		Urban green							
				Parks		Housing estate green		Streetside green		Average	
		n	%	n	%	n	%	n	%	n	%
20	*Chrysotropia ciliata* (Wesm.)	0.093	31.0	+	+	0.002	0.7	–	–	+	+
21	*Chrysopa perla* (L.)	–	–	0.001	0.2	–	–	–	–	+	+
22	*Chrysopa viridana* Schn.	–	–	0.002	0.3	+	+	+	+	+	+
23	*Chrysopa nigricostata* Brau.[1]	–	–	0.001	0.2	0.002	0.7	–	–	0.001	0.3
24	*Chrysopa septempunctata* Wesm.	0.002	0.6	0.014	2.4	0.025	8.6	0.005	4.4	0.015	4.6
25	*Anisochrysa prasina* (Burm.)	0.019	6.3	0.084	14.4	0.078	26.7	0.004	3.5	0.056	17.1
26	*Chrysoperla carnea* (Steph.)	0.082	27.3	0.085	14.6	0.053	18.1	0.036	31.6	0.058	17.7
27	*Cunctochrysa albolineata* (Kill.)	0.009	3.0	0.033	5.7	0.015	5.1	0.013	11.4	0.020	6.1
	Total	0.300		0.583		0.292		0.114		0.327	

[1] In an earlier paper (Czechowska 1982) this species was erronously indicated as *Chrysopa flavifrons* Brau.

Chrysoperla carnea (27.3%), and *Nineta flava* (18.7%) *Chrysotropia ciliata* is a stenotopic hygrophilous species, characteristic of habitats of this type *Chrysoperla carnea* is a eurytopic species with a very large ecological amplitude. It occurs in very different habitats both open and wooded. *Nineta flava* is a polytopic species occurring in wooded habitats of different types. Its thermal-humidity optimum lies in not too wet but also not too dry habitats. Its physical habitat requirements are intermediate between those of *Chrysotropia ciliata* and *Anisochrysa prasina*. The latter is relatively abundant in linden-oak-hornbeam forests only on drier, insolated sites. Instead, it usually dominates in pine forests, where *Nineta flava* is occasional. Another rather abundant species in linden-oak-hornbeam forests in *Hemerobius humulinus* (6%).

COMMUNITIES IN URBAN GREEN AREAS OF WARSAW

In linden canopy of urban green areas 21 neuropteran species were caught (Tab. 2). Like in natural linden-oak-hornbeam forests, the family *Chrysopidae* was the richest (10 species; 82% of the material collected), and then *Hemerobiidae* (9 species; 18% of the material). The family *Coniopterygidae* was represented by two species, both sporadically caught. The family *Raphidiidae* was totally absent. The dominant species was *Nineta flava*, accounting for 36%, and the group of subdominant species consisted of *Chrysoperla carnea* (17.7%), *Anisochrysa prasina* (17.1%), and *Hemerobius humulinus* (11.6%).

To determine the degree of constancy in the occurrence of different neuropteran species in urban green areas, a four-degree Tischler's scale was used (Trojan 1975). According to this scale, the frequency (C) of absolutely constant species is 100—76%, and then 75—51% for constant species, 50—26% for accessory species, and 25—0% for accidental species.

In the urban biocoenosis, the species absolutely constant, recorded from all or almost all the study plots consisted of *Nineta flava* (C=100%), *Chrysoperla carnea* (C=100%), *Cunctochrysa albolineata* (C=100%), *Chrysopa septempunctata* (C=100%), *Hemerobius humulinus* (C=100%), *Anisochrysa prasina* (C=81%), and *Wesmaelius subnebulosus* (C=81%). The constant species (C=63%) were *Sympherobius pygmaeus* and *Wesmaelius nervosus*. The accessory species comprised *Hemerobius lutescens* (C=45%), *Chrysopa viridana* (C=45%), and *Chrysopa perla* (C=36%). The remaining 10 species belonged to the group of accidental species.

To check whether or not the species composition and abundance of neuropteran communities occurring in linden canopy are representative of the entire urban green, control samples were taken from other tree

Table 3. Occurrence and abundance of neuropterans in parks of Warsaw (n — index of abundance, + — n < 0.001)

No.	Study area, plot / Species	Łazienki Park		Cemetery of Soviet Soldiers						Saxon Garden						Praski Park					
		II		I		II		Average		I		II		Average		I		II		Average	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1	*Coniopteryx tineiformis* Curt.	0.003	0.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	*Coniopteryx esbenpeterseni* Tjed.	–	–	–	–	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–
3	*Drepanopteryx phalaenoides* (L.)	–	–	–	–	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–
4	*Wesmaelius nervosus* (Fabr.)	0.005	1.5	0.001	0.3	0.010	1.0	0.006	0.9	0.006	1.0	0.006	0.6	0.006	0.7	–	–	0.013	1.7	0.007	1.5
5	*Wesmaelius subnebulosus* (Steph.)	–	–	0.007	2.2	0.020	2.1	0.014	2.2	0.029	5.0	0.050	5.1	0.040	5.1	0.006	3.7	0.016	2.1	0.011	2.4
6	*Hemerobius humulinus* L.	0.060	18.3	0.053	16.6	0.096	9.9	0.075	11.6	0.069	12.0	0.162	16.5	0.116	14.8	0.027	16.6	0.061	7.9	0.044	9.4
7	*Hemerobius micans* Oliv.	–	–	0.001	0.3	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–
8	*Hemerobius lutescens* Fabr.	0.009	2.7	–	–	0.008	0.8	0.004	0.6	+	+	–	–	+	+	0.012	7.4	0.014	1.8	0.013	2.8
9	*Sympherobius pygmaeus* (Ramb.)	–	–	+	+	–	–	+	+	–	–	–	–	–	–	0.002	1.2	–	–	0.001	0.2
10	*Sympherobius elegans* (Steph.)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.002	1.2	–	–	0.001	0.2
11	*Nineta flava* (Scop.)	0.146	44.5	0.096	30.0	0.511	52.5	0.304	46.8	0.239	41.4	0.418	42.6	0.329	42.1	0.045	27.8	0.352	45.8	0.199	42.6
12	*Nineta vittata* (Wesm.)	–	–	–	–	+	+	+	+	0.001	0.2	+	+	+	+	–	–	–	–	–	–
13	*Chrysotropia ciliata* (Wesm.)	–	–	–	–	0.002	0.2	0.001	0.2	–	–	–	–	–	–	–	–	–	–	–	–
14	*Chrysopa perla* (L).	0.001	0.3	0.002	0.6	–	–	0.001	0.2	+	+	+	+	+	+	–	–	0.003	0.4	0.002	0.4
15	*Chrysopa viridana* Schn.	0.003	0.9	–	–	–	–	–	–	–	–	–	–	–	–	0.007	4.3	0.002	0.3	0.005	1.1
16	*Chrysopa nigricostata* Brau.	–	–	–	–	–	–	–	–	–	–	0.005	0.5	0.003	0.4	–	–	0.002	0.3	0.001	0.2
17	*Chrysopa septempunctata* Wesm.	0.009	2.7	–	–	0.020	2.1	0.010	1.5	0.012	2.1	0.038	3.9	0.025	3.2	0.005	3.1	0.023	3.0	0.014	3.0
18	*Anisochrysa prasina* (Burm.)	0.018	5.5	0.126	39.4	0.178	18.3	0.152	23.4	0.050	8.7	0.065	6.6	0.058	7.4	0.015	9.3	0.143	18.6	0.079	16.9
19	*Chrysoperla carnea* (Steph.)	0.047	14.3	0.024	7.5	0.103	10.6	0.064	9.9	0.120	20.8	0.157	16.0	0.139	17.8	0.024	14.8	0.116	15.1	0.070	15.0
20	*Cunctochrysa albolineata* (Kill.)	0.027	8.2	0.010	3.1	0.025	2.6	0.018	2.8	0.051	8.8	0.080	8.2	0.066	8.4	0.017	10.5	0.023	3.0	0.020	4.3
	Total	0.328		0.320		0.973		0.649		0.577		0.981		0.782		0.162		0.768		0.467	

species. A high similarity was found in the species composition of neuropterans occurring on different tree species both in Warsaw and in surrounding linden-oak-hornbeam forests. Some differences were recorded for the group of accessory and occassional species. However, rather large seasonal differences were found in the abundance of neuropteran communities on different tree species. Mean values of abundance indices for neuropterans living in the Saxon Garden on lindens, maples, and horse-chestnuts were 1.125, 1.450, and 0.880, respectively. In the Łazienki Park, they were 0.610 on lindens, 0.370 on oaks, 0.320 on hornbeams, and 1.050 on alders. But the mean number of neuropterans on all these trees was similar to that on lindens. In the Saxon Garden this mean differed by 2.2%, and in the Łazienki Park by 3.8%.

Also in the linden-oak-hornbeam forests the difference between mean numbers of neuropterans on lindens and on the other tree species was only 3% over the study period. Thus, the species composition and abundance of neuropteran communities on lindens are representative of the whole habitat.

PARKS

In linden canopy of Warsaw parks, 20 neuropteran species were recorded (Tabs 2 and 3). A highest number of 16 species were caught in the park at the Cemetery of Soviet Soldiers. On other study areas there were 11—14 species.

The index of similarity (calculated from Sörensen's formula) between neuropteran communities in the parks was rather high, being 77% on the average, and ranging from 67 to 82%.

Mean abundance index for neuropteran communities in the parks was 0.583 (Tab. 2). The least abundant communities occurred in the Łazienki Park (0.328), the most abundant in the Saxon Garden (0.782) (Tab. 3).

Neuropterans living in the parks were dominated by *Nineta flava* (46.4%). Subdominant species comprised *Chrysoperla carnea* (14.6%), *Anisochrysa prasina* (14.4%), and *Hemerobius humulinus* (12.9%). Other rather abundant species included *Cunctochrysa albolineata, Chrysopa septempunctata,* and *Wesmaelius subnebulosus.*

The neuropteran communities of parcticular parks have a common pattern of dominance structure. It is characterized by a high disproportion between the abundance of the dominant species and that of the other species (Figs 1 and 4A). *Nineta flava* has optimum habitat conditions in parks, thus this is the most abundant species there. Subdominant species differed from one park to another (Fig. 1). There was a relationship between their abundance and the age of the park and its spatial structure.

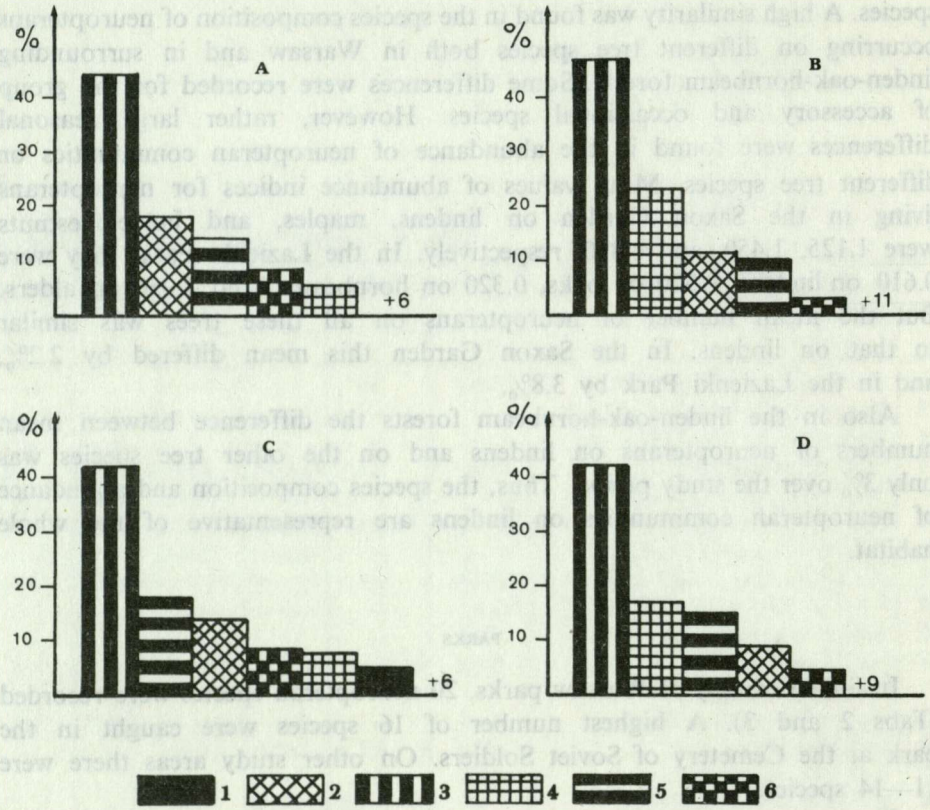

Fig. 1. Dominance structure of neuropteran communities occurring in linden canopy in parks of Warsaw. A — Łazienki Park; B — park at the Cemetery of Soviet Soldiers; C — Saxon Garden; D — Praski Park; 1 — *Wesmaelius subnebulosus*; 2 — *Hemerobius humulinus*; 3 — *Nineta flava*; 4 — *Anisochrysa prasina*: 5 — *Chrysoperla carnea*; 6 — *Cunctochrysa albolineata*; 7 — other species

In parks with fragments of a loose, light structure, *Anisochrysa prasina* populations are abundant. This is the case of the young park at the Cemetery of Soviet Soldiers and of the Praski Park, where the study was carried out in an avenue bordered by 30—40 year old lindens. In old and shady parks, this species was outnumbered by *Chrysoperla carnea* and *Hemerobius humulinus*.

The total abundance of neuropteran communities in parks is determined by the abundance of potential victims. The size of neuropteran populations is proportional to food resources, and food resources increased as the size of the parks decreased and as the urban pressure grew. The four

study parks arranged from the Łazienki through the Praski Park and the park at the Cemetery of Soviet Soldiers to the Saxon Garden from a gradient of a decreasing size of green area and increasing abundance of neuropteran communities. The greatest differences in the parameters of neuropteran communities occurred between the Saxon Garden and the Łazienki Park.

The mean abundance index for neuropterans in the Saxon Garden was more than twice as high as in the Łazienki Park, and in 1975 even three times as high. These two parks differed not only in size but also in their location in the town. The Saxon Garden is situated in the centre of Warsaw, and borders on streets with intense traffic. The Łazienki Park is situated in the Vistula escarpment region, near a large green complex. It covers an area 5 times as large as that of the Saxon Garden. In the Saxon Garden there are mass appearances of aphids, leafhoppers, coccids, and also acarids. In the Łazienki Park, the numbers of these arthropods were much lower. For example, the number of aphids per 100 linden leaves was 872 in the Saxon Garden and only 41 in the Łazienki Park in 1975 (Czechowska, unpublished data).

There is, however, a certain critical value of the habitat size below which the number of neuropterans declines, though food resources are abundant. This does not relate to parks, however, but to some green habitats of housing estates and streetside green areas.

GREEN AREAS OF HOUSING ESTATES

In linden canopy of housing estates, 13 neuropteran species were recorded (Tabs 2 and 4). Their number ranged from 7 to 9 on particular plots.

The mean value of the index of similarity for neuropteran communities living in housing estates was 69%. The highest similarity was found between the communities of Wierzbno and Muranów (the similarity index of 88%), and the lowest one between the communities of Wierzbno and M.D.M. (56%), these two districts being extremely different in terms of the design of built-up areas and size of their green habitats.

The mean number of neuropterans in housing estates was 0.292, which is half of their number in the parks. The range of this index, however, was very large for respective plots. The most abundant communities occurred in Wierzbno, which is loosely built-up with rich, well cultivated, and diverse plant cover. The abundance index of this community (0.642) was even higher than the mean value for parks. Neuropterans were least abundant in closely built-up areas such as the M.D.M. courtyard, where the index of abundance was merely 0.105.

The dominant species in the green of housing estates comprised *Anisochrysa prasina* (26.7%) and *Nineta flava* (26.4%). The group of subdominant

Table 4. Occurrence and abundance of neuropterans in housing estate green areas of Warsaw (n — index of abundance, + — n < 0.001)

No.	Species \ Study area (plot)	Wierzbno (II)		Muranów (II)		MDM (II)	
		n	%	n	%	n	%
1	*Coniopteryx tineiformis* Curt.	0.004	0.6	—	—	—	—
2	*Coniopteryx esbenpeterseni* Tjed.	0.003	0.4	—	—	—	—
3	*Wesmaelius subnebulosus* (Steph.)	0.005	0.8	0.005	3.8	0.030	28.5
4	*Hemerobius humulinus* L.	0.060	9.3	0.005	3.8	0.005	4.8
5	*Sympherobius elegans* (Steph.)	—	—	—	—	0.005	4.8
6	*Nineta flava* (Scop.)	0.150	23.4	0.060	46.2	0.020	19.0
7	*Chrysopa ciliata* Wesm.	—	—	—	—	0.005	4.8
8	*Chrysopa viridana* Schn.	—	—	—	—	+	+
9	*Chrysopa nigricostata* Brau.	—	—	—	—	0.005	4.8
10	*Chrysopa septempunctata* Wesm.	0.050	7.8	0.020	15.4	0.005	4.8
11	*Anisochrysa prasina* (Burm.)	0.230	35.8	0.005	3.8	—	—
12	*Chrysoperla carnea* (Steph.)	0.100	15.6	0.030	23.1	0.030	28.5
13	*Cunctochrysa albolineata* (Kill.)	0.040	6.2	0.005	3.8	—	—
Total		0.642		0.130		0.105	

species consisted of *Chrysoperla carnea* (18.1%), *Chrysopa septempunctata* (8.6%), and *Hemerobius humulinus* (7.9%).

Neuropteran communities occurring in green areas of housing estates were characterized by much more diverse dominance structure than those living in the parks (Fig. 2). The community occurring in Wierzbno had a particularly even distribution of the proportion of individual species (Fig. 2A). The dominance structure of neuropterans in Muranów (Fig. 2B) was rather similar to that recorded in the parks, because of a high proportion of *Nineta flava*. The abundance index of this species, however, was lower by a factor of 4, as compared with the parks. The neuropteran community of M.D.M. showed some similarity to that occurring in streetside plots close to parks. Both were characterized by a high proportion of *Wesmaelius subnebulosus and Chrysoperla carnea* (Figs 2C and 3).

The housing estates under study differed in site conditions. This is reflected in the dominance of different species in particular communities. The most abundant species in Wierzbno were *Anisochrysa prasina* and *Nineta flava*, in Muranów *Nineta flava*, and in M.D.M. *Chrysoperla carnea* and *Wesmaelius subnebulosus*. Dominant species are indicators of the habitat quality, and the abundance of neuropteran communities was related to the size of green habitats. The abundance of local neuropteran communities decreased in the gradient of three habitats of decreasing size: Wierzbno, Muranów, and M.D.M. considered as typical of green habitats in housing estates of Warsaw (Tab. 4). The mean area of a single green habitat

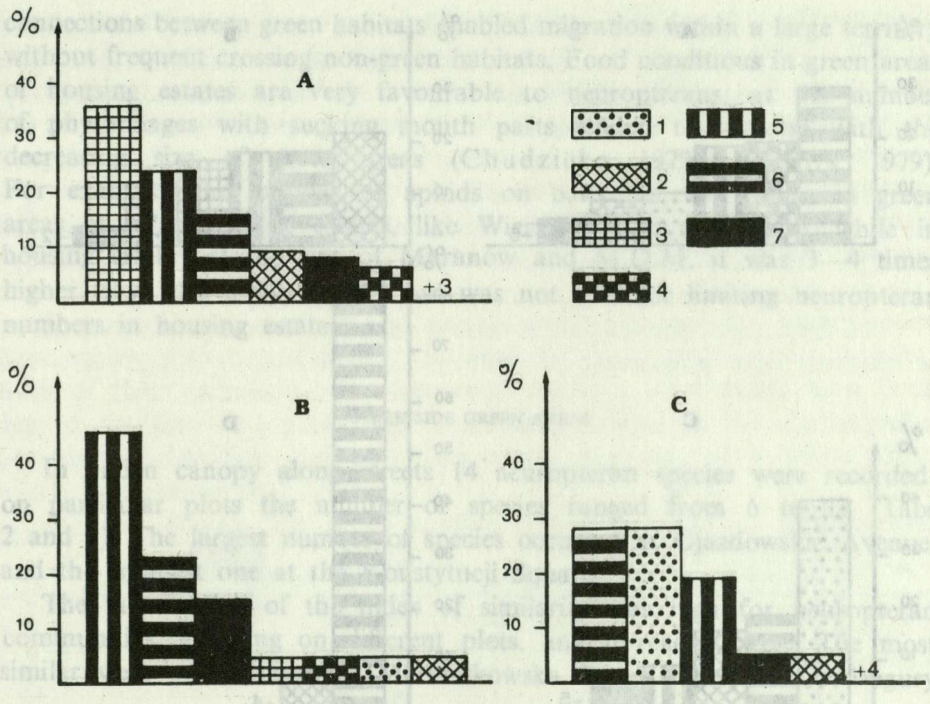

Fig. 2. Dominance structure of neuropteran communities occurring in linden canopy in housing estates green of Warsaw. A — Wierzbno; B — Muranów; C — M.D.M; 1 — *Wesmaelius subnebulosus*; 2 — *Hemerobius humulinus*; 3 — *Anisochrysa prasina*; 4 — *Cunctochrysa albolineata*; 5 — *Nineta flava*; 6 — *Chrysoperla carnea*; 7 — *Chrysopa septempunctata*

in Wierzbno ranged from 50 to 600m^2, and particular green areas are connected with each other. Green areas of Muranów cover about 200 m^2 each: they are rather densely spotted with trees, and separated by more closely built-up areas. Habitat conditions were extremely unfavourable in a small courtyard in M.D.M. It was surrounded by high, densely packed buildings. The green of M.D.M. covered an area of about 150m^2 and it consisted of a lawn, 2—3 trees, and a few shrubs.

In this sequence of plots, the difference in size between green areas of Wierzbno and Muranów is greater than between green areas of Muranów and M.D.M. This is reflected in the abundance of particular neuropteran communities. The index of abundance in Wierzbno was 5 and 6 times higher than in Muranów and M.D.M., respectively, while for these two last plots the values of abundance index were similar (0.130 and 0.105, respectively). In this sequence, the neuropteran community of Muranów represented to some degree an intermediate link. Its species composition was more similar to the community of Wierzbno, and its abundance index was closer to

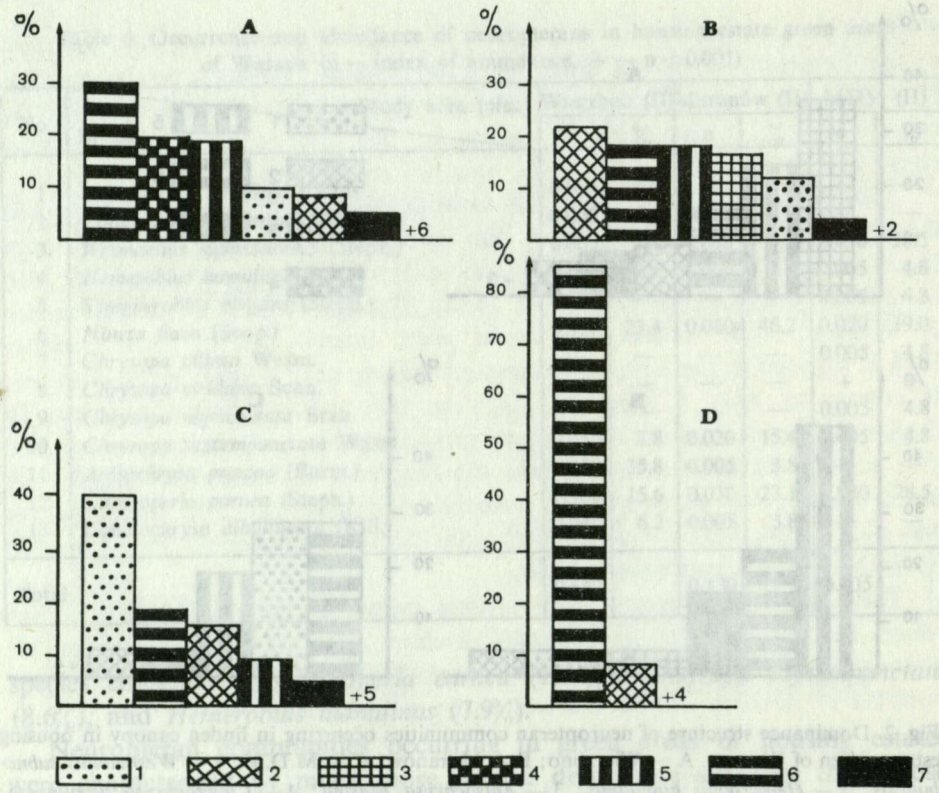

Fig. 3. Dominance structure of neuropteran communities occurring in linden canopy in streetside green of Warsaw. A — Ujazdowskie Avenue; B — Żwirki i Wigury Avenue; C — Marszałkowska Street; D — Konstytucji Square; 1 — *Wesmaelius subnebulosus*; 2 — *Hemerobius humulinus*; 3 — *Anisochrysa prasina*; 4 — *Cunctochrysa albolineata*; 5 — *Nineta flava*; 6 — *Chrysoperla carnea*; 7 — *Chrysopa septempunctata*

that of the community living in M.D.M. Small numbers of neuropteran communities of green areas in Muranów and M.D.M. were also a result of their isolation from neighbouring green areas and large green complexes. These housing estates are situated far from parks.

The smaller the green area, the less diverse are habitat conditions. A natural tendency of organisms to search for optimum conditions, coupled with a positive phototropism of neuropterans, enhance rather dispersal than cumulation of the population. And the isolation (physical barriers and distance to the park) precludes a rapid recovery.

A different situation was in Wierzbno. Sufficiently large patches of highly diversified vegetation created a more heterogeneous habitat, with a higher capacity than in Muranów and M.D.M. At the same time, wide and numerous

connections between green habitats enabled migration within a large territory without frequent crossing non-green habitats. Food conditions in green areas of housing estates are very favourable to neuropterans, as the number of phytophages with sucking mouth parts tended to increase with the decreasing size of green areas (Chudzicka 1979, Rychlik 1979). For example, the number of aphids on oaks per 100 leaves in green areas of large housing estates, like Wierzbno, was about 500, while in housing estates of the size of Muranów and M.D.M. it was 3—4 times higher (Rychlik 1979). Thus food was not a factor limiting neuropteran numbers in housing estates.

STREETSIDE GREEN AREAS

In linden canopy along streets 14 neuropteran species were recorded; on particular plots the number of species ranged from 6 to 12 (Tabs 2 and 5). The largest number of species occurred at Ujazdowskie Avenue, and the smallest one at the Konstytucji Square.

The mean value of the index of similarity was high for neuropteran communities occurring on different plots, and it reached 72%. The most similar were communities at Marszałkowska Street and Żwirki i Wigury

Table 5. Occurrence and abundance of neuropterans in streetside green areas of Warsaw (n — index of abundance, + — n < 0.001)

No.	Study area (plot) / Species	Ujazdowskie Avenue		Żwirki i Wigury Avenue		Marszałkowska Street		Konstytucji Square	
		n	%	n	%	n	%	n	%
1	*Coniopteryx tineiformis* Curt.	0.003	1.4	—	—	—	—	—	—
2	*Wesmaelius nervosus* (Fabr.)	0.001	0.5	0.003	4.1	0.006	4.6	—	—
3	*Wesmaelius subnebulosus* (Steph.)	0.023	10.4	0.009	12.3	0.053	40.5	—	—
4	*Hemerobius humulinus* L.	0.019	8.6	0.016	22.0	0.020	15.3	0.004	8.3
5	*Hemerobius lutescens* Fabr.	0.003	1.4	—	—	—	—	—	—
6	*Sympherobius pygmaeus* (Ramb.)	—	—	—	—	0.003	2.3	+	+
7	*Sympherobius elegans* (Steph.)	0.003	1.4	—	—	—	—	—	—
8	*Sympherobius klapaleki* Zel.	+	+	—	—	—	—	—	—
9	*Nineta flava* (Scop.)	0.042	19.0	0.013	17.8	0.012	9.2	0.001	2.1
10	*Chrysopa viridana* Schn.	0.001	0.5	—	—	0.002	1.5	—	—
11	*Chrysopa septempunctata* Wesm.	0.011	5.0	0.003	4.1	0.006	4.6	+	+
12	*Anisochrysa prasina* (Burm.)	—	—	0.012	16.4	0.004	3.0	—	—
13	*Chrysoperla carnea* (Steph.)	0.066	29.9	0.013	17.8	0.024	18.3	0.041	85.4
14	*Cunctochrysa albolineata* (Kill.)	0.043	19.5	0.004	5.5	0.001	0.7	0.002	4.2
Total		0.215		0.073		0.131		0.048	

Avenue (89%). The lowest similarity was found between the communities at Ujazdowskie Avenue (in the neighbourhood of the Łazienki Park) and Konstytucji Square (no large green areas in the neighbourhood (Tab. 7).

The mean index of abundance in streetside green areas was 0.114 (Tab. 2). The highest abundance was recorded at Ujazdowskie Avenue (0.215), and the lowest one at Konstytucji Square (0.048) (Tab. 5).

The dominant species in the streetside green was *Chrysoperla carnea* (31.6%), and the subdominant species consisted of *Wesmaelius subnebulosus* (18.4%), *Nineta flava* (14.9%), and *Hemerobius humulinus* (13.2%).

The dominance structure of streetside communities was characterized by a relatively high proportion of *Chrysoperla carnea* (Figs 3 and 4C). The

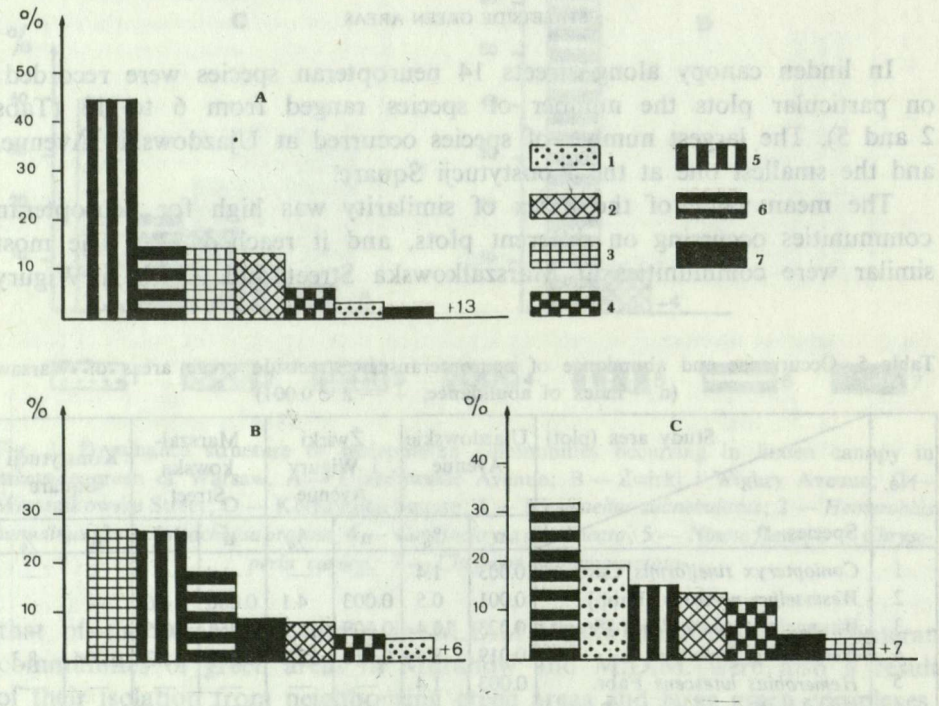

Fig. 4. Dominance structure of neuropteran communities occurring in linden canopy in different types of urban green habitats of Warsaw (mean values for all study areas). A — parks; B — housing estate green; C — streetside green; 1 — *Wesmaelius subnebulosus*; 2 — *Hemerabius humulinus*; 3 — *Anisochrysa prasina*; 4 — *Cunctochrysa albolineata*; 5 — *Nineta flava*; 6 — *Chrysoperla carnea*; 7 — *Chrysopa septempunctata*

proportion of *Wesmaelius subnebulosus* was 4 times as high as in the green areas of housing estates, and 8 times as high as in the parks.

Particular plots were dominated by different species: *Hemerobius humulinus* at Żwirki i Wigury Avenue, *Wesmaelius subnebulosus* at Marszałkowska

Street, and *Chrysoperla carnea* at Ujazdowskie Avenue and at Konstytucji Square (Figs 3A, B, C, D). Neuropteran communities at Żwirki i Wigury Avenue and Ujazdowskie Avenue had a rather uniform distribution of the proportions of particular species. In the communities at Marszałkowska Street and Konstytucji Square the proportion of the dominant species was considerably higher than those of the other species. This was particularly the case of Konstytucji Square, where the number of species was very low, and *Chrysoperla carnea* accounted for 85% of the community members (Fig. 3D).

The species composition and abundance of neuropteran communities in streetside sites depended on the distance to a large green complex. Both of them increased with decreasing distance. This might have been due to the fact that parks had a softening effect on the microclimate of streetside habitats, and they also played the role of a refuge from which immigration was possible.

For this reason, the most suitable conditions were at Ujazdowskie

Table 6. Neuropteran communities in urban green habitats of Warsaw

Habitat	Study area	Index of abundance	Number of species	Dominant species	Percent of dominants
Parks	Łazienki Park	0.328	11	*Nineta flava* *Hemerobius humulinus*	44.5 18.3
	Cemetery of Soviet Soldiers	0.649	16	*Nineta flava* *Anisochrysa prasina*	46.8 23.4
	Saxon Garden	0.782	12	*Nineta flava* *Chrysoperla carnea*	42.1 17.8
	Praski Park	0.466	14	*Nineta flava* *Anisochrysa prasina*	42.6 16.9
Housing estate green	Wierzbno (II)	0.642	9	*Anisochrysa prasina* *Nineta flava*	35.8 23.4
	Muranów (II)	0.130	7	*Nineta flava* *Chrysoperla carnea*	46.2 23.1
	M.D.M. (II)	0.105	9	*Wesmaelius subnebulosus* *Chrysoperla carnea*	28.5 28.5
Streetside green	Ujazdowskie Ave.	0.215	12	*Chrysoperla carnea* *Cunctochrysa albolineata*	30.7 19.5
	Żwirki i Wigury Ave.	0.073	8	*Hemerobius humulinus* *Chrysoperla carnea*	22.0 17.8
	Marszałkowska St.	0.131	10	*Wesmaelius subnebulosus* *Chrysoperla carnea*	40.5 18.3
	Konstytucji Sq.	0.048	6	*Chrysoperla carnea*	85.4

Avenue close to the Łazienki Park. The number of species occurring there (12) was even higher than within the park (11), and the abundance index was not much lower (Tabs 3 and 5). A little different situation was in the case of the plot at Żwirki i Wigury Avenue bordering on the park at the Cemetery of Soviet Soldiers. In contrast to the Łazienki Park, which is covered with an old tree stand also in its marginal parts, the park at the Cemetery of Soviet Soldiers has large lawns with few trees in the part adjoining the street. Thus, its favourable effect on the streetside green cannot be so intense, and this is reflected first of all in a relatively low abundance of its neuropteran community.

The lowest abundance of neuropterans, which was from 1.5 to 4.4 times lower than on the other streetside plots, was recorded at Konstytucji Square. It may be even suggested that the individuals captured there (mainly *Chrysoperla carnea*) did not form a permanent community, but they only visited this area, being attracted by intense lights of the street and buildings. The distance from this plot to the nearest large green complex (Ujazdowski Park) was about 700m.

Abundant, sometimes mass appearances of sucking phytophages are observed in streetside green. Thus, food conditions are extremely favourable to neuropterans. But usually unsuitable site conditions preclude the utilization of these rich food resources.

THE EFFECT OF URBAN PRESSURE ON COMMUNITIES

Urban pressure effects neuropterans occurring in linden canopy mainly through climatic conditions, which differ from those in natural habitats. Urban climate is charàcterized by higher temperatures and lower air humidity. Particularly large differences occur in air humidity. Mean annual air humidity in Warsaw is from 3 to 6% lower than in nonurban habitats (Bednarek 1979). *Chrysotropia ciliata*, a hygrophilous species predominating neuropteran communities in neighbouring linden-oak-hornbeam forests, is absent from Warsaw most probably because of the habitat overdrying. Urban habitats are occupied by species with lower moisture requirements. Their distribution in Warsaw, however, is not uniform. Community abundance and species diversity mostly depend on the size of green areas, spatial structure of the vegetation, and local microclimate. All these habitat components are interrelated, and their net effect determines the impact of urban pressure. The smaller the green area, the greater effects of urban pressure on neuropteran communities. They are reflected in the reduced abundance, species richness, and shifts in dominant species.

Built-up areas, squares and streets heat more than green areas, and

Table 7. Index of similarity (%) for neuropteran communities on different study areas of urban green of Warsaw

	Łazienki Park	Cemetery of Soviet Soldiers	Saxon Garden	Praski Park	Wierzbno (II)	Muranów (II)	MDM (II)	Ujazdowskie Avenue	Żwirki i Wigury Avenue	Marszałkowska Street	Konstytucji Square
Łazienki Park		67	82	80	70	63	50	78	74	76	47
Cemetery of Soviet Soldiers	67		81	73	64	61	48	57	67	69	55
Saxon Garden	82	81		80	70	78	50	69	84	76	59
Praski Park	80	73	80		61	67	35	77	73	83	60
Wierzbno (II)	70	64	70	61		88	56	67	82	74	67
Muranów (II)	63	61	78	67	88		63	63	93	74	77
MDM (II)	50	48	50	35	56	63		67	59	63	53
Ujazdowskie Avenue	78	57	69	77	67	63	67		70	73	56
Żwirki i Wigury Avenue	74	67	84	73	82	93	59	70		89	71
Marszałkowska Street	76	69	76	83	74	74	63	73	89		75
Konstytucji Square	47	55	59	60	67	77	53	56	71	75	

they desiccate the microclimate. This has been analyzed in detail in parks (Saxon Garden, park at the Cemetery of Soviet Soldiers) bordering on streets with intense traffic. It has been found that air temperature drops by 1—1.5°C on the average (depending on the time of the day) from the street towards the centre of the park, while the relative air humidity increases by 6—8%. The effect of the street covers 200m, thus stable microclimate can occur only in green areas of more than 400m in diameter (Bednarek 1979, Bednarek, Huculak, in print, Kossowska 1977, Okołowicz, Kossowska 1974).

In the region of the Cemetery of Soviet Soldiers and the Saxon Garden, a transect distribution of adult and larval *Neuroptera* was examined. For this purpose three sites were selected within each complex at different distances from the street. They were located as follows:

1. A streetside plot adjoining the park (this was Żwirki i Wigury Avenue at the Cemetery of Soviet Soldiers, and Marszałkowska Street at the Saxon Garden).
2. Park periphery (50—60m from the street; the plots Cemetery of Soviet Soldiers I and Saxon Garden II, respectively).
3. Park centre (about 160m from the street; the plots Cemetery of Soviet Soldiers II and Saxon Garden III).

The number of adults in neuropteran communities of the two green complexes increased with air humidity. The lowest abundance index was found on the streetside plots (0.105 on the average), and the highest on the plots in the park centres (0.979 on the average) (Tabs 8 and 9). The material collected from successive plots accounted for 7%, 29%, and 64% of the material from entire green complexes.

The drying effect of streets can be reduced or intensified depending on the spatial structure of the vegetation. Dense tree stand along the entire transect in the Saxon Garden enhanced air humidity and similar microclimatic conditions on the two within-park plots. As a result, differences in the community abundance between these two plots were relatively low, while differences between these plots and the streetside plot were large (Tab. 8).

A different situation existed in the park at the Cemetery of Soviet Soldiers. Largely spaced trees and their clumps enhanced a rapid increase in air temperature and the flow of warm air from the street. As a result more than 70% of neuropterans occurred in the centre of the park, that is, on plot II (Tab. 8).

Vast areas of open lawns separating clumps of trees form, in a sense, barriers separating particular neuropteran communities. This is the case of the region of the park at the Cemetery of Soviet Soldiers, where specific neuropteran communities occurred along the transect, depending on site conditions on successive plots. They differed in the number of species and in the dominant species. There were 8 species dominated by *Hemerobius humulinus* on the streetside plot, 10 species dominated by *Anisochrysa prasina* on the peripheral park plot, and 13 species dominated by *Nineta flava* on the central park plot (Fig. 5).

In the region of the Saxon Garden, where tree stand was dense along the transect, the number of neuropteran species on respective plots was almost indentical (10, 10, and 11, respectively). *Wesmaelius subnebulosus* was most abundant on the streetside plot. The two plots in the park

Table 8. Neuropteran communities along two transects within the regions of the Cemetery of Soviet Soldiers and the Saxon Garden

Green complex, plot / Community characteristics	Cemetery of Soviet Soldiers			Saxon Garden		
	Street	I	II	Street	I	II
Index of abundance	0.073	0.320	0.973	0.131	0.577	0.981
Percentage of the total material	5.3	23.4	71.2	7.8	34.2	58.0
Number of species	8	10	13	10	11	11
Dominant species	*Hemerobius humulinus*	*Anisochrysa prasina*	*Nineta flava*	*Wesmaelius subnebulosus*	*Nineta flava*	*Nineta flava*

Table 9. The distribution of abundance of different species in neuropteran communities along transects: mean values for the Cemetery of Soviet Soldiers and the Saxon Garden regions (n — index of abundance, + — <0.001)

No.	Situation of the plot / Species	Street		Park periphery		Park centre	
		n	%	n	%	n	%
1	*Coniopteryx esbenpeterseni* Tjed.	—	—	—	—	+	+
2	*Drepanopteryx phalaenoides* (L.)	—	—	—	—	+	+
3	*Wesmaelius nervosus* (Fahr.)	0.005	4.8	0.004	0.9	0.008	0.8
4	*Wesmaelius subnebulosus* (Steph.)	0.031	29.5	0.018	4.0	0.035	3.6
5	*Hemerobius humulinus* L.	0.018	17.1	0.061	13.6	0.129	13.2
6	*Hemerobius micans* Oliv.	—	—	+	+	—	—
7	*Hemerobius lutescens* Fabr.	—	—	+	+	0.004	0.4
8	*Sympherobius pygmaeus* (Ramb.)	0.002	1.9	+	+	—	—
9	*Nineta flava* (Scop.)	0.013	12.4	0.168	37.4	0.465	47.5
10	*Nineta vittata* (Wesm.)	—	—	+	+	+	+
11	*Chrysotropia ciliata* (Wesm.)	—	—	—	—	0.001	0.1
12	*Chrysopa perla* (L.)	—	—	0.001	0.2	+	+
13	*Chrysopa viridana* Schn.	0.001	1.0	—	—	—	—
14	*Chrysopa nigricostata* Brau.	—	—	—	—	0.003	0.3
15	*Chrysopa septempunctata* Wesm.	0.005	4.8	0.006	1.3	0.029	3.0
16	*Anisochrysa prasina* (Burm.)	0.008	7.6	0.088	19.6	0.122	12.5
17	*Chrysoperla carnea* (Steph.)	0.019	18.0	0.072	16.0	0.130	13.2
18	*Cunctochrysa albolineata* (Kill.)	0.003	2.9	0.031	6.9	0.053	5.4
	Total	0.105		0.449		0.979	

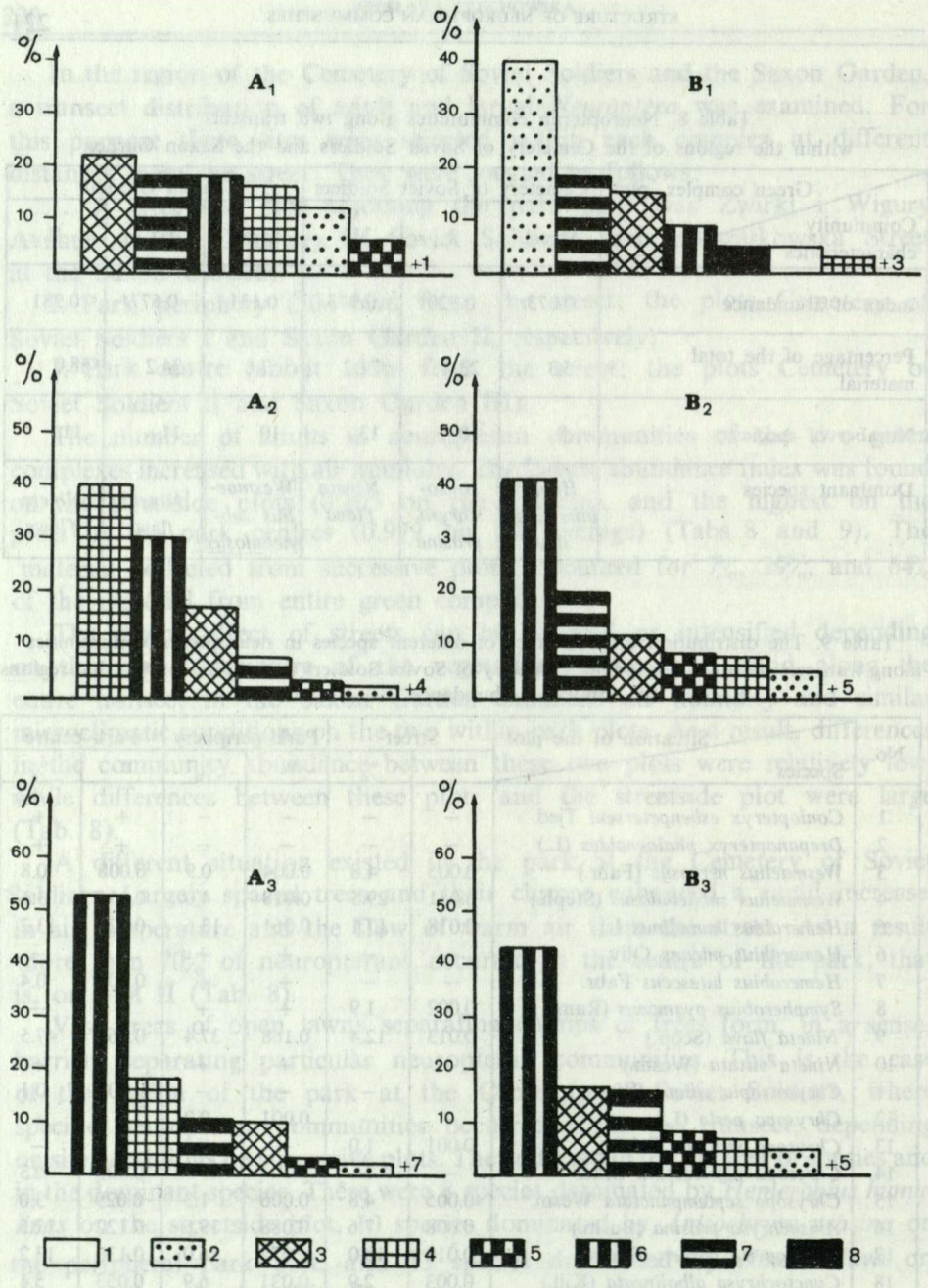

Fig. 5. Changes in the dominance structure of neuropteran communities occurring in linden canopy along transects in Warsaw. A — Cemetery of Soviet Soldiers + Żwirki i Wigury Avenue; B — Saxon Garden + Marszałkowska Street; A, $(B)_{1,2,3}$ — plots in the transect (from the street towards park centre); 1 — *Wesmaelius nervosus*; 2 — *Wesmaelius subnebulosus*; 3 — *Hemerobius humulinus*; 4 — *Anisochrysa prasina*; 5 — *Cunctochrysa albolineata*; 6 — *Nineta flava*; 7 — *Chrysoperla carnea*; 8 — *Chrysopa septempunctata*.

were dominated by *Nineta flava*, which was a subdominant species on the streetside plot (Fig. 5).

Also the content and distribution of CO, CO_2, N_2O_3 and dust were measured in the Saxon Garden, park at the Cemetery of Soviet Soldiers, and the adjoining streets. The intensity of traffic was similar at the two parks. It amounted to 2000—2100 vehicles per hour of measurements and 19000—20000 vehicles per 24 hours (Skorupski 1976).

Like in the case of humidity, there were also differences in the distribution of pollution of these two sites, resulting from differences in the vegetation structure. In the Saxon Garden, where the ventilation was poor, the concentration of pollution along the entire transect (300 m) was high, not much lower than in the street. There were 4mg/m^3 of CO, 700mg/m^3 of CO_2, and 0.3mg/m^3 of N_2O_3. In the park at the Cemetery of Soviet Soldiers, where the ventilation was good, the concentration of pollution decreased along the transect. At a distance of 150m from the street the concentration of oxides was 1mg/m^3 for CO, 500mg/m^3 for CO_2, and 0.3mg/m^3 for N_2O_3, and it was maintained at this level up to a distance of 300m from the street (Skorupski 1976).

Although the air pollution was higher in the Saxon Garden, the number of neuropterans was higher there, as compared with the park at the Cemetery of Soviet Soldiers. This may suggest that higher air pollution has no substantial effect on abundance of these insects. Table 9 shows the distribution of numbers of particular species in the parks and bordering streets. These are mean values for the Saxon Garden, the park at the Cemetery of Soviet Soldiers, and adjoining streetside plots. Of 15 species recorded there, 6 increased in number from the street towards the park centre. These were most abundant species in parks, such as *Hemerobius humulinus, Nineta flava, Chrysopa septempunctata, Anisochrysa prasina, Chrysoperla carnea*, and *Cunctochrysa albolineata*. This was not the case of *Wesmaelius subnebulosus* and *W. nervosus*. Their abundance was higher on the streetside plots and on central park plots, as compared with peripheral park plots. The occurrence of other, accessory species was usually determined by their specific habitat requirements. *Sympherobius pygmaeus* or *Chrysopa viridana*, which prefer higher temperatures, occurred on the streetside plots, while *Chrysopa perla*, which is a hygrophilous species, occurred deep in parks.

The distribution of larval neuropterans in the street-park green complexes was largely affected by meteorological conditions. At high air humidity, the largest number of larvae was collected from the places of the highest aphid density, thus from the streetside plots. This was the case in a cool and rainy season of 1974. The sum of annual rainfall then amounted to 691mm (159mm above the mean), and 45% of the neuropteran larvae

were collected from streetside lindens. In the next season, which was dry and hot (the sum of annual rainfall was only 432mm), the correlation with food resources was disturbed. The highest number of larvae was recorded in peripheral parts of the parks.

Obviously, the migration of neuropterans towards peripheral parts of the parks, thus the number of eggs laid there, also depend on other factors. This may be a net result of many complicated interactions between

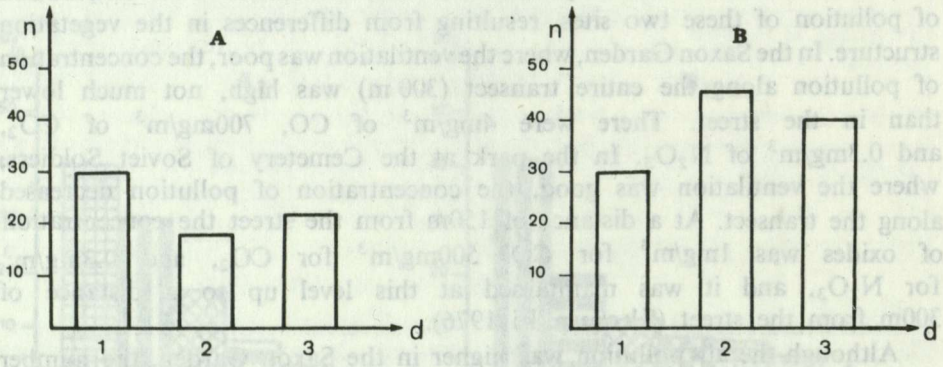

Fig. 6. Relative abundance (n) of larval neuropterans in linden canopy of parks and adjoining streets in Warsaw (mean values for all study areas) in the years with extreme weather conditions. (A — 1974; B — 1975, see the text), 1 — streetside plot, 2 — park periphery, 3 — park centre

neuropterans and other animals, including parasitism, predation, and competition for food.

On the scale of the entire urban green habitat, differentiation of site conditions is also reflected in the character of neuropteran communities. Thus, parks are dominated by *Nineta flava*, a shade-seeking species inhabiting most humid sites. Green areas of housing estates are dominated by *Anisochrysa prasina*, a species more photophilous than *N. flava*. Streetside green, which is the least suitable habitat, is dominated by a eurytopic species, *Chrysoperla carnea*. In this habitat also the proportion of species with small body sizes of the family *Hemerobiidae* increased. In parks, the proportion of neuropterans of this family was 18%, in housing estates 12.4%, and in streetside habitats as many as 34%.

As a result of increasing urban pressure, neuropteran communities are simplified. In extreme cases differences between those living in parks and on lindens isolated from large green habitats by a wide built-up area are very large; the number of species can drop by a factor of 3, and the abundance index by a factor of 12.

A COMPARISON OF COMMUNITIES IN URBAN GREEN HABITATS AND NATURAL LINDEN-OAK-HORNBEAM FORESTS

In linden canopy of Warsaw, 21 neuropteran species were recorded, while 20 in linden canopy of linden-oak-hornbeam forests of the Mazovian Lowland. These two habitat types shared 14 species, the index of similarity of their faunas being 68%.

Mean abundance of urban neuropteran communities was 0.327. It was a little higher than in liden-oak-hornbeam forests, where it reached a mean value of 0.300, ranging from 0.110 to 0.504.

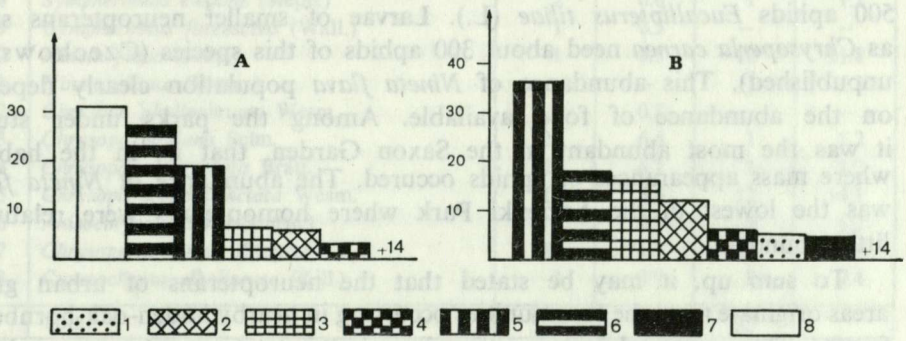

Fig. 7. Dominance structure of neuropteran communities occurring in linden canopy in a natural habitat and in urban green areas of Warsaw (mean values). A — linden-oak-hornbeam forest (*Tilio-Carpinetum*); B — urban green; 1 — *Wesmaelius subnebulosus*; 2 — *Hemerobius humulinus*; 3 — *Anisochrysa prasina*; 4 — *Cunctochrysa albolineata*; 5 — *Nineta flava*; 6 — *Chrysoperla carnea*; 7 — *Chrysopa septempunctata*; 8 — *Chrysotropia ciliata*

Among the species shared by the two habitat types, in the town there were almost all the species abundant in the forest. Some of them occurred in much higher numbers in the town. The abundance of *Hemerobius humulinus*, *Nineta flava*, and *Cunctochrysa albolineata* was doubled, that of *Anisochrysa prasina* was increased by a factor of 3, and *Chrysopa septempunctata* by a factor of 7. At the same time the abundance of *Chrysotropia ciliata*, *Chrysoperla carnea*, and many accessory species was reduced.

The most important difference between neuropteran communities of urban and forest lindens concerns the dominant species. In linden-oak-hornbeam forests the most abundant species was *Chrysotropia ciliata*. *Nineta flava*, the most abundant species of the urban habitat, was on the third position in the forests (after *Chrysoperla carnea*). In the town, habitat conditions are suitable for this species, particularly in parks. The average abundance index of *Nineta flava* in the parks was 4.6 times higher then in lin-

den-oak-hornbeam forests. The main reason of an abundant occurrence of this species in the town, besides suitable abiotic conditions, were, most probably the rich food resources in the urban habitat. Neuropterans associated with tree canopy feed on different arthropods with soft bodies, particularly on homopterans. In urban habitats these insects are extremely abundant, and they form the basis of the trophic chain in zoocoenoses (Pisarski, Trojan 1976a, b, c, Pisarski 1979). The number of aphids in urban parks is on the average 10 times higher than in non-urban forest habitats (Rychlik 1979). *Nineta flava* is a large species with a high fecundity, but it requires an abundant food supply to reach high abundance. Larvae of this species consume over their developmental period about 500 aphids *Eucallipterus tiliae* (L.). Larvae of smaller neuropterans such as *Chrysoperla carnea* need about 300 aphids of this species (Czechowska, unpublished). This abundance of *Nineta flava* population clearly depends on the abundance of food available. Among the parks under study, it was the most abundant in the Saxon Garden, that is, in the habitat where mass appearances of aphids occured. The abundance of *Nineta flava* was the lowest in the Łazienki Park where homopterans were relatively little abundant.

To sum up, it may be stated that the neuropterans of urban green areas originate from the communities occurring in nearby linden-oak-hornbeam forests. The compared communities were similar in the species composition, number of species, and abundance. The basic difference is that *Chrysotropia ciliata*, the dominant species of neuropteran communities occurring in forests, has been replaced by *Nineta flava* in urban habitats, which belongs to the group of subdominant species in forest habitats.

COMPARISON OF THE RESULTS OBTAINED BY MOERICKE'S CUPS AND A LIGHT TRAP

In 1976—1977 in Warsaw, insects were additionally caught by a light trap. This trap was set in the centre of the town, on the sixth floor of the Institute of Zoology at Wilcza Street.[4] This method is commonly used to capture neuropterans. Moericke's cups were not used for this purpose so far. They provided, however, a rich and interesting material, so it seems useful to compare the results obtained by two methods. For this purpose the material from 16 Moericke's cups was used. They were set in the centre of Warsaw near the light trap, and at the same time. The cups were placed in the courtyard of the Institute of Zoology at Wilcza Street, in a courtyard in M.D.M., and at the Konstytucji Square.

The material from the light trap consisted of 323 individuals representing

[4] The light trap was supplied with a 125-watt UV lamp, two 25-watt fluorescent lamps, and a 100-watt bulb.

Table 10. Results of neuropteran capture by a light trap and Moericke's cups in the centre of Warsaw in 1976—1977 (N — number of individuals)

No.	Species \ Method	Light trap		Moericke's cups	
		N	%	N	%
1	*Wesmaelius nervosus* (Fabr.)	1	0.3	–	–
2	*Wesmaelius subnebulosus* (Steph.)	–	–	15	17.6
3	*Hemerobius humulinus* L.	4	1.2	4	4.7
4	*Hemerobius stigma* Steph.	5	1.5	–	–
5	*Hemerobius nitidulus* Fabr.	8	2.5	–	–
6	*Hemerobius lutescens* Fabr.	2	0.6	–	–
7	*Sympherobius pygmaeus* (Ramb.)	2	0.6	1	1.2
8	*Sympherobius elegans* (Steph.)	2	0.6	1	1.2
9	*Sympherobius fuscescens* (Wall.)	1	0.3	–	–
10	*Nineta flava* (Scop.)	1	0.3	10	11.8
11	*Nineta ciliata* (Wesm.)	–	–	1	1.2
12	*Chrysopa phyllochroma* Wesm.	1	0.3	–	–
13	*Chrysopa viridana* Schn.	21	6.5	1	1.2
14	*Chrysopa nigricostata* Brau.	20	6.2	1	1.2
15	*Chrysopa septempunctata* Wesm.	18	5.6	12	14.1
16	*Anisochrysa prasina* (Burm.)	3	0.9	1	1.2
17	*Chrysoperla carnea* (Steph.)	231	71.7	29	34.1
18	*Cunctochrysa albolineata* (Kill.)	3	0.9	8	9.4
	Total	323		95	

16 species. The material from all the Moericke's cups comprised 95 individuals representing 13 species. There were significant differences in the species composition and abundance obtained by these two methods (Table 10).

The material obtained from the light trap was characterized by a high proportion of *Chrysoperla carnea* (71%). The next most abundant species were *Chrysopa viridana* (6.5%) and *Ch. nigricostata* (6.2%), the species which are rare in urban green areas of Warsaw. *Nineta flava*, the dominant species in Warsaw parks, was represented by only one individual. *Wesmaelius subnebulosus*, a characteristic species of the entire urban green, was totally lacking.

The material from Moericke's cups was also dominated by *Chrysoperla carnea*, but its proportion was considerably lower (34%). The next most abundant species were *Wesmaelius subnebulosus* (17%), *Chrysopa septempunctata* (14%), *Nineta flava* (11.8%), and *Cunctochrysa albolineata* (9.4%). Two species abundantly captured by the light trap, *Chrysopa viridana* and *Ch. nigricostata*, were represented by single individuals.

The above results show that these two capture methods are very selective. The results obtained by the light trap were probably influenced by differences in the sensitivity to light in particular species, and also in their tendency to distant flights. Moericke's cups seem to provide

less biased results, though differences in the response of different species to the yellow colour cannot be excluded. An important advantage of this method is its local range, which allows a precise determination of the fauna of small, strictly delimited areas.

CONCLUSIONS

In linden canopy of Warsaw 21 neuropteran species were recorded The mean abundance index of neuropteran communities was 0.327.

All types of urban green areas shared 10 neuropteran species, of which 7 belonged to the group of absolutely constant in the urban habitat. They comprised *Wesmaelius subnebulosus, Hemerobius humulinus, Nineta flava, Chrysopa septempunctata, Chrysoperla carnea, Anisochrysa prasina*, and *Cunctochrysa albolineata*. At the same time these were most abundant species in the town. Neuropteran communities in parks were dominated by *Nineta flava*, in housing estates by *Anisochrysa prasina*, and in streetside habitats by *Chrysoperla carnea*.

The distribution of neuropterans in urban habitats was mostly determined by site conditions and to a lower extent by trophic conditions.

The highest species richness and abundance of neuropteran communities was observed in central parts of the parks, where the air humidity was the highest and microclimate was relatively stable.

Neuropteran communities tended to be simplified;
— in peripheral parts of the parks,
— in housing estates with decreasing size of green areas,
— in streetside green with increasing distance to a park.

In all these cases, the deterioration of the site conditions was related to a reduced habitat heterogenity, lowered air humidity, and reduced microclimatic stability.

Neuropterans have abundant food resources in urban habitats, as aphids and leafhoppers are abundant in all types of urban green areas; much more abundant than in neighbouring linden-oak-hornbeam forests.

After *Coccinellidae*, neuropterans are the second important group of aphidophages that can control the abundance of sucking phytophages in the canopy of urban trees (Czechowska et al. 1979). But because of their ecological requirements, neuropterans are important mainly in larger green complexes, in parks and large housing estates.

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STRUKTURA ZGRUPOWAŃ SIATKOSKRZYDŁYCH (*NEUROPTEROIDEA*) W ZIELENI MIEJSKIEJ WARSZAWY

STRESZCZENIE

Strukturę zgrupowań *Neuroptera* badano w koronach lip w trzech głównych środowiskach

zieleni miejskiej Warszawy: w parkach, w zieleni osiedli mieszkaniowych i w zieleni ulicznej.

Najwyższą liczebność zgrupowania sieciarki osiągają w parkach; wskaźnik liczebności wynosi tam przeciętnie 0,583. Gatunkiem dominującym jest *Nineta flava*. W zieleni osiedlowej przeciętny wskaźnik liczebności zgrupowań wynosi 0.292. Najbardziej liczebnymi gatunkami są: *Anisochrysa prasina* i *Nineta flava*, dominujące w poszczególnych obiektach. Najmniej liczebne zgrupowania (wskaźnik 0,114) występują w zieleni ulicznej. Poszczególne zgrupowania różnią się dominantami, a gatunkiem ogólnie najliczniejszym w tym środowisku jest *Chrysoperla carnea*. W skali całej zieleni miejskiej średni wskaźnik liczebności *Neuroptera* wynosi 0,327, a dominantami są *Nineta flava* (36%), *Chrysoperla carnea* (17.7%) i *Anisochrysa prasina* (17.1%).

Rozmieszczenie sieciarek w biocenozie miejskiej jest uzależnione od warunków abiotycznych, głównie wilgotności. Najbardziej liczebne populacje tych owadów i zgrupowania o najbogatszym składzie gatunkowym występują w centralnych rejonach dużych kompleksów zieleni. Miejsca te charakteryzują się największą wilgotnością i stosunkowo stabilnym mikroklimatem.

Spadek liczebności zgrupowań i ubożenie składu gatunkowego obserwuje się w miarę zmniejszania się powierzchni zieleni. Tendencja ta występuje w ciągu: parki — osiedla — ulice oraz w grupie obiektów osiedlowych. Podobna tendencja zaznacza się w obrębie poszczególnych parków, w kierunku od centrum ku peryferiom. Zjawiska te towarzyszą pogarszaniu się warunków siedliskowych, czego podłożem jest spadek wilgotności środowiska. Nie stwierdzono natomiast bezpośredniego wpływu na zgrupowania sieciarek zanieczyszczeń przemysłowych i motoryzacyjnych.

Środowisko miejskie zapewnia sieciarkom obfitą bazę pokarmową głównie w postaci mszyc. Owady te występują licznie we wszystkich środowiskach zieleni miejskiej, a ich liczebność jest tam znacznie wyższa niż w okolicznych lasach grądowych.

Sieciarki są drugą po biedronkach ważną grupą afidofagów, mogącą w istotny sposób regulować liczebność fitofagów ssących w koronach drzew miejskich. Ze względu jednak na ich wymagania siedliskowe, ekologiczne znaczenie sieciarek ujawnia się głównie w większych kompleksach zieleni, a więc w parkach i dużych osiedlach mieszkaniowych.

Porównując zgrupowania sieciarek z zieleni miejskiej Warszawy i homologicznych dla tego obszaru okolicznych lasów grądowych (*Tilio-Carpinetum*), stwierdzono podobieństwo ich liczebności oraz składów gatunkowych. Zasadnicza różnica dotyczy gatunków dominujących. W lasach grądowych najwyższą przeciętną liczebnością odznacza się *Chrysotropia ciliata*. Ten wilgociolubny gatunek właściwie nie wnika na przesuszone tereny miejskie. Ubytek ten jest zrekompensowany zwiększoną liczebnością innych gatunków, przede wszystkim *Nineta flava*.

СТРУКТУРА СООБЩЕСТВ СЕТЧАТОКРЫЛЫХ (*NEUROPTEROIDAE*) ГОРОДСКИХ ЗЕЛЕНЫХ НАСАЖДЕНИЙ ВАРШАВЫ

РЕЗЮМЕ

Видовой состав и количественное соотношение в сообществах сетчатокрылых были исследованы в разного типа городской зелени Варшавы. Констатировали, что эти сообщества зависят от урбанизационного пресса. Исследования провели в трех типах городской зелени: парках, зеленых насаждениях жилых районов и уличных насаждениях.