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Origin and variability of the fauna of urbanized areas[1]

[With 6 tables and 11 figures in the text]

Abstract. The invertebrate fauna of the green in Warsaw is rich, but heterogeneous in respect of origin. It consists not only of indigenous species but also of those from other habitats. The percentage of the latter in the fauna of Warsaw in considerable and in most of the animal groups studied they constitute 30–40%. The internal variability of the fauna in the urban green is higher than of the fauna in original natural habitats. The extent of this variability reflects the manner in which a given area has been managed and utilized.

INTRODUCTION

Urbanization is one of the processes that greatly change the natural environment, and the habitat conditions characteristic of a city result from a complete transformation of the original habitat (ANDRZEJEWSKI 1975, FRANKIE, EHLER 1978). Man's intensive utilization of a given habitat and all the technological problems this involves give rise to a number of changes in both the abiotic and biotic factors in the habitat.

During preliminary work connected with the development of infrastructure (waterworks, sewers) and housing, many water – yielding strata are intersected, and this results in lowering the level of groundwater. Apart from this, most open waters are liquidated in the course of area management. The structure of the soil is destroyed, too – soil gets mixed with subsoil and scraps of building materials. That is the reason why in Warsaw most soils are either non-structural or rubble-transported ones.

Buildings and asphalt or concrete streets and squares cover a considerable part of the city. Rain water from these areas is drained off directly into canals and this greatly reduces water supplies in urbanized areas. At the same time, the surfaces of

[1] The paper is based on the results of long-term investigations carried out at the Institute of Zoology PAS in the Warsaw metropolis and in the natural and paranatural habitats within the original environment of Warsaw [PISARSKA, GARBARCZYK (eds.) 1989, CHUDZICKA, PISARSKA (eds.) 1989].

buildings and streets overheat and accumulate a lot of heat which is then given off into the nearest environment.

All these phenomena together, i.e. liquidation of open waters, draining off most rain water into canals, lower lovels of ground waters and the accumulation of heat by buildings and streets, lead to a distinct drying and warming up of the climate and to over-drying of the soil.

This phenomenon is further intensified by a lot of heat given off by industrial plants, transport and heated buildings. In a city, both industry and transport emit into the environment not only heat but also enourmous amounts of chemical substances, and electromagnetic and acoustic waves. As a result of this the environment becomes extremely polluted. These substrances settle on plants, penetrate into the soil and ground waters. In consequence the soil gets salinized and acidulous, contaminated with heavy metals, hydrocarbons and many other chemical compounds. Many of these substances find their way into plants and accumulate in their tissues.

Most frequently, the indigenous flora is almost completely destroyed during construction work and later, when the management of a given area begins. Foreign plants are introduced in its place. The very high density of people in cities leads to intensive utilization of urban green areas. In most cities a dense network of concrete roads and paths has converted green areas into small isolated green patches. These plots are usually sown with grass, and what happens most frequently is that the grass is mown and all dead organic matter (dead grass blades, leaves, twigs) are raked out and removed from the city. Such procedures leave lawns with thin low grass and bare dry soil showing everywhere. However, the expansive natural vegetation cannot be eliminated even by man's constant practices and it overgrows lawns anyway. As a result of this, after a few years, the plant communities developing on lawns are similar to the meadow vegetation of the alliance *Arhenatherion* or *Cynosurion*. Since the environment is over-dry, polluted and impoverished the primary production on urban lawns is lower than that in meadows.

Trees and bushes are planted in urban green areas either separately, in rows or in clusters. In Warsaw, most of them are indigenous trees, mainly species of a linden-oak-hornbeam forest (*Tilio-Carpinetum*) although many species of trees and bushes come from other habitats or even from other biogeographic zones.

RESULTS AND DISCUSSION

Green plots in Warsaw are a heterogeneous habitat consisting of two overlapping ecosystems – the meadow and the forest ones. The fauna of this highly degraded habitat is relatively rich despite the fact that the peculiar conditions in the city are a barrier for many animal species occurring in the potential habitats i.e. in *Tilio-Carpinetum* forests and moist meadows. The number of species recorded in the green of Warsaw is only several per cent lower than the number of species occurring in potential habitats (Tab. I).

Table I. Number of species (N) choosen groups of animal

Taxon	Original habitats	Urban greenery					
		Total		From original habitats		From alien habitats	
	N	N	%	N	%	N	%
Homoptera:							
Auchenorrhyncha	113	107	94.69	74	69.16	33	30.84
Coleoptera:							
Elateridae	20	18	90.00	12	66.67	6	33.33
Chrysomelidae	51	41	80.39	28	68.29	13	31.71
Coccinellidae	24	32	133.33	20	62.50	12	37.50
Hymenoptera:							
Sphecidae	59	69	116.95	41	59.42	28	40.58
Vespidae	23	12	52.17	11	91.67	1	8.33
Lepidoptera:							
Noctuidae	89	44	49.44	33	75.00	11	25.00
Total	379	323	85.22	219	67.80	104	32.20

These areas are inaccessible to most hygrophilous and shade-loving species and also to species feeding on decaying organic matter such as dead leaves, wood or fungi developing in it. This group also includes a number of species living in tree canopies whose development partly takes place in forest soil or in the undergrowth. There are many other species never found there – phytophagous ones whose host plants have been eradicated or those that are sensitive to food contamination (phytophagous species feeding on the external parts of plants) or to environment pollution (soil species with no resistance to the salinity and acidification of the soil).

The losses in the species composition of the fauna are largely compensated by immigration of species from other, alien habitats (Figs. 1–4). They are mainly xerophilous species from coniferous forests and xerothermal grasslands, but this group also includes species with other habitat requirements e.g. carr species which enter these areas together with their host plants grown by man. Species of foreign origin have a considerable share in the fauna of the city, e.g. in *Sphecidae* and *Coccinellidae* they constitute about 40%, in *Auchenorrhyncha, Noctuidae, Chrysomelidae, Elateridae* – about 30%.

It has been recorded that new animal communities develop in urban green areas. They differ from homologous communities of the potential habitats not only in the species composition but in the structure as well. These changes have a different character depending on the biotic group making a given community, and on its origin. For instance in the groups of *Coccinellidae,* and *Elateridae* the abundance of most forests species and that of many meadow apecies decreases. Species that were dominant in the original habitat are transferred into the group of accessary species.

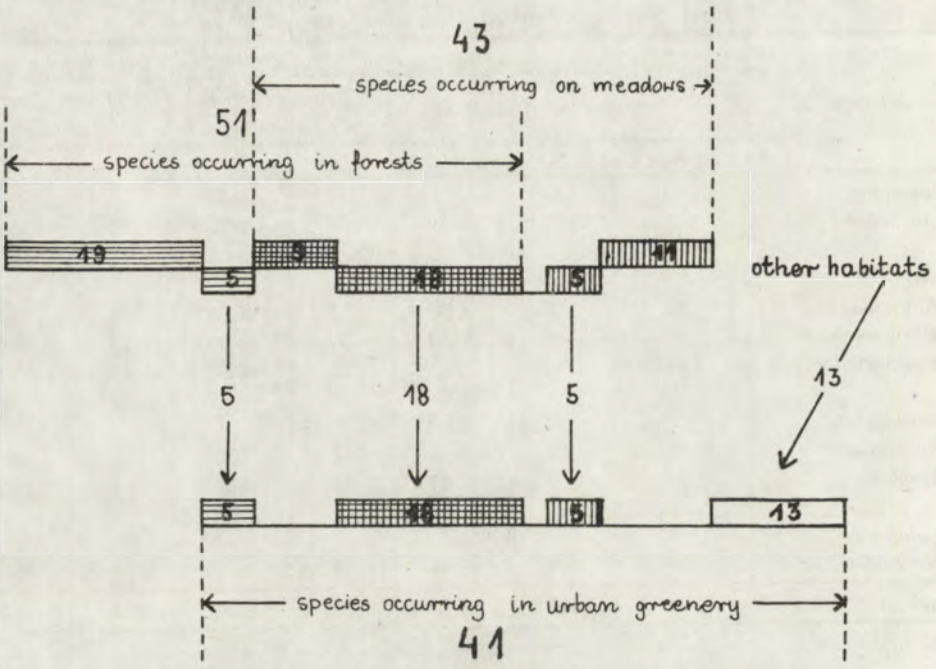

Fig. 1. Origin of *Chrysomelidae* in urban greenery.

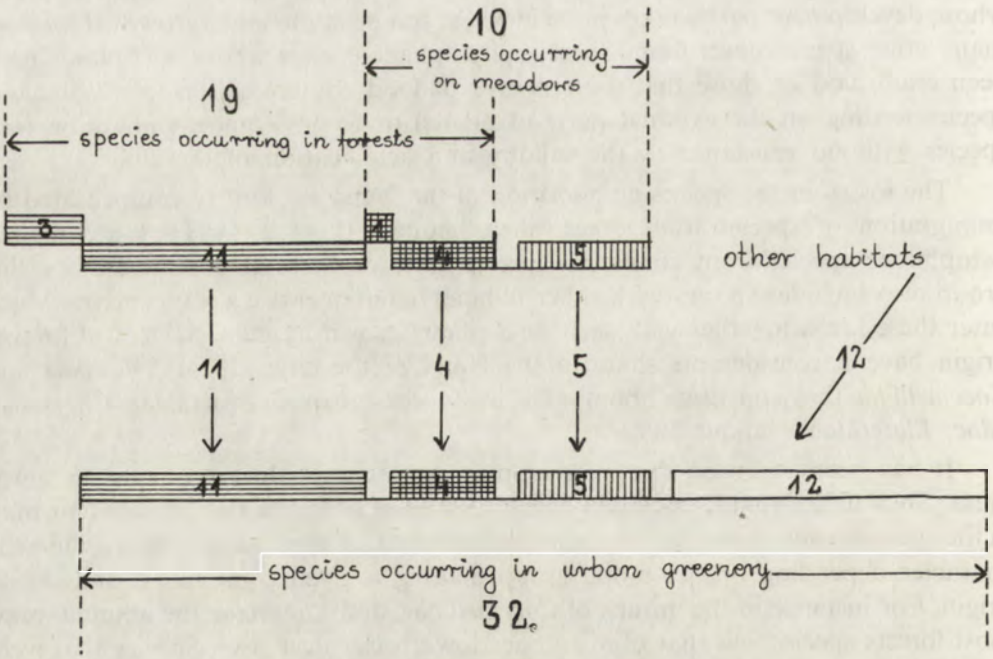

Fig. 2. Origin of *Coccinellidae* in urban greenery.

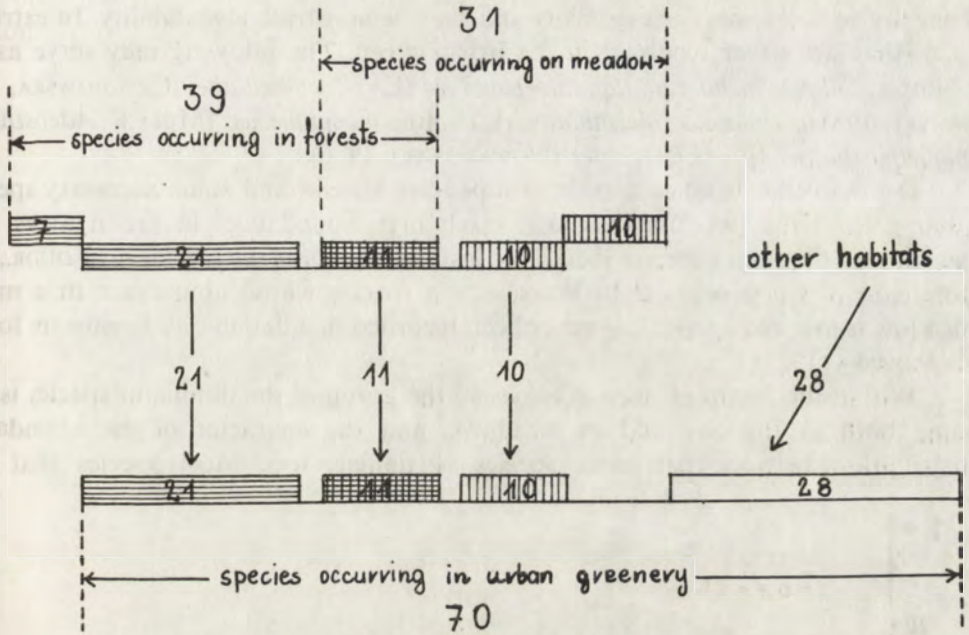

Fig. 3. Origin of *Sphecidae* in urban greenery.

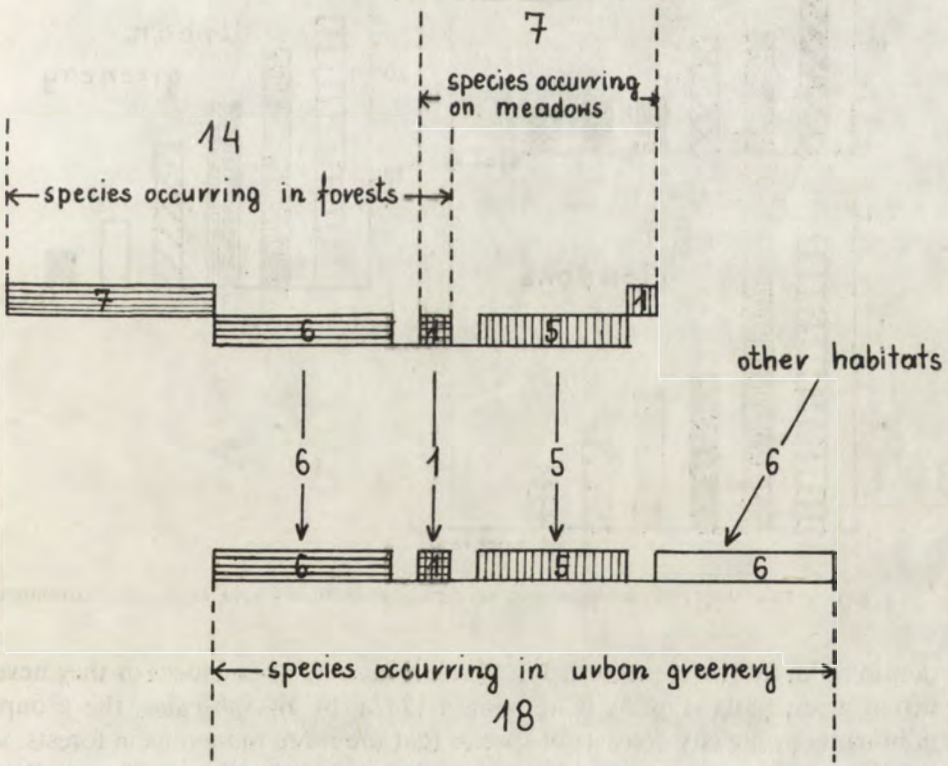

Fig. 4. Origin of *Elateridae* in urban greenery.

They are recorded only occasionally and they demonstrate low stability. In extreme cases they are never recorded in the urban green. The folowing may serve as an example: *Subcoccinella vigintiquatuorpunctata* (L.) (*Coccinellidae*) (CZECHOWSKA, BIELAWSKI 1981), *Dalopius marginatus* (L.), *Athous subfuscus* (MÜLL.), *Adeosthetus quadripustulatus* (F.) (*Elateridae*) (NOWAKOWSKI 1986).

On the other hand in certain groups alien species and some accessary species coming from the potential habitats, reach high abundances in urban areas and become the dominant species there. For instance, *Longitarsus succinneus* FOUDR., the dominant of *Chrysomelidae* in Warsaw is a species whose abundance in a moist meadow is low; the species has never been recorded in a linden-oak-hornbeam forest (WĄSOWSKA 1987).

Within the group of *Auchenorrhyncha* the group of the dominant species is the same both in the city and in meadows, and the character of the abundance distribution between particular species is similar, too. Most species that are

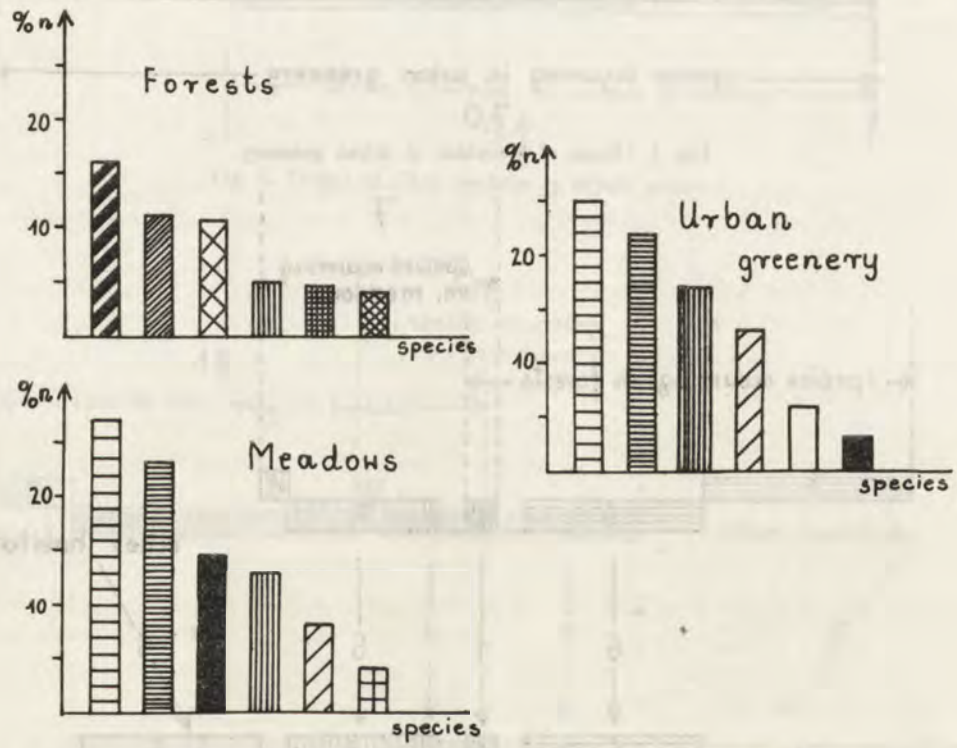

Fig. 5. Dominants of *Auchenorrhyncha* communities in different kinds of environments.

dominant in forests are recorded in Warsaw in small abundances or they never enter urban green plots (Fig. 5). (CHUDZICKA) 1987a, b). In *Sphecidae*, the group of the dominants in the city consists of species that are more numerous in forests, whereas the species of a moist meadow have a small abundance in the city (Fig. 6). Within the

group of *Vespoidea* the dominant of a linden-oak-hornbeam forest and the meadow dominant are co-dominants in the city (Fig. 7) (SKIBIŃSKA 1986, 1987).

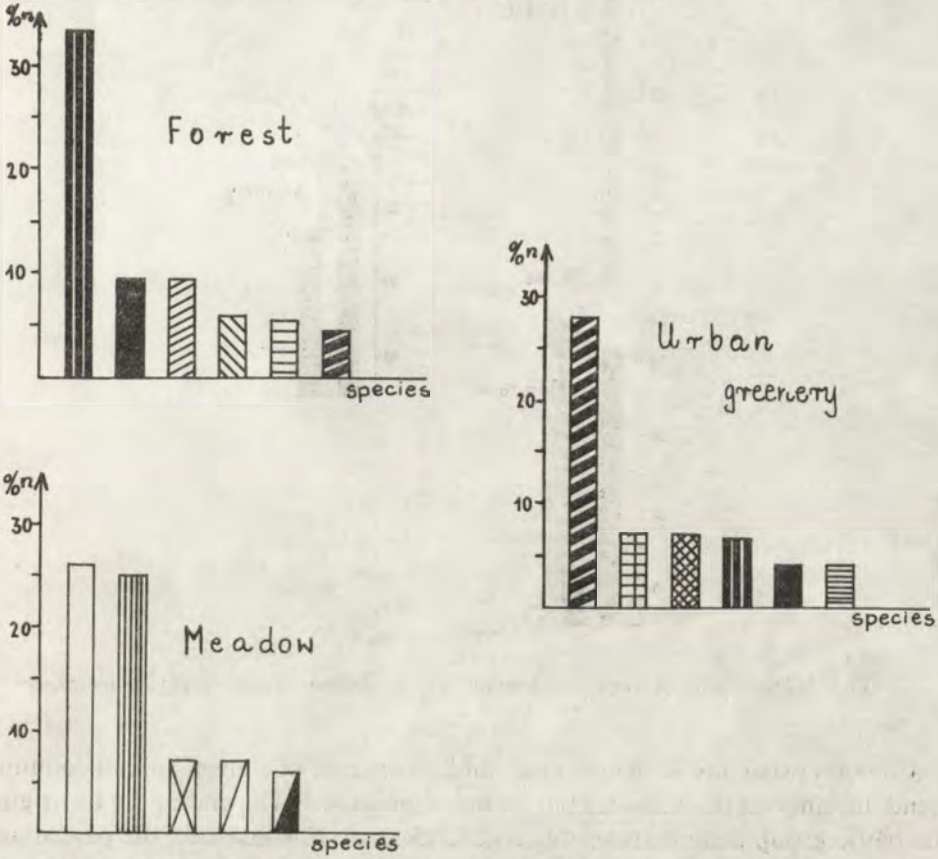

Fig. 6. Dominants of *Sphecidae* communities in different kinds of environments.

Very often, the differences in the domination structure between animal communities in the natural habitats and in the urban green are not limited only to qualitative changes (other dominant species), but there also appear very significant quantitative changes in the character of the abundance distribution between particular species. Animal communities in natural habitats are frequently characterized by differences in the abundance of particular species considerably lower than those in the urban fauna. Such a community has, as a rule, several species in the groups of dominants and subdominants and a numerously represented group of influents, whereas accessary species constitute only a small percentage of this community. The changes that urbanization pressure causes in the structure of communities tend towards a decrease in the number of the dominant species accompanied by an increase in the abundance of the species occupying this position. The number of species in the groups of subdominants and influents also decreases with a simultaneous decrease in the abundance of these species, but the number of accessary species increases (Fig. 8).

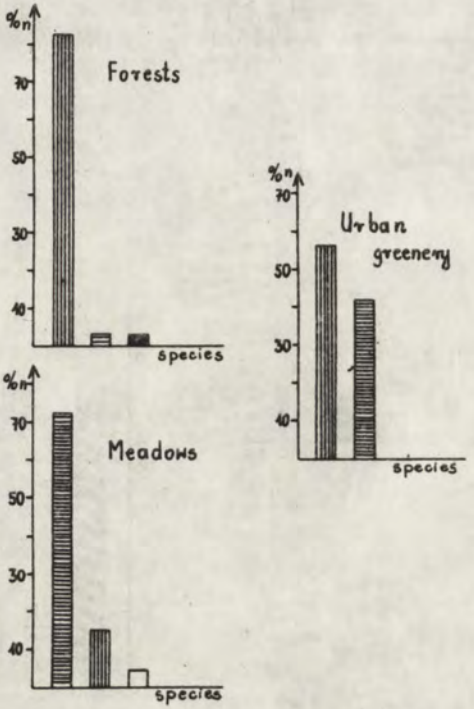

Fig. 7. Dominants of *Vespoidea* communities in different kinds of environments.

Changes occurring in the structure and abundance of a given animal community depend not only on its character but on its origin as well. Depending on its origin the same biotic group demonstrates different tendencies. For instance, the percentage of sucking phytophages in the herb layer of urban lawns is lower than in meadows (Tab. II), but in tree canopies – much higher than in forests (Tab. III).

Within the communities of *Aphidoidea, Auchenorrhyncha* (sucking phytophages) or of *Coccinellidae, Sphecidae* (predators) connected with tree canopies there are species that find favourable conditions in urban green areas and therefore they

Table II. Proportion (%) of biotic groups in the herb layer

Groups	Meadow	Urban greenery
Phytophages chewing	4.5	5.8
Phytophages sucking	67.0	48.0
Miners	5.3	26.7
Predators	4.6	2.6
Parasitoids	18.5	16.9

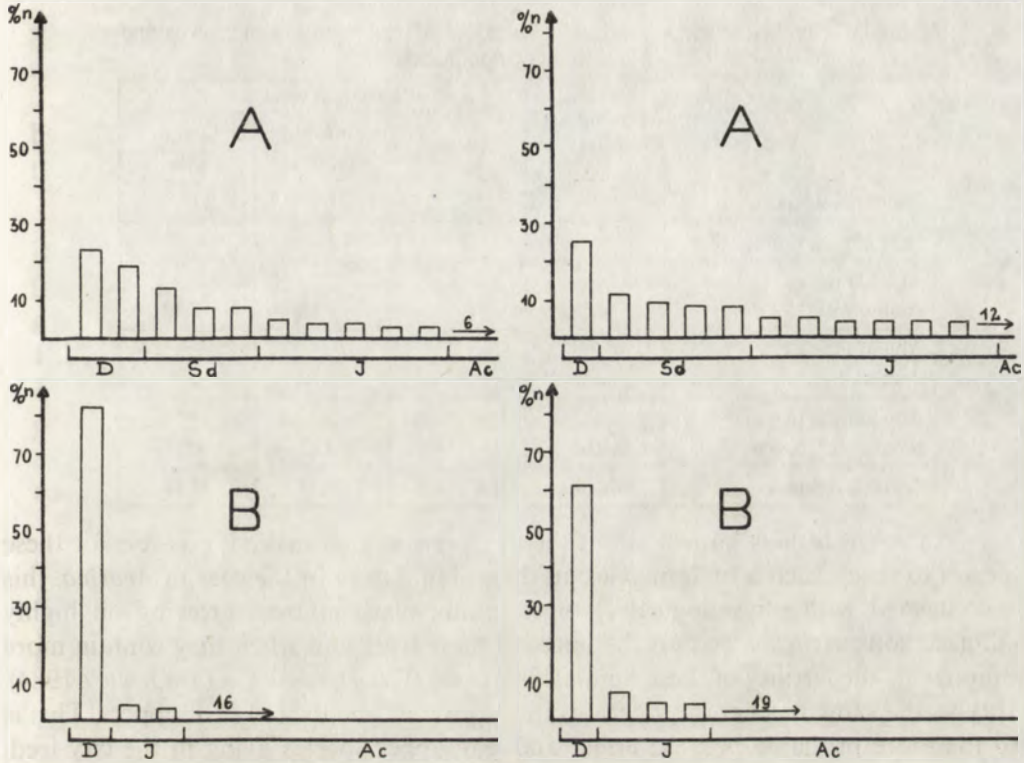

Fig. 8. Comparison of domination structure of *Sphecidae* communities in natural habitats (A) and urban greenery (B); D – dominants, Sd – subdominants, I – influents and Ac – accessary species.

increase their abundance. Among phytophages the abundance of such species generally increases together with an increase in the intensity of urban pressure and they reach their highest abundances in the extremely over-dry, polluted and isolated streetside green (Fig. 9). The increase in the abundance of these groups, and strictly speaking of certain species, is so high that the total abundance of the fauna of tree canopies in Warsaw exceeds that in linden-oak-hornbeam forests. The example of leafhoppers shows clearly that the increase in the abundance of the community is caused solely by high abundance of only one dominant (*Alebra wahlbergi*) (Tab. IV).

Table III. Proportion (%) of biotic groups in tree crowns layer

Groups	Deciduous forest	Urban greenery
Phytophages chewing	30.7	5.8
Phytophages sucking	28.4	87.8
Predators	8.4	2.6
Parasitoids	32.5	3.6

Table IV. Number of species and abundance of leafhoppers in linden crowns and proportion of dominants

	Deciduous forest	Urban greenery		
		Parks	Housing estates	Street-side
Number of species	19	15	11	11
Number of dominants	9	2	1	1
Abundance of community	0.5	2.59	4.13	7.40
Abundance of dominants	0.45	2.25	3.50	6.87
Abundance of remaining species	0.05	0.34	0.63	0.57
% of dominants	90.00	86.87	84.75	92.84

At present little is known about the mechanisms that make it possible for these species to reach such a high increase in their abundance. In the case of *Acarina*, this is connected with physiological changes taking place in trees growing on highly salinized soils. *Acarina* feed on the juices of these trees and when they contain more aminoacids the fertility of these animals increases (KROPCZYŃSKA – LINKIEWICZ 1984). Maybe, the same mechanism operates in the case of aphids and leafhoppers. This is all the more probable because aphid and leafhopper species living in the city feed, just like *Acarina*, on the juice taken from cells. Other characteristic features of these

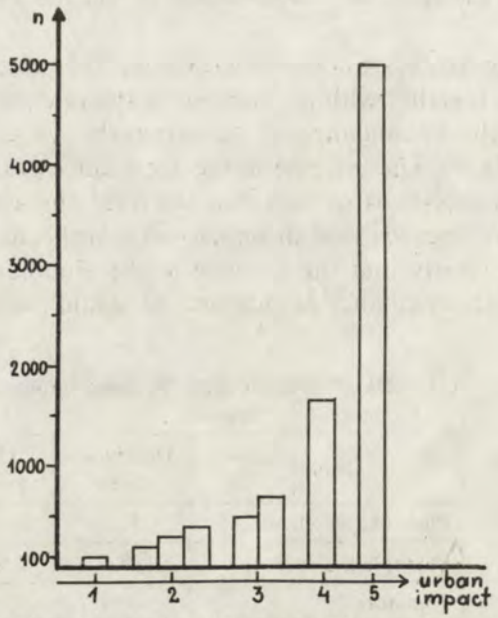

Fig. 9. Abundance of aphids on *Quercus robur* (L.); 1 – natural habitats, 2 – parks, 3 – housing estates, 4 – street-side green adjacent to parks, 5 – isolated street-side green.

species are: a small body size, the occurrence of at least two generations a year, and an intire life cycle completed in tree canopies.

An increase in the abundance of ladybirds is connected with a very rich food basis they find in these areas – with aphids whose abundance is many times higher than in natural habitats (Fig. 10).

An increase in the abundance of predatory *Hymenoptera* of the family *Sphecidae* is due to two factors. The first is, just as in the case of ladybirds, an exceptionally rich food basis which, in the form of aphids, is available to representatives of various genera of this family. For instance, the abundance of *Hymenoptera* of the genus *Passaloecus* in urban green is twice as high as that in natural habitats, of the genus *Pemphredon* – fourfold higher, of *Psenulus* – eightfold. Podsolization of the majority of green plots is the second factor. *Mellinus arvensis* – a coniferous forest species appears there in profusion. The abundance increase of this species in urban green is almost fortyfold in comparison with its abundance in a linden-oak-hornbeam forest.

These changes in the species composition and abundance of particular animal communities are followed by a change in the percentage and importance of particular biotic groups in zoocenoses. Sucking phytophages (aphids and leafhoppers) become an absolutely dominant group in the tree canopies in urban green areas (Tab. II).

The animal communities occurring in the herb layer of urban lawns come mainly from meadow habitats. They show a decrease in the number of species and most of them also a decrease in the abundance. The total abundance of the fauna of the herb layer of urban lawns is lower than that in meadows. This decrease is mainly due to a nearly 50% drop in the abundance of one of the dominant groups – leafhoppers. However, there is an increase in the percentage and importance of

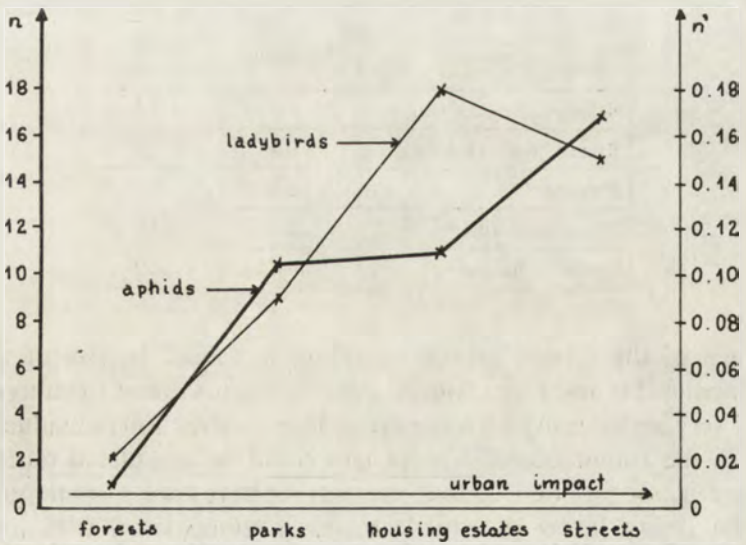

Fig. 10. Relationships between the abundances of aphids (n) and ladybirds (n') and urban pressure.

mining insects on urban lawns (Tab. II). Yet this increase in the abundance of mining insects does not compensate for the losses in the abundance of the entire fauna of this layer caused by leafhoppers.

The abundance of beetles of the family *Curculionidae* – typical chewing phytophages – increases in the herb layer of urban lawns and that is an astonishing phenomenon. This increase is due to species whose almost entire development (from egg to pupa) takes place in the soil (CHOLEWICKA, unpublished data). In this layer chewing phytophages are an expansive group demonstrating a considerable increase in abundance.

Most of the soil fauna of urban lawns also comes from meadow habitats. A low density of the herb layer on urban lawns, an absence of the litter layer and a considerable over-drying of the soil are responsible for the fact that the habitat conditions on lawns resemble those found in the early succession stages. Thanks to gardening care urban lawns are kept at the succession stage for a long time. As a result of such habitat conditions numerous succession species that appear in the soil fauna reach very high abundance. They cause a distinct increase in the abundance of most biotic groups of the mesofauna and macrofauna of the soil. A significant increase in abundance is also demonstrated by ants and in the end they are an absolutely dominant group, and constitute 67% of the abundance of the fauna in this layer (Tab. V). However, there are practically only two species – *Lasius niger* and *L. flavus*.

It must be pointed out that two biotic groups – chewing phytophages and saprophages – gain in importance in the urban soil fauna. A considerable increase in

Table V. Proportion (%) of biotic groups in the fauna of soil

Groups	Meadow	Urban greenery
Rhizophages chewing	3.6	5.3
Rhizophages sucking	0.4	3.5
Predators	9.8	9.8
Makrosaprophages	5.0	13.9
Omnivorous (ants)	46.8	66.9

the abundance of the former group, including larvae of beetles of the families *Elateridae*, *Scarabeidae* and *Curculionidae* poses a serious threat to cultivated plants. They reach a very high density on some urban lawns – over 100 individuals per 1 m^2. An increase in the abundance of saprophages could be considered positive for soil processes were it not for the fact that mesosaprophages are a biotic group whose abundance on urban lawns greatly decreases in comparison with meadows (in meadows – 53000/m^2; in the city – 23000/m^2). This is, therefore, a case of a change in

the structure of the soil fauna – an increase in the abundance of animals that crumble organic remains and a decrease in the abundance of species responsible for the humification and mineralization processes. This leads to impoverishment of the soil.

The variety and mosaic character of the fauna of urban green must be borne in mind while discussing the subject. Natural habitats such as forests and meadows are not completely homogeneous habitats either, but the differences between the neighbouring parts are not big and the transitions are smooth. The degree of the fauna variability in different areas within the same type if habitat reflects the character of a given habitat. This is shown by an index obtained from the total number of species in proportion to the mean number of species ($\Sigma N/\tilde{N}$) occurring within habitats of the same type. In totally homogeneous habitats the value of this proportion equals one, and along with an increase in the degree of habitat differentiation the value of the index is higher and higher. That is why the index has lower values for natural habitats than for urban green (Fig. 11). The number of constant species drops in urban green and this, too, indicates an internal differentiation of the urban fauna (Tab. VI).

Table VI. Fauna of the herb layer in orginal and urban habitats exemplified by leafhoppers; ΣN – total number of species in a given type of habitat, $\tilde{N}$ – mean number of species on one plots

	Orginal habitat Meadow	Urban greenery			
		Parks	Housing Estates	Street-side	Total
ΣN	53	50	47	44	67
$\tilde{N}$	39	27	19	22	23
$\Sigma N/\tilde{N}$	1.36	1.85	2.47	2.00	2.91
Number of constant species	35	22	15	16	30
Percent of constant species	89.7	81.5	78.9	72.7	63.8

In urban areas particular patches of vegetation are more or less isolated from one another and there may be great differences between them. The habitat conditions on particular plots depend on many factors such as age, size, number of trees and extent of pollution, and housing i.e., generally speaking, on the character of management and on the way of utilization of a given area. So big habitat differences result in distinct changes in the species richness and structure of the fauna between particular types of green. It is usually richer in parks than in the green of housing estates or on streetside strips. Yet at the same time the fauna of parks, within certain groups, shows a far smaller internal differentiation (Fig. 11).

Urban lawns are often separated by wider or narrower belts of asphalt or by buildings and that is why they form islands or archipelagoes at some distance from

one another. According to the law of inhabiting of islands (Mac Arthur, Wilson 1967) the richness of their fauna depends on their size and distance from "main land" i.e. from natural habitats surrounding a city and on the number of habitats.

In the transect of increasing urban pressure, beginning with the natural habitats through parks, housing estate green to streetside strips the number of animal species occurring in one separate plot ("island") drops far more than the number of all species recorded in a particular type of urban green. Therefore, the species composition of the fauna of urban green can be described as rich (the number of species is often higher than that in homologous natural habitats), but at the same time it is labile because it frequently is a result of great differences between particular urban lawns. Apart from a group of expansive species occurring in all green areas there is recorded, both in urban green and in islands, a quantitatively large group of species that are less expansive and appear occasionally on separate urban lawns.

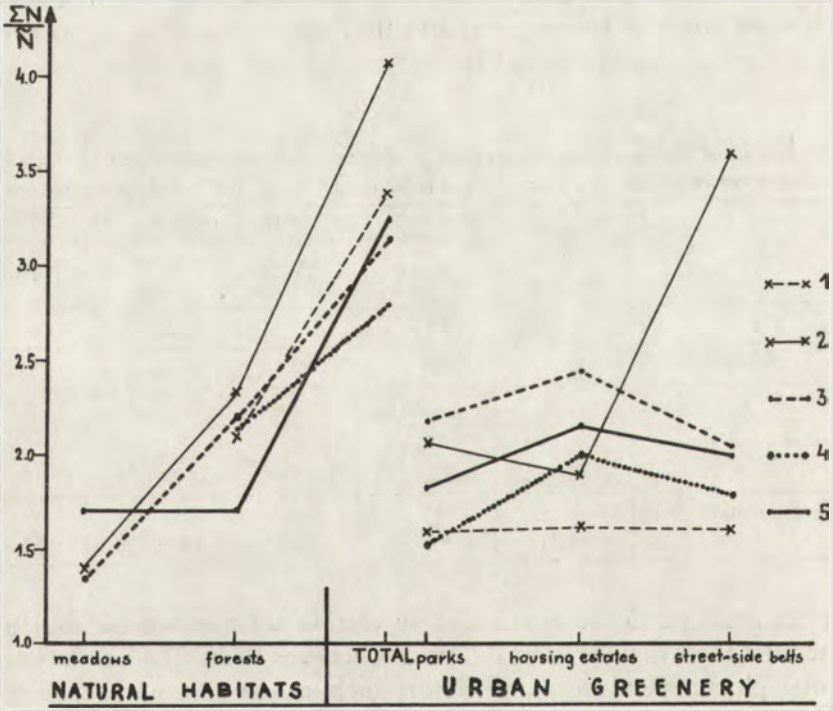

Fig. 11. Value of proportion $\Sigma N/\tilde{N}$ for various taxons in natural habitats and urban greenery; 1– *Vespoidea*, 2 – *Elateridae*, 3 – *Auchenorrhyncha*, 4 – *Sphecidae*, 5 – *Chrysomelidae*.

This relatively big group of species (that occur occasionally on particular lawns) is very important for maintaining the richness of the fauna and it constitutes a reserve pool of species which may use empty ecological niches and thus enrich the fauna of particular green plots. If the species composition of the fauna in urban green is to remain rich it is necessary to create a system of ecological corridors that would

enable animals to migrate from one green plot to another. The presence of large green complexes with a rich and stable fauna, for instance parks, is very important in cities because such complexes are a refuge for the fauna.

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STRESZCZENIE

[Tytuł: Pochodzenie i zróżnicowanie fauny terenów zurbanizowanych]

Ekosystemy miejskie mają charakter heterogeniczny. Złożone są one z dwu nakładających się ekosystemów – łąkowego i leśnego. Fauna bezkręgowców zieleni Warszawy jest bogata lecz niejednorodna pod względem pochodzenia. Liczba gatunków występujących w zieleni miejskiej jest zaledwie o kilkanaście procent niższa niż liczba gatunków w środowiskach potencjalnych tj. lasach grądowych

(*Tilio-Carpinetum*) i na łąkach świeżych (*Arhenatherion*). Oprócz gatunków rodzimych występują również gatunki pochodzące z obcych siedlisk. Są to głównie gatunki sucholubne, pochodzące z borów i muraw, ale spotykamy także gatunki o innych wymaganiach siedliskowych np. łęgowe, które wkraczają na te tereny wraz z roślinami żywicielskimi sadzonymi przez człowieka. Gatunki obcego pochodzenia mają znaczny udział w faunie Warszawy, w większości badanych grup stanowią około 30–40%.

Zespoły zwierząt występujące w mieście znacznie różnią się składem gatunkowym, liczebnością i strukturą (biotyczną, dominacyjną) od homologicznych zespołów w środowiskach potencjalnych. Zmiany te, w zależności od grupy biotycznej tworzącej dany zespół i od jego pochodzenia mają różny charakter.

Fauna w zieleni miejskiej wykazuje znacznie większe wewnętrzne zróżnicowanie niż w środowiskach naturalnych. Stopień jej zróżnicowania odzwierciedla sposób zagospodarowania i użytkowania terenu. W mieście stwierdzono znaczne różnice w bogactwie gatunkowym i strukturze zgrupowań między poszczególnymi typami zieleni, a nawet pomiędzy poszczególnymi powierzchniami w obrębie tego samego typu. Najsilniejsze zróżnicowanie wykazuje fauna zieleńców osiedlowych i przyjezdniowych.

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