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An evaluation of an urban environment on the basis of faunisctic data

Abstract. The characterization and evaluation of groupings of invertebrates inhabiting different types of green space in Warsaw is presented. In the description of multispecies faunistic groups, the following variables were taken into consideration: species richness, abundance, and description of the dominance structure, biotic structure and degree of differentiation. Comparative analysis of the variables describing the groupings (taxocenes, phagic groups, trophic levels) allowed the state of the environment to be described, and evaluated – through evaluation of the degree of complexity of the whole system.

ENVIRONMENT AND FAUNA

The process of urbanization affects more and more of the natural environment, and has a decisive influence on the composition and structure of the plants and animals inhabiting an area. The fauna and flora is transformed through the physio-chemical changes which arise in environments under the influence of urbanization. The urban environment covers an ever greater area and is coming to represent a specific type of biotope for many species of plant and animal.

The agglomeration of Warsaw has been founded mainly on one type of habitat: *Tilio-Carpinetum*. Other habitat types occur on small fragments only. The city differs considerably from the land surrounding it in the composition of its vegetation, which has almost all been planted. Green spaces, parks, and the green areas of housing estates have a different plant species composition to the neighbouring non-urbanized areas. In place of the natural communities of lime-oak-hornbeam forest, parkland with a grassy herb layer has been introduced. This often lacks any shrub layer. Elsewhere, dense groups of shrubs are being established, or carpets of grass in the form of lawns. Trees from native habitats (lime-oak-hornbeam forest) are planted in Warsaw, along with many species of trees and shrubs derived from other habitats and even from other geographical zones. Similarly, in the herb layer, besides the vegetation typical of meadows and pastures (*Arrhenatherion*, *Cynosurion*), vegetation of foreign origin is well-represented. Lawn vegetation is also the effect of

management practices; as various mixtures of grass are sown, ornamental plants planted and wild vegetation exterminated.

The green spaces of Warsaw constitute a heterogeneous environment compounded from two overlapping ecosystems: those of meadow and woodland. The type of urban green spaces is determined by the role it has to play, and its diversity – by the manner in which it is used. In consequence, it is possible to note the creation of new animal communities in urban green spaces. These differ considerably from homologous communities in the potential environment, not only in terms of their species composition, but also in their structure.

The best illustration of changes occurring in the fauna inhabiting an environment may be given by examples of the transformations in inverterbrate groupings. This is firstly because the links between particular invertebrate species or groups of species and different types of environment are clearer and stricter than in the case of the majority of vertebrates. On account of their relatively short life-spans, the reaction of invertebrates to environmental stress may be noted more rapidly. Secondly, the invertebrate fauna is represented by such a large number of species that each environment may be characterized by the occurrence there of different multi-species groupings. Thirdly and finally, invertebrates are useful because they inhabit all the stratocenoses – soils, the epigeon, the herb layer, the shrub layer and the tree canopy. Analyses of the internal organization of faunistic groupings allows for characterization at many levels and for the state of the environment, and the changes occurring in it, to be evaluated.

The majority of taxonomic groups down to the family level are composed of species having a diversity of environmental requirements. As a rule, in each taxon of this rank there are both eurytopic species and those with a narrower range of tolerance to habitat conditions, i. e. poli-, oligo- or stenotopic species. A taxon of family rank generally includes species with a wide range of diet – both polyphages and those with a more restricted diet – oligophages and monophages. Sometimes it may also be heterogeneous with regard to the type of food required by different species within it (and therefore species may find places at various trophic levels) and thus both phytophages and zoophages or saprophages may be included in it.

In connection with this, analysis of the species composition of a family in a given environment, and of the population representation of particular species, may define the typical fauna of a given type of environment. The changes taking place in the environment may be reflected in structural changes amongst the communities analyzed.

The characteristics of the taxocene (or a fragmet of it) include in basic form: species composition (list and number of species), abundance and a description of the dominance structure. In association with analysis of the preferences and environmental plasticity of particular species, these basic parameters allow for the richness and diversity of a given faunistic configuration in the environment to be estimated. They also form the basis for the estimation of the degree of transformation of the environment as compared to its potential richness.

For many years, the Institute of Zoology of the Polish Academy of Sciences has carried out faunistic researches on the Warsaw agglomeration and in natural and semi-natural habitats (i. e. the potential "mother" habitat for Warsaw). This research

allows for the characterization of invertebrate communities inhabiting urban green spaces because:

– the research embraces the majority of the invertebrates of Warsaw green spaces, representing various phagic groups and trophic levels. These are, amongst annelid worms – *Enchytraeidae* and *Lumbricidae*, amongst the arachnids – *Aranei* and *Opiliones*, amongst crustaceans – *Isopoda*, and amongst the insects, both wingless (*Collembola*) and all the greater orders of winged insects, from which more than 50 taxa are taken into consideration at the level of the family or superfamily.

– the research includes various stratocenoses – soil, herb layer and the tree canopy.

– material from the studied taxa was collected using standard quantitative methods from different types of green space – parks, the green spaces of housing estates and greenery by roads. Fauna from soil was obtained from 20 study areas, from more than 30 for the epigeon and herb layer, and from the tree canopy from 15 areas.

– while elaborating on the results, the same methods for the analysis of the material were used.

The vast amount of material obtained in this way allows for the evaluation of the urban environment with the use of comparative analyses of various parameters which describe the faunistic groupings (CHUDZICKA, PISARSKA (eds) 1989, CZECHOWSKI 1982, CZECHOWSKI, PISARSKI (eds) 1981, 1986a, b, CZECHOWSKI et al. (eds) 1981, 1982, GARBARCZYK (ed.) 1990, GARBARCZYK, PISARSKA (eds) 1981, LUNIAK, PISARSKI (eds) 1982, PISARSKA, GARBARCZYK (eds) 1989).

Species richness. 3800 species of invertebrate animals have been recorded from Warsaw green spaces. This represents nearly 50% of the species listed from the Mazovian Lowland (Fig. 1). The number of species reported in Warsaw is lower by only 10–20% than that recorded in the potential environments, i.e. lime-oak-hornbeam forests (*Tilio-Carpinetum*) and meadows (*Arrhenatherion*). On the basis of the number of species, it may therefore be claimed that the fauna of the city is rich in

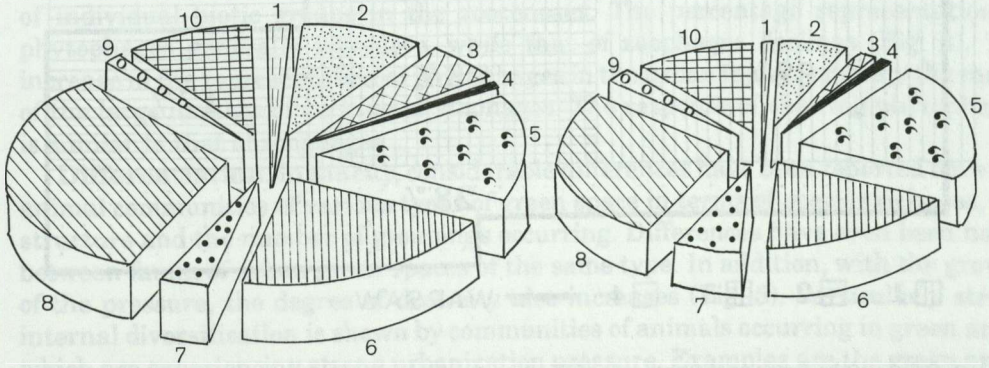

Fig. 1. Various groups of invertebrates of the Mazovian Lowland (left) and the greenery of Warsaw (right); 1 – *Collembola*, 2 – *Homoptera*, 3 – *Heteroptera*, 4 – *Neuropteroidea*, 5 – *Coleoptera*, 6 – *Hymenoptera*, 7 – *Lepidoptera*, 8 – *Diptera*, 9 – other arthropods, 10 – *Arachnoidea*.

spite of the fact that conditions created by the urban environment are a barrier to many species. It is practically inaccessible for the majority of shade-loving species, for hygrophilous species, and for those which feed on decaying organic matter such as dead leaves and wood, and the fungi developing in or on them. This group also includes a number of species which inhabit the tree canopy, but which pass part of their development in forest soil or in the leaf litter. A number of herbivorous species whose foodplants have been exterminated are not encountered in the city, and neither are species sensitive to the contamination of their food (e. g. species feeding on the external parts of plants), nor those sensitive to the contamination of the environment (these are mainly soil species intolerant of the salinity or acidity of soil).

The analysis of the species richness of the invertebrate fauna in the green spaces of Warsaw must be linked inseparably with the analysis of its origins. As was mentioned earlier, the green spaces of Warsaw are a heterogeneous environment, and the fauna living in them is also heterogeneous. Following from the analysis of species composition, it may be suggested that more than 30% of species in the Warsaw fauna originate in lime-oak-hornbeam forest and 17% in wet meadows. Over 20% of species occur in the both forests and meadows. The remainder are alien species inhabiting other environments (Fig. 2). These are mainly xerophilous species from forests and grasslands, but species with other habitat requirements are also encountered, such as those from carr woodland glades, which enter the city along with foodplants introduced by man (CHUDZICKA et al. 1990).

The creation of new faunistic communities is often observed in urban green spaces, and these changes are of different character depending on the biotic group creating a given community and on the origin of that community.

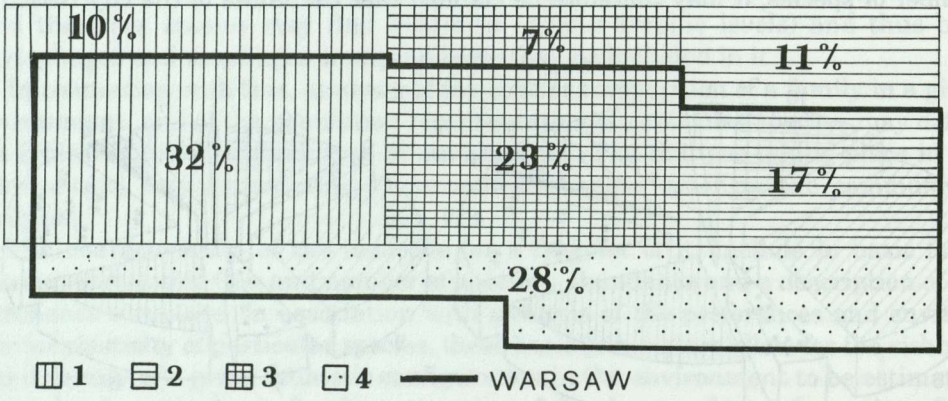

Fig. 2. Origin of the fauna in the greenery of Warsaw; 1 – species occurring in lime-oak-hornbeam forest (*Tilio-Carpinetum*), 2 – species occurring in meadows (*Arrhenatherion* or *Cynosurion*), 3 – species occurring in both *Tilio-Carpinetum* forests and meadows (*Arrhenatherion* or *Cynosurion*), 4 – species occurring in other, alien habitats.

Dominance structure. In comparison with that found in natural environments, the dominance structure of urban faunistic groups is generally characterized by an increase in the representation of dominant species (usually just one or two) and a simultaneous decrease in the representation of the remaining species (Fig. 3). In conditions of strong urbanization pressure, a considerable proportion of the species represented by small numbers of individuals are eliminated. In such communities, only the dominant species are constant, and the remainder occur only sporadically. This kind of dominance structure is defined as a structure characterizing degradation.

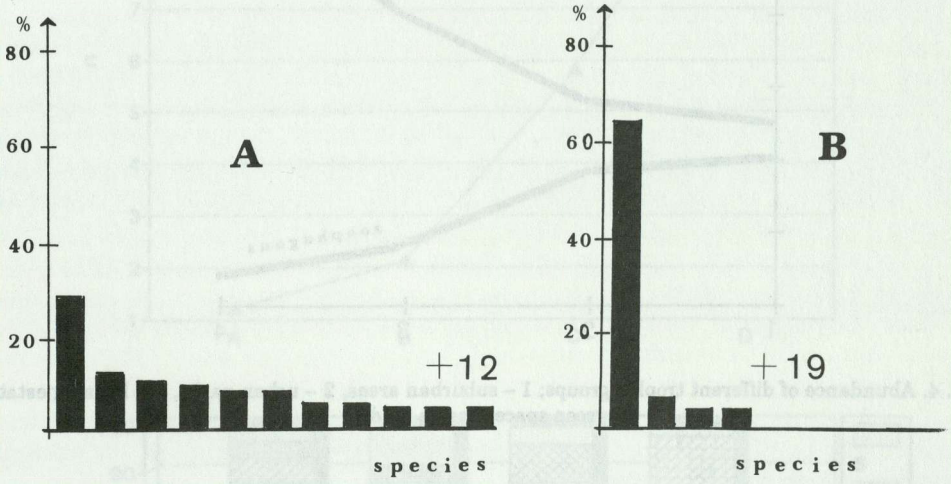

Fig. 3. Comparison of the dominance structure of communities of *Sphecidae* in natural forests (A) and in urban greenery (B)

Biotic structure. In urban environments, a change is noted in the representation of individual biotic groups in the zoocenoses. The percentage representation of phytophages generally increases, while that of zoophages declines (Fig. 4). The increase in the representation of phytophages in the urban fauna is merely the result of the large number of sucking phytophages. The response of chewing phytophages is similar to that of zoophages.

Differentiation. In the city, considerable differences have been reported between animal communities of various types of green space in terms of species richness, the structure and the number of groupings occurring. Differences have even been noted between fauna of urban green spaces of the same type. In addition, with the growth of the pressure, the degree of diversity also increases (Fig. 5). Particularly strong internal diversification is shown by communities of animals occurring in green areas which are experiencing strong urbanization pressure. Examples are the green areas in housing estates and by roads. This diversification is the result of the environmental conditions prevalent in individual green spaces. These conditions are related to many factors, such as the age and size of the green space, the structure of the

vegetation, the amount of tree cover and the level of pollution, as well as the degree to which the area is built up. In general, the environmental conditions prevailing in urban green spaces depend above all on the type of management experienced and the manner in which the area is used.

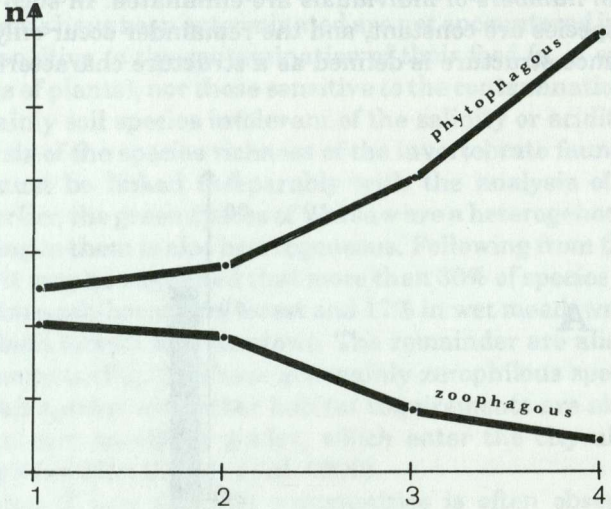

Fig. 4. Abundance of different trophic groups; 1 – suburban areas, 2 – urban parks, 3 – housing estates, 4 – green spaces beside roads.

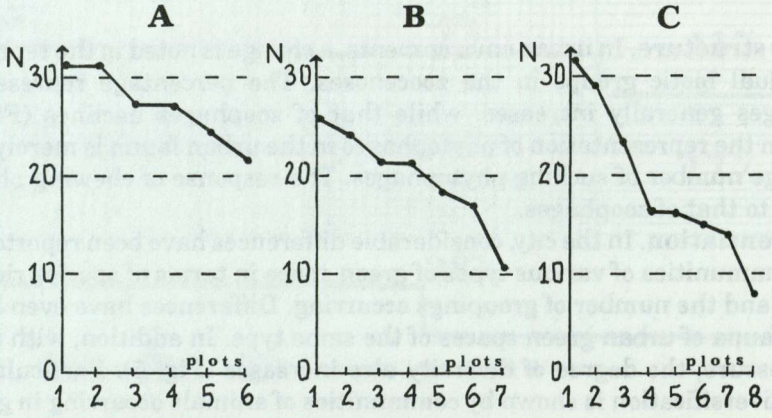

Fig. 5. Number of species of leafhoppers in urban greenery; A – parks, B – housing estates, C – green spaces beside roads.

Abundance. The population level in communities occurring in urban green spaces is the consequence of structural transformations which involve, above all, a rise in the representation of the species dominant within groupings. It is these species which determine abundance in urban communities (and therefore of the whole fauna)

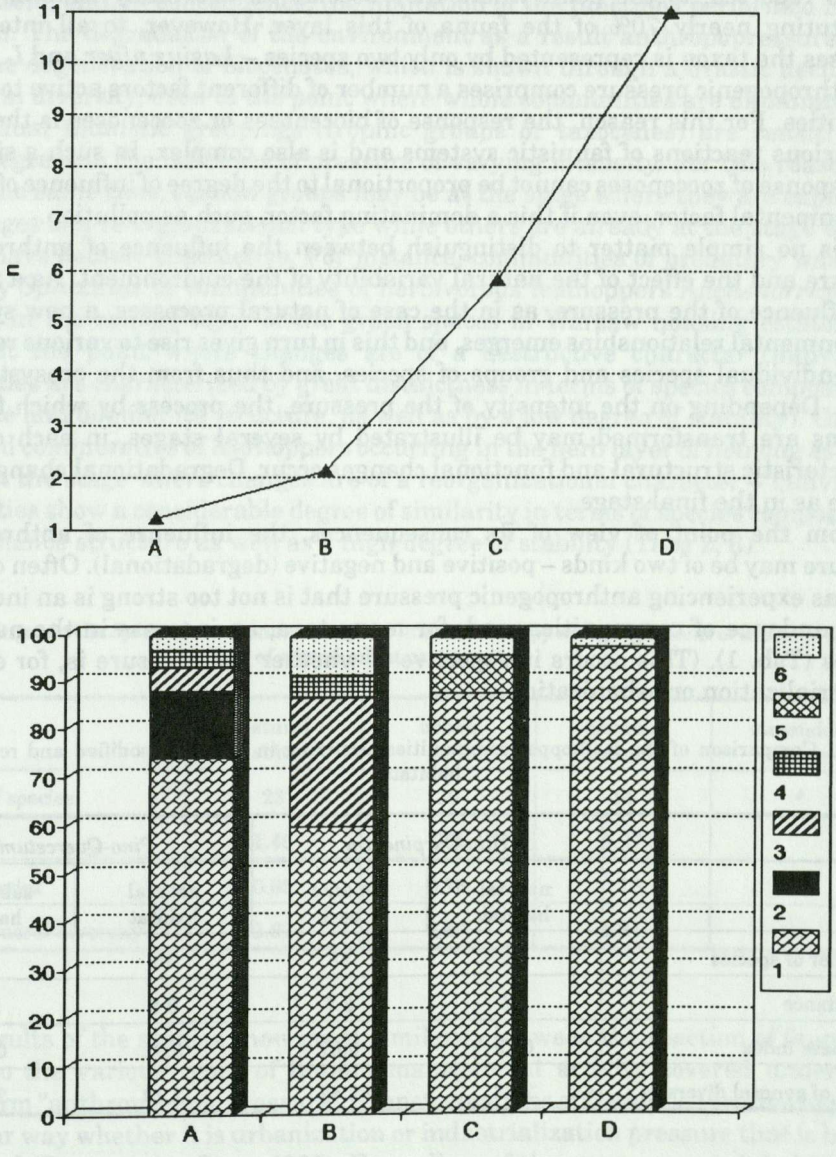

Fig. 6. Changes in the abundance (n) and dominance structure of the leafhopper guild associated with the lime (*Tilia cordata*) canopy along a gradient of urban pressure; A – manor park, B – urban park, C – housing estate, D – isolated lime tree; 1 – *Alebra wahlbergi*, 2 – *Alnetoidia alneti*, 3 – *Fagocyba cruenta*, 4 – *Pediopsis tiliae*, 5 – *Edwardsiana ampliata*, 6 – other species.

to a considerably greater degree than in natural environments. For example, an increase in abundance of the leafhopper populations inhabiting the crowns of lime trees is the result of the numerical prevalence of just one species – *Alebra wahlbergi* (Fig. 6). In a similar way, in the epigeon, a considerable increase in the numbers of ants is reported, to the point where they become an absolutely dominant group constituting nearly 70% of the fauna of this layer. However, to all intents and purposes the taxon is represented by only two species – *Lasius niger* and *L. flavus*.

Anthropogenic pressure comprises a number of different factors active to varying intensities. For this reason, the response of biocenoses or zoocenoses is the sum of the various reactions of faunistic systems and is also complex. In such a situation, the response of zoocenoses cannot be proportional to the degree of influence of a single environmental factor, even if this a dominating factor, such as pollution.

It is no simple matter to distinguish between the influence of anthropogenic pressure and the effect of the natural variability of the environment. As a result of the influence of the pressure, as in the case of natural processes, a new system of environmental relationships emerges, and this in turn gives rise to various responses from individual species and groups of species, and thus from the ecosystem as a whole. Depending on the intensity of the pressure, the process by which faunistic systems are transformed may be illustrated by several stages, in each of which characteristic structural and functional changes occur. Degradational changes occur as late as in the final stage.

From the point of view of its consequences, the influence of anthropogenic pressure may be of two kinds – positive and negative (degradational). Often observed in areas experiencing anthropogenic pressure that is not too strong is an increase in the abundance of communities, and, for many taxa, an increase in the number of species (Tab. 1). (This occurs irrespective of whether the pressure is, for example, industrialization or urbanization).

Table 1. Comparison of the leafhopper communities occurring in natural, modified and restructured habitats.

	Tilio-Carpinetum		*Pino-Quercetum*	
	natural habitat	manor park	natural habitat	suburban habitat
Number of species	31	38	10	25
abundance	1.5	3.7	0.5	5.5
evenness index	0.79	0.67	0.91	0.71
index of general diversity	2.73	2.42	2.10	2.28

This is the result of the creation of new habitats and the enhancement of the mosaic character of habitats in a given area. For example, the introduction of a greater number of plant species or the creation of conditions suitable for them, results in an increase in the richness of the fauna, which becomes more diversified at

individual levels of organization. It may be assumed that the faunistic systems still retain relative structural and functional stability.

The negative influence of pressure results in impoverishment of biocenoses, and this mainly involves a decrease in species richness, the simplification of the structure of the system, and, in consequence, the limitation of the functions performed by the ecosystem. The degradation of the environment as a result anthropopressure may lead to the degeneration of biocenoses, which is shown through a drastic decline in the general diversity, even to the point where whole communities are eliminated.

Individual faunistic groupings (trophic groups or taxocenes) are sensitive to various degrees to the influence of pressure of varying intensity. For this reason, at one and the same time, certain groups may be at the stage where they are experiencing changes of a re-organizational type while others are already at the stage where changes have become destructive. For instance, communities of predatory wasps of the family *Sphecidae* or communities of herbivorous leafhoppers *Auchenorrhyncha* occurring in the canopy layer of the green spaces in Warsaw housing estates are already at the point where changes are of a destructive character (individual communities are characterized by great distinctness in terms of species composition, abundance and dominance structure, as well as by a low degree of stability). On the other hand communities of leafhoppers occurring in the herb layer of housing estates are still at the stage where changes are of a reorganizational character – individual communities show a considerable degree of similarity in terms of species composition and dominance structure as well as a high degree of stability (Tabs 2, 3).

Table 2. Changes in the *Sphecidae* communities of the lime tree canopy along a gradient of urban pressure; * – lack of a permanent community.

	natural habitat	urban park	housing estates	streetside green
Number of species	23	39	14	*
abundance	1.46	7.9	6.27	
evenness index	0.85	0.78	0.76	
index of general diversity	2.67	2.87	1.81	

The results of the studies show great similarity between the reaction of faunistic systems to the various types of human management activity covered under the general term "anthropogenic pressure". Transformations of faunistic systems happen in a similar way whether it is urbanization or industrialization pressure that is being experienced (DĄBROWSKA-PROT 1985). Regardless of the stratocenoses inhabited or the trophic level to which they belong, faunistic groupings of environments experiencing strong anthropogenic pressure are characterized by:

– a smaller number of species than communities from natural environments,
– an increase in the representation of eurytopic species,

– an increase in the representation of phytophagous species, sometimes even of saprophagous species, with a simultaneous decrease in the representation of zoophages,

– a reconstruction of communities leading to the increased representation of species including individuals of small size, with the simultaneous elimination of the representation of species with larger individuals.

– changes in the dominance structure which often involve an increase of the rank (representation) of dominant species,

– amongst phytophages (inhabiting the herb layer and canopy) there is an increase in the representation of sucking phytophages and a simultaneous decrease in the representation of chewing phytophages.

Table 3. Changes in the leafhopper communities along a gradient of urban pressure.

	Lime tree canopy				Herb layer			
	natural habitat	urban park	housing estates	street-side green	natural habitat	urban park	housing estates	street-side green
Number of species	17	18	13	10	31	31	26	8
Abundance	0.5	1.7	8.4	10.4	1.5	9.2	10.0	1.4
evenness index	0.88	0.62	0.35	0.08	0.79	0.73	0.72	0.36
index of general diversity	2.50	1.62	0.89	0.18	2.73	2.15	2.00	1.11

SUMMARY

Faunistic data can convey much information, allowing for an estimation of the resources of the animal world at a particular place and time. The multi-directional analysis of these represents a basis for a characterization of the state of the environment, and the changes occurring within it. Research carried out over many years in the green space of Warsaw and the natural and modified environments (in the "mother" habitats for Warsaw) has been used in the evaluation and valuation of the restructured urban environment. This research embraced about 50 taxa of invertebrate at the rank of family or superfamily. These reperesented various trophic levels and phagic groups, and inhabited various stratocenoses (the soil layer, the epigeon, the herb layer and the canopy). In its basic form, the characterization of multi-species faunistic systems embraced species composition (list and count of species), population size, and a description of the dominance structure. In association with an analysis of the preferences and environmental plasticity of individual species, these parameters allowed the richness and diversity of faunistic communities in the urban environment to be evaluated. In addition, biocenotic indicators were used to measure and evaluate faunistic groupings. As a consequence of this, it was possible to value communities and - through the creation of gradient series - to describe the stages of the changes taking place in the environment.

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