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Diversity of reactions of insect communities as a response to anthropogenic pressure

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Abstract. A characteristics and a comparative analysis of the fauna of natural and modified habitats are carried out; insect communities inhabiting a pine-oak mixed forest (*Pino-Quercetum*) and a moist coniferous one (*Peucedano-Pinetum*), a linden oak-hornbeam forest (*Tilio-Carpinetum*) and an ash-alder one (*Circaeo-Alnetum*) are taken into consideration. Over 30 multispecies communities representing 10 taxa are analysed. Changes are estimated by means of parameters which define faunistic communities and which are as follows: species composition, number of species, abundance, Soerensen index of the similarity of species composition, dominance index, Pielou evenness index, and Shannon and Weaver index of general diversity.

Key words: insect communities, anthropogenic pressure

INTRODUCTION

To distinguish effects of anthropopressure from those of natural changes in the environment is not an easy task. As a result of this pressure, just as in the case of natural processes, a new configuration of habitat relationships is formed which, in turn, results in various reactions of particular species, of groups of species and, in consequence, of the entire ecosystem.

From the point of view of the effects of its workings, the impact of anthroporessure may be twofold, and it may lead either to an increase or a decrease in faunal diversity. When in a given area new habitats are formed or, the mosaic-like character of habitats becomes richer there may be a reason for the fauna being richer because it becomes more diverse at particular levels of organization. A negative (degradation) effect of anthropogenic pressure results in impoverishment of the organization of the biocoenosis and consists mainly in a decrease in species richness, in simplification of the structure of the complex and, in consequence, in simplification of the function of the ecosystem. Environmental degradation due to anthropopressure may lead to degeneracy of biocoenoses.

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It is justifiable to say that within the least modified habitats changes in animal communities consist in changes in the position particular species occupy in dominance structure while the general form pattern of this structure is maintained and the species composition of communities remains virtually unchanged. In more deformed habitats, there are recorded qualitative changes consisting in a change in the species composition and in the number of species, and in a higher disproportion in the abundance of dominant species and in that of the other species in a given community. Some species typical of a given habitat are eliminated from these communities and foreign elements appear there. As a rule, stenotopes, i.e. species characterized by a narrower range of tolerance to habitat conditions are the first to be eliminated, whereas eurytopes become more and more abundant. In the case of certain communities (e.g. *Sphecidae* and *Noctuidae*) in restructured and degraded habitats (e.g. small plots of urban greenery in the center of a town) one can no longer speak of a permanent species composition because only accidental species are recorded there. However, under the same conditions, other communities (e.g. *Auchenorrhyncha*) maintain a permanent albeit highly reduced species composition but, at the same time, only individual species reach high abundances. It occasionally happens that the species composition is limited only to those dominant species. Generally, they are eurytopic species (CHUDZICKA and SKIBIŃSKA 1994).

It is the aim of this paper to present how wide-ranging are reactions of animal communities to the workings of a fairly weak anthropogenic pressure. Insect communities occurring in modified and natural forest habitats of various types were analyzed comparatively. The analysis covered eight communities from pine forests (*Peucedano-Pinetum*), nine from pine-oak mixed ones (*Pino-Quercetum*), ten from linden oak-hornbeam ones (*Tilio-Carpinetum*), and seven from ash-alder ones (*Circaeo-Alnetum*). All in all, over 30 selected multispecies communities of insects belonging to ten different taxa were analyzed. These may be assumed to constitute a model complex illustrating the pattern of structures within the entire ecosystem, and their analysis makes it possible to estimate the species diversity of the fauna at a particular place and time, and also to describe the condition of the environment and the changes occurring there.

MATERIAL AND METHODS OF ANALYSES

The present paper is based on results of wide-scale studies carried out simultaneously in various types of forest under anthropopressure, situated in the Mazovian Lowlands. The analyses covered insect communities of different taxon which inhabited a pine-oak mixed forest (*Pino-Quercetum*) and a moist one (*Peucedano-Pinetum*), and a linden oak-hornbeam forest (*Tilio-Carpinetum*) and an ash-alder one (*Circaeo-Alnetum*); all forests were at Białołęka Dworska (a suburban district of Warsaw) (GARBARCZYK and PISARSKA 1981). Due to their proximity to the metropolis these forests are subject to a fairly strong impact of anthropopressure but their vegetation is not formed artificially, as is the case with parks. These habitats are referred to as modified ones because their plant composition, just as in the natural environment, is in agreement with a given habitat even though a considerable proportion of alien species is recorded (ROO-ZIELIŃSKA 1981). The control group consisted of faunistic communities of the same taxonomic status and occurring in the same type of natural forest habitats. These were large forest complexes situated far from cities and from sources of industrial pollution, and which therefore were under relatively low anthropopressure. Communities recorded in these forest complexes were treated as "standards" serving as a reference in comparative analyses.

The following invertebrate communities were selected for analyses: *Collembola*, of *Coleoptera – Carabidae, Elateridae* and *Chrysomelidae*, of *Homoptera – Auchenorrhyncha*, of *Lepidoptera – Noctuidae*, of *Hymenoptera – Sphecidae* and *Vespoidea* and of *Diptera – Tachinidae* and *Sarcophagidae*. They represented four basic biocoenotic layers, namely: soil (*Collembola* and *Elateridae*), epigeon (*Carabidae*), undergrowth (*Auchenorrhyncha* and *Chrysomelidae*), tree canopies (*Noctuidae, Sphecidae, Vespoidea, Tachinidae* and *Sarcophagidae*).

The analyzed faunistic material was collected by standard quantitative methods. Soil samples were collected into a soil corer in two series (in spring and in autumn). Epigeon samples were collected into pitfall traps, undergrowth ones into entomological sweep-nets and canopy ones into Moericke traps. In each habitat catches were made during two growing seasons, from April to November.

In order to estimate changes recorded in the communities analyzed different parameters describing faunistic communities were used, and the extent and criteria of their limitations and application correctness were discussed. The simplest way to characterize any multispecies community is through its species composition, abundance and quantitative interrelations of its components, i.e. through dominance structure. Even these basic parameters when supplemented with an analysis of the preferences and habitat tolerance of particular species allow for an estimate of the richness and diversity of a given faunistic complex.

Number of species. This value, given as one estimated directly from a sample, may provide information about fauna richness. Changes in fauna richness may be defined by those in the number of species in communities occurring in the habitat studied only provided the latter changes are permanent and significant. When the number of species in communities which are being compared is similar, an analysis of changes may be made only in the qualitative aspect, i.e. on the basis of the characteristics of species composition.

Relative abundance of a community. This value, just like the number of species, is established empirically. Only mean values from many years may be used in a bioindicatory estimate of changes occurring in the environment because only such values can describe the direction of permanent changes there.

Species composition. This provides a basis for determining the direction of changes occurring in the environment because it makes possible a detailed analysis of the requirements and habitat preferences of particular species, especially of those with a significant and directed change in abundance. The similarity of the species composition of the compared communities occurring in habitats of the same type, in natural and modified ones, has been determined by Soerensen index (*So*):

$$So = \frac{2c}{a+b}\,100\%$$

where: a – number of species in community 1; b – number of species in community 2; c – number of common species.

Biocoenological indices universally used in zoocoenological studies are useful for measurement and estimation of selected faunistic communities. Particularly useful ones are the following: dominance index (*d*), Pielou evenness index (*J*) and Shannon and Weaver general diversity index ($\overline{H}$). Changes in the values of these indices define objectively the direction of transformations of faunistic communities even when the number of species and the total abundance of these communities is subject to no significant changes. The number of species and the differentiation in their abundance, i.e. dominance structure, form the basis for calculating all these indices.

$$d = \sum \left(\frac{n}{N} \right)^2$$

where: n – species relative abundance index; N – community relative abundance index.

$$e = \frac{\overline{H}}{\ln S}$$

where: $\overline{H}$ – general diversity index; S – number of species.

$$H = -\sum \left(\frac{n}{N} \right) \ln \left(\frac{n}{N} \right)$$

where: n – species relative abundance index; N – community relative abundance index.

The evenness index gives information about "justice" in distribution of the abundance of individuals between particular species within a community. The dominance index is yet another one which provides information about the dominance structure of communities. Differences in values of the dominance index often bring out the significance of a particular species more distinctly than do differences in the values of the evenness index.

The measure taken by Shannon and Weaver from information theory is a species diversity measure which is most frequently used in ecological and faunistic studies. It is one of the best indices for comparisons because it depends relatively little on the size of a sample. When the general diversity index is used it is possible to determine both the species richness of the fauna and the dominance structure of communities as well. Higher values of the index are obtained when, in a given habitat, the number of species is high and the abundance distribution of particular species within a community is even. The values of the index drop as the number of species decreases and when the abundance percentage of one species dominant within the community is distinctly high.

CHARACTERISTICS AND ANALYSIS OF CHANGES IN THE VALUES OF SELECTED INDICES

Communities of springtails (*Collembola*) in habitats of the same type, natural and modified ones, clearly differ in their species composition (*So* = 35%–50%). In modified habitats, regardless of their type, a fairly significant decrease in the number of species was recorded, and the abundance of the communities decreased too (Table 1). The proportion of species of open areas recorded in communities in modified forest

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habitats was significantly higher (16%) than that in homologous natural habitats where the species constituted merely a few per cent. In modified habitats there took place qualitative changes in the dominance structure of communities of *Collembola*. Dominant forest species were replaced by eurytopic and polytopic ones associated with open areas. As far as humidity requirements are concerned a decline of hygrophilous species was recorded (STERZYŃSKA 1981).

Table 1. Comparison of insect communities occuring in natural (A) and modified (B) habitats

Taxon	Habitat	Number of species		Abundance index		Soerensen index (%)
		A	B	A	B	
Collembola	*Peucedano-Pinetum*	26	12	6.50	2.20	42
	Pino-Quercetum	17	13	4.40	2.10	50
	Tilio-Carpinetum	44	19	12.00	2.40	35
	Circaeo-Alnetum	28	20	7.70	3.00	no data
Elateridae	*Pino-Quercetum*	5	10	70.60	23.80	67
	Tilio-Carpinetum	8	11	36.30	32.50	53
	Circaeo-Alnetum	9	10	26.90	69.43	42
Carabidae	*Peucedano-Pinetum*	13	12	6.10	3.40	40
	Pino-Quercetum	17	18	19.40	10.80	58
	Tilio-Carpinetum	38	37	15.30	21.40	45
	Circaeo-Alnetum	34	28	14.10	17.30	42
Auchenorrhyncha	*Peucedano-Pinetum*	14	10	0.70	1.50	42
	Pino-Quercetum	10	23	0.50	5.50	32
	Tilio-Carpinetum	31	28	1.50	2.30	54
	Circaeo-Alnetum	30	27	2.70	1.00	60
Chrysomelidae	*Tilio-Carpinetum*	21	18	0.22	0.74	62
Sphecidae	*Peucedano-Pinetum*	35	46	0.11	0.20	59
	Pino-Quercetum	46	49	0.11	0.11	55
	Tilio-Carpinetum	23	49	0.02	0.09	50
Vespoidea	*Peucedano-Pinetum*	9	8	0.06	0.18	47
	Pino-Quercetum	12	12	0.08	0.21	67
	Tilio-Carpinetum	17	15	0.06	0.14	63
Noctuidae	*Peucedano-Pinetum*	23	16	6.70	2.00	15
	Pino-Quercetum	57	35	27.00	5.50	46
	Tilio-Carpinetum	67	60	43.40	23.30	55
	Circaeo-Alnetum	21	9	11.20	4.40	27
Tachinidae	*Peucedano-Pinetum*	46	52	0.57	0.67	57
	Pino-Quercetum	71	54	0.81	0.59	53
	Tilio-Carpinetum	55	55	0.81	0.92	56
	Circaeo-Alnetum	22	22	0.52	0.55	29
Sarcophagidae	*Peucedano-Pinetum*	12	18	0.23	1.04	60
	Pino-Quercetum	20	17	0.61	0.94	70
	Tilio-Carpinetum	21	19	0.83	1.50	65
	Circaeo-Alnetum	14	8	0.75	0.31	46

No significant differences were recorded in the values of biocoenological indices describing the communities of *Collembola* (Table 2). The values of indices $\overline{H}$, J and d show relatively small differences even in linden oak-hornbeam habitats for which this taxon is considered to be an indicatory one, defining the kind of soil and the degree of its transformation (STERZYŃSKA 1990).

Within communities of soil *Elateridae* occurring in modified habitats recorded were alien species, mainly those associated with open areas, and a higher percentage of ubiquitous species. In natural habitats favourable to them forest species constituted from 79% (in an ash-alder forest) to 100% (in a linden oak-hornbeam forest) of the total abundance of the community there, whereas in the homologous modified habitats forest species constituted merely from 4% (in a linden oak-hornbeam forest) to 85% (in an ash-alder forest) of the total abundance (NOWAKOWSKI 1981, 1991).

Table 2. Values of indices characterizing insect communities in natural (A) and modified (B) habitats

Taxon	Habitat	Dominance index		Evenness index		Index of general diversity	
		A	B	A	B	A	B
Collembola	*Tilio-Carpinetum*	0.18	0.20	0.69	0.74	1.77	1.56
Elateridae	*Pino-Quercetum*	0.38	0.30	0.75	0.66	1.21	1.52
	Tilio-Carpinetum	0.33	0.59	0.60	0.32	1.24	0.77
	Circaeo-Alnetum	0.58	0.71	0.40	0.31	0.87	0.72
Carabidae	*Peucedano-Pinetum*	no data	no data	0.40	0.71	1.01	1.57
	Pino-Quercetum	0.16	0.17	0.80	0.75	2.06	2.04
	Tilio-Carpinetum	0.15	0.23	0.65	0.59	2.09	1.98
	Circaeo-Alnetum	no data	no data	0.82	0.79	2.78	2.60
Auchenorrhyncha	*Peucedano-Pinetum*	0.22	0.45	0.74	0.47	1.95	1.08
	Pino-Quercetum	0.13	0.15	0.91	0.71	2.10	2.28
	Tilio-Carpinetum	0.11	0.14	0.79	0.73	2.73	2.49
	Circaeo-Alnetum	0.16	0.08	0.72	0.87	2.48	2.86
Chrysomelidae	*Tilio-Carpinetum*	0.14	0.10	0.82	0.89	2.27	2.58
Sphecidae	*Peucedano-Pinetum*	0.13	0.38	0.74	0.42	2.67	1.61
	Pino-Quercetum	0.14	0.31	0.71	0.60	2.74	2.26
	Tilio-Carpinetum	0.17	0.15	0.87	0.84	2.68	3.28
Vespoidea	*Peucedano-Pinetum*	0.66	0.77	0.40	0.19	0.89	0.51
	Pino-Quercetum	0.63	0.75	0.32	0.25	0.80	0.62
	Tilio-Carpinetum	0.62	0.47	0.32	0.60	0.84	1.63
Noctuidae	*Tilio-Carpinetum*	0.08	0.07	0.71	0.76	2.98	3.10
Tachinidae	*Peucedano-Pinetum*	0.06	0.05	0.85	0.86	3.25	3.39
	Pino-Quercetum	0.05	0.07	0.83	0.84	3.55	3.35
	Tilio-Carpinetum	0.11	0.06	0.71	0.82	2.85	3.31
	Circaeo-Alnetum	0.25	0.51	0.64	0.43	1.97	1.32
Sarcophagidae	*Peucedano-Pinetum*	0.25	0.40	0.68	0.46	1.70	1.32
	Pino-Quercetum	0.23	0.32	0.66	0.54	1.99	1.52
	Tilio-Carpinetum	0.18	0.31	0.78	0.55	2.06	1.61
	Circaeo-Alnetum	0.29	0.33	0.64	0.61	1.69	1.28

In all elaterid communities in deformed habitats, regardless of the type of forest, the disproportions in the abundance distribution of particular species were greater than those in homologous natural habitats, a fact reflected in lower values of index J (Tables 1 and 2). Moreover, elaterid communities react to increasing anthropopressure by decreasing their general diversity. Only the value of index $\overline{H}$ was higher in a modified pine-oak mixed forest than in a homologous natural habitat – the community from the modified habitat was characterized by a number of species twice that in the community from a natural mixed forest.

Carabid communities from modified habitats do not, in respect of the number of species, differ greatly from communities in homologous natural habitats (CZECHOWSKI 1981). On average, 24 species were recorded in one habitat; the natural habitats studied had 25 species. Yet differences in the species composition were very significant. The qualitative similarity index of carabid communities from corresponding natural and modified habitats was low, and only communities from pine-oak mixed forests might be considered similar (Table 1). Carabid communities from modified habitats were characterized by a particularly distinct phenomenon of forest carabids being replaced by field or ubiquitous species. The position of these species in the dominance structure of the communities was an essential indicator of the extent of their modification. Relatively the smallest differences were recorded for communities from pine-oak mixed forests; in a community occurring in a natural mixed forest nine species out of ten most numerous ones were forest forms, whereas in a community from a modified pine-oak mixed forest only six species within this group were forest forms. Carabid communities from linden oak-hornbeam and ash-alder forests were more deformed than those from pine forests. In a natural linden oak-hornbeam forest nine species out of ten most abundant ones in the community were typically forest forms, whereas in a deformed community only four species; the situation in ash-alder forest was similar, in a natural habitat there were eight forest species, whereas in a deformed one – only four (CZECHOWSKI 1981 and unpubl. data). It follows from an analysis of the parameters describing carabid communities that habitat modification had only small impact on the decrease in the total diversity and uniformity of the distribution of abundance percentages of particular species. This held true both for communities occurring in a mixed forest and for those from linden oak-hornbeam and ash-alder forests. Only in the case of communities from pine forests was an opposite tendency recorded (Table 2).

Leafhoppers (*Auchenorrhyncha*) of the undergrowth layer reacted to anthropopressure mainly by a change in the abundance of their communities. In modified habitats the abundance of leafhopper communities in a linden oak-hornbeam forest and in a pine one was twice higher, in a pine-oak mixed forest tenfold higher, and only in a modified ash-alder one a lower abundance of leafhoppers was recorded (Table 1). A higher abundance percentage of xerophilous species was recorded in communities from modified habitats when these were compared with homologous natural ones. The proportion of these species increased from 3% in natural habitats to over 18% at Białołęka (CHUDZICKA 1981, 1987). Leafhopper communities from the undergrowth also reacted to anthropogenic modification of the habitat by rebuilding their dominance structure towards an increase in the abundance of the dominant species. This was reflected in the values of index *J* (only the community from an ash-alder forest showed an opposite tendency) (Table 2). Leafhopper communities inhabiting tree canopies, just as those in the undergrowth, reacted to anthropogenic modification of the habitat by a change in their quantitative ratios. Thus for instance the same 13 species of leafhoppers were recorded in mixed forests, both natural and modified, but the abundance of the community in the modified habitat was distinctly higher. And an increase in the abundance index of leafhopper communities occurring in the canopies of different trees was not identical: birch – from 0.93 to 1.37, pine – from 0.25 to 0.66, linden – from 0.50 to 3.50 (CHUDZICKA 1981).

Chrysomelid (*Chrysomelidae*) communities react to habitat modifications mainly by impoverishment in species composition. The number of species in a modified linden oak-hornbeam forest was lower than that in a homologous natural habitat (Table 1). Such a tendency was also recorded during studies conducted on chrysomelid communities in moist pine forests in other regions of Poland in Roztocze and in Bory Tucholskie. The number of species recorded in a highly deformed moist pine forest in Bory Tucholskie was lower than that in a much less modified moist pine forest in the Roztoczański National Park. Habitat modification also resulted in changes in the abundance of chrysomelid communities although it was directed differently in different types of habitat. Their abundance increased in a modified linden oak-hornbeam forest, whereas it decreased in a modified moist pine one (WĄSOWSKA 1989, 1994).

Digger wasp (*Sphecidae*) communities reacted to habitat modification by enrichment of species composition, by an abundance increase and by changes in dominance structure consisting in a decrease in the uniformity degree of the distribution of abundance of particular species (Tables 1 and 2). Only the communities occurring in two pine-oak mixed forests (one natural and one modified), did not differ in abundance, and they differed only slightly in the number of species; however, significant differences were recorded in their dominance structures (Table 1). In the natural pine-oak mixed forest five most abundant species constituted about 65% of the abundance of the entire community, whereas in the modified one – 65% of the abundance of the entire community was made by just two species.

The value of the general diversity index ($\overline{H}$) for digger wasp communities from a pine-oak mixed forest and pine forest in modified habitats was lower than that in natural ones. Only in a modified linden oak-hornbeam forest was an increase recorded in the degree of general diversity (Table 2).

Sphecidae are a group which originates from light mixed forests and for this reason they prefer conditions found in natural forest habitats of these types. Natural linden oak-hornbeam forests being too shaded and moist are not readily inhabited by these insects, and ash-alder forest habitats are generally avoided. The digger wasp community in a natural linden oak-hornbeam forest consisted of only 23 species, whereas in a thinned modified linden oak-hornbeam forest twice as many species were recorded. Also the relative abundance of the community in the modified linden oak-hornbeam forest was distinctly higher. This considerable enrichment of the fauna was reflected in the values of the general diversity index ($\overline{H}$) which was considerably higher for the community in the modified linden oak-hornbeam forest (SKIBIŃSKA 1981, 1986).

A comparison of the vespid (*Vespoidea*) communities of all habitats studied, made in pairs of homologous habitats – a natural forest and a modified one – revealed small differences in species composition (Table 1); this held true both for social wasps and for solitary ones. However, their reaction to habitat modification was manifested in a distinctly higher abundance of the communities. The distribution of abundance proportions among particular species of a given community and, consequently, the values of indices *J* and *d* changed differently in a linden oak-hornbeam forest and still differently in pine ones (Table 2). The dominance structure of a community in a modified linden oak-hornbeam forest was characterized by a more even distribution than was the structure of a community from a natural linden oak-hornbeam forest. Quite opposite tendencies were recorded for the vespid communities from coniferous forests, but these changes were more distinct in pine forests than in pine-oak mixed ones, and the differences in index values were higher (SKIBIŃSKA 1981, 1987).

Noctuid (*Noctuidae*) communities reacted to anthropogenic deformation of the habitat first of all by a change in quantitative ratios. Both the number of species and the abundance of noctuids in all modified forests were lower than those in natural habitats (Table 1). Changes in the number of species and in abundance were accompanied by significant changes in the species composition. The proportion of forest species was distinctly lower while that of species which prefer open areas was higher. The highest differences in species composition and abundance were recorded in an ash-alder forest, the lowest in a linden oak-hornbeam one (WINIARSKA 1981, 1990).

It follows from an analysis of the parameters describing tachinid (*Tachinidae*) communities that habitat modification had hardly any impact on the abundance and number of species. So, for instance, in two out of four habitats studied, in an ash-alder and a linden oak-hornbeam one, the number of species was identical both in the natural and in the modified habitats (Table 1). The abundance, too, differed only slightly in natural and deformed habitats. In both types of forest, the general diversity of communities and the uniformity of abundance distribution among particular species which was expressed by the values of indices $\overline{H}$ and *J* were very similar in natural and modified habitats. More distinct differences were recorded for communities from an ash-alder forest (Table 2) (DRABER-MOŃKO 1981).

A more distinct reaction to habitat modification was recorded in other *Diptera*, namely in flesh-flies (*Sarcophagidae*). In all modified habitats the general diversity of communities was lower, and dominance structure had been changed towards an increase in the percentage of the dominant species (Tables 1 and 2). Impoverishment of the species composition with a simultaneous increase in the abundance was recorded for communities in a modified linden oak-hornbeam forest and in a pine-oak mixed one. In a modified pine forest, however, both the abundance of the community and the number of species increased, whereas in an ash-alder one the tendencies were just the opposite (DRABER-MOŃKO 1981).

ESTIMATE OF THE EXTENT OF HABITAT MODIFICATION ON THE BASIS OF FAUNISTIC INDICATORS

It follows from an analysis of the similarity of species composition of different invertebrate communities in natural forests and in those under anthropogenic pressure that an ash-alder forest was the most modified habitat and a linden oak-hornbeam one the least (Fig. 1). In a modified ash-alder forest as many as 83% of the invertebrate communities analysed showed no similarity of species composition to

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that in "standard" communities from a homologous natural habitat. A pine forest was the second most modified habitat and 63% of the communities there showed a lack of species composition similarity to communities from a natural forest.

In linden oak-hornbeam forests and in pine-oak mixed ones on the other hand the species composition similarity of the communities occurring there, in the natural-modified set, was relatively high. In a modified linden oak-hornbeam forest only 20% of the communities analysed showed no similarity to the communities from a natural habitat, whereas in a modified pine-oak mixed forest 33% of the communities were dissimilar.

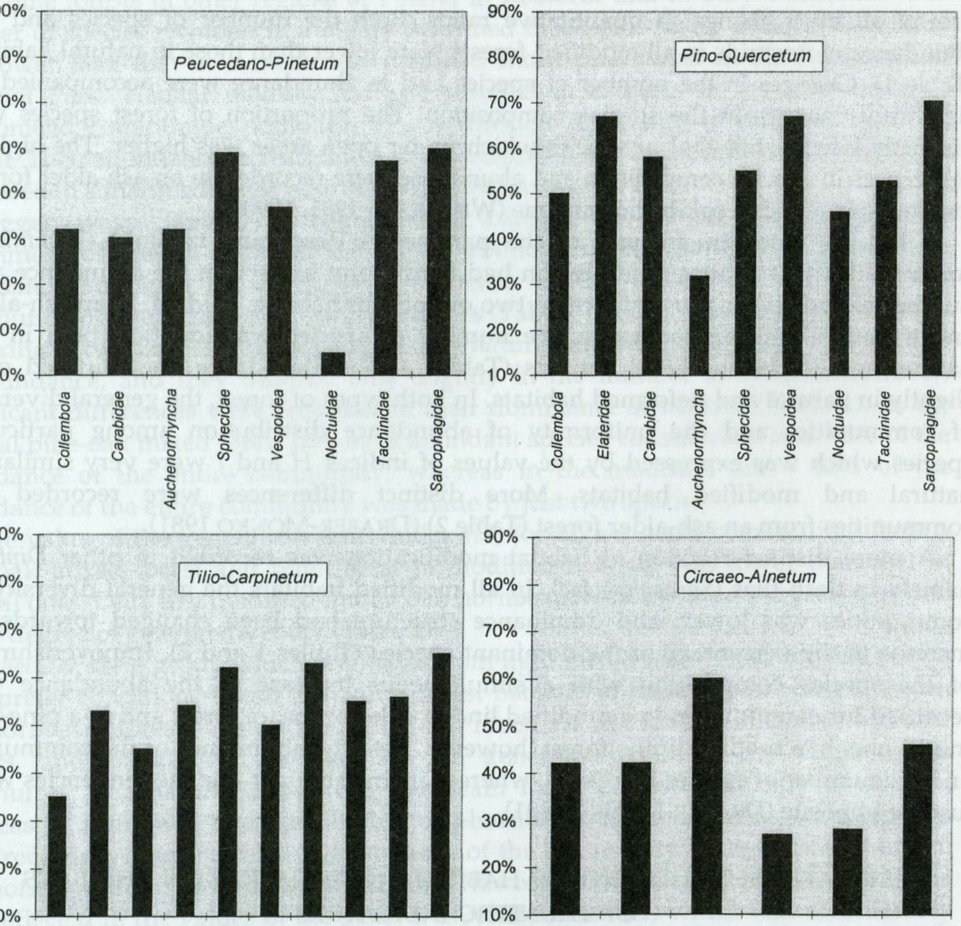

Fig. 1. Similarity of the species composition (Soerensen index) of insect communities in natural and modified habitats.

In most of the taxa studied, changes in invertebrate communities in the most modified habitat, namely in an ash-alder forest, consisted in a distinct decrease in the number of species and in abundance; and an opposite tendency was recorded only in communities of *Elateridae* (Fig. 2). Communities in a modified ash-alder forest were characterized by a lower degree of uniformity distribution of abundance proportions of particular species and by a decrease in general diversity. The range of these changes was relatively small. The greatest differences in the values of indices J and $\bar{H}$ were recorded for tachinid communities, whereas the lowest range of changeability was recorded for *Carabidae* (Fig. 2).

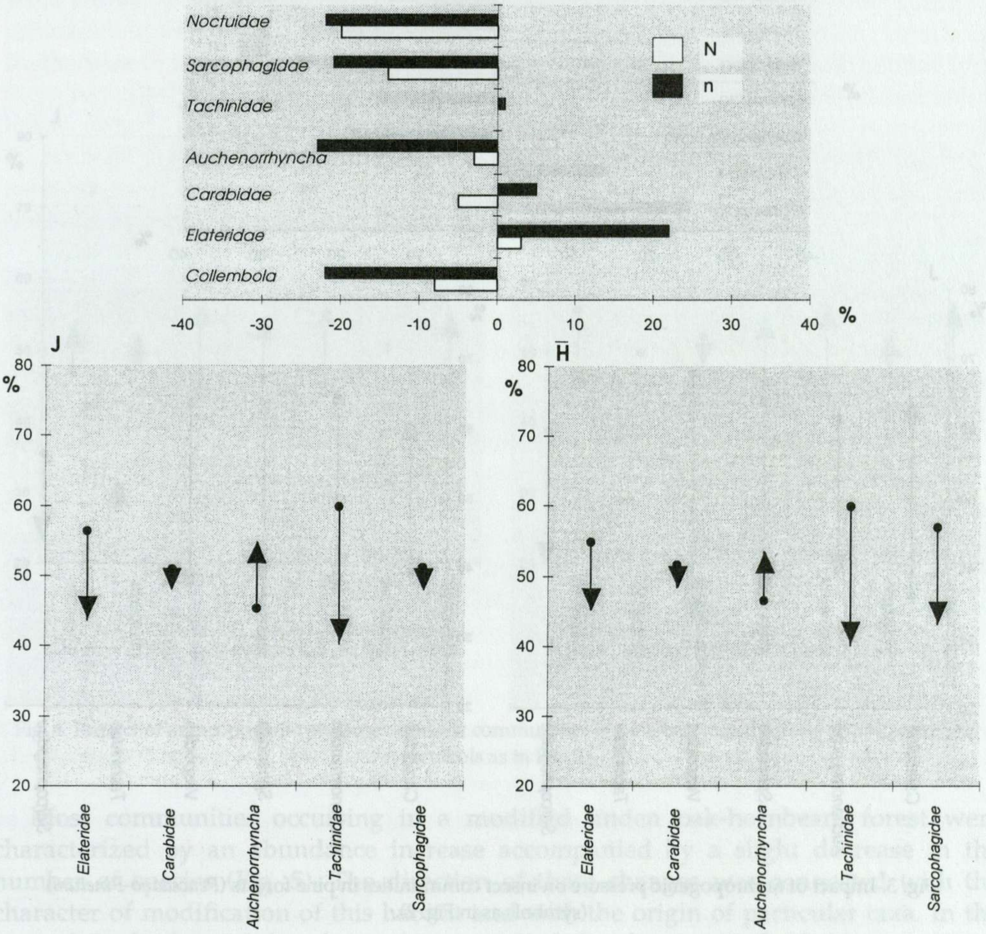

Fig. 2. Impact of anthropogenic pressure on insect communities in ash-alder forests (*Circaeo-Alnetum*) (N – number of species, n – abundance index, J – Pielou index, $\bar{H}$ – Shannon and Weaver index).

Changes in communities occurring in the second most modified habitat, namely in a pine forest, were manifested both in the number of species and in abundance, and also in dominance structure. Modification of the pine forest brought about a distinct decrease in the uniformity of abundance distribution among particular species and a decrease in the general diversity of communities. A distinctly opposite tendency was recorded only in carabid communities (Fig. 3). Changes in the number of species of more deformed communities, dissimilar in respect of species composition, consisted in impoverishment of species composition while all communities with some degree of similarity (within the range of 60%) were characterized by a number of species higher than that in communities from a natural pine forest (Fig. 3).

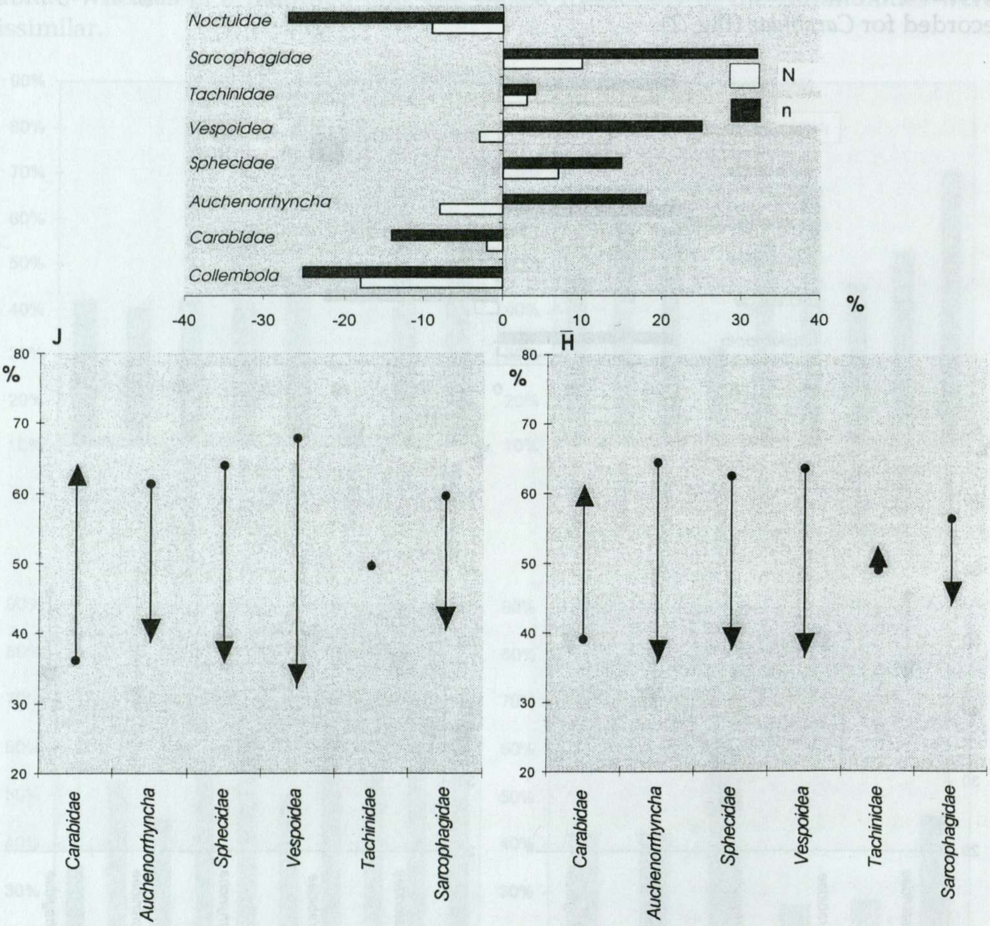

Fig. 3. Impact of anthropogenic pressure on insect communities in pine forests (*Peucedano-Pinetum*) (symbols as in Fig. 2).

With regard to the number of species and to abundance the changes in insect communities occurring in a modified pine-oak mixed forest were significant but not directed. However, a uniform tendency was recorded in the restructuring of the dominance structure of these communities. This tendency consisted, first of all, in an increase in the degree of the distribution uniformity of abundance proportions of particular species in the communities, and this was reflected in an increase in the value of Pielou index (J) (Fig. 4).

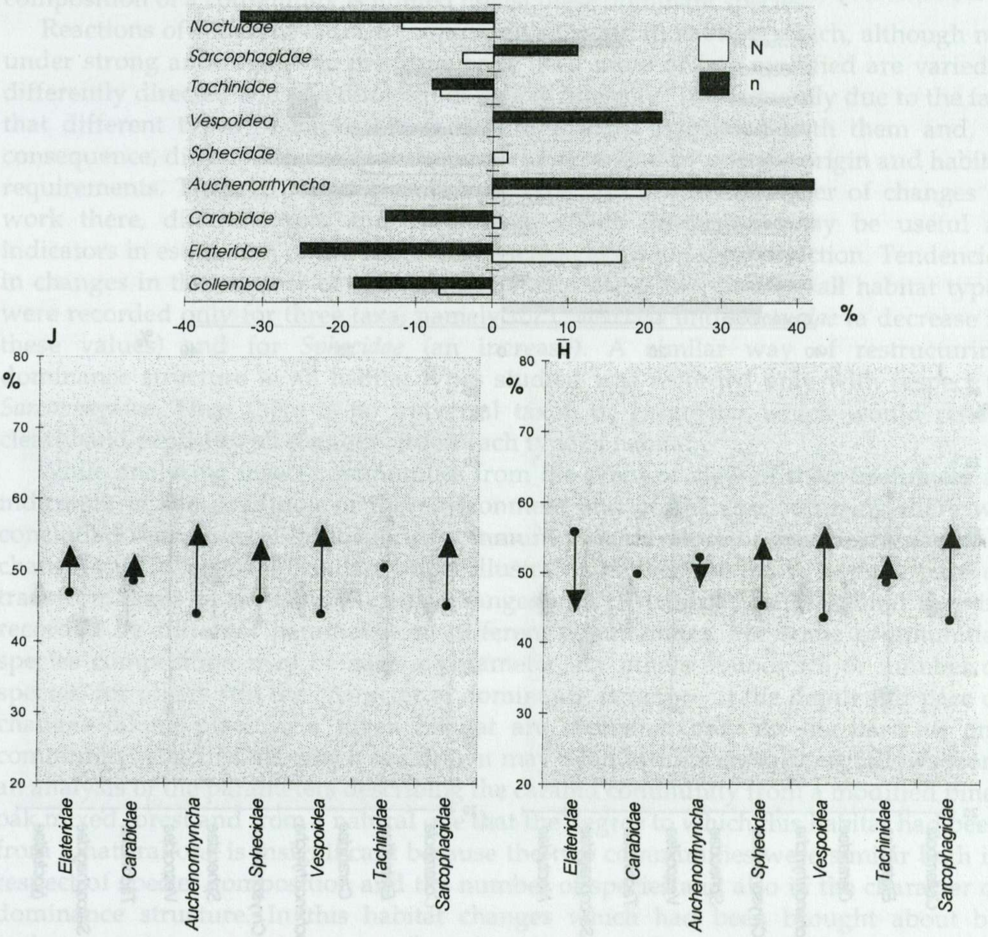

Fig. 4. Impact of anthropogenic pressure on insect communities in pine-oak mixed forests (*Pino-Quercetum*) (symbols as in Fig. 2).

Most communities occurring in a modified linden oak-hornbeam forest were characterized by an abundance increase accompanied by a slight decrease in the number of species (Fig. 5). The direction of these changes was connected with the character of modification of this habitat and with the origin of particular taxa. In the case of the linden oak-hornbeam forest studied the changes in the habitat consisted mainly in a decreasing degree of canopy denseness; this had natural consequences in changes both in abiotic factors (greater insolation, lower humidity) and in biotic ones (changes in vegetation). Due to this, species preferring such new habitat conditions reacted by an abundance increase, and an abundance increase of entire communities followed (of ten communities studied seven reacted in this way). With regard to parameters illustrating the uniformity of abundance distribution among particular species and the degree of general diversity the reactions of particular communities were variously directed and of a different degree of intensity (Fig. 5).

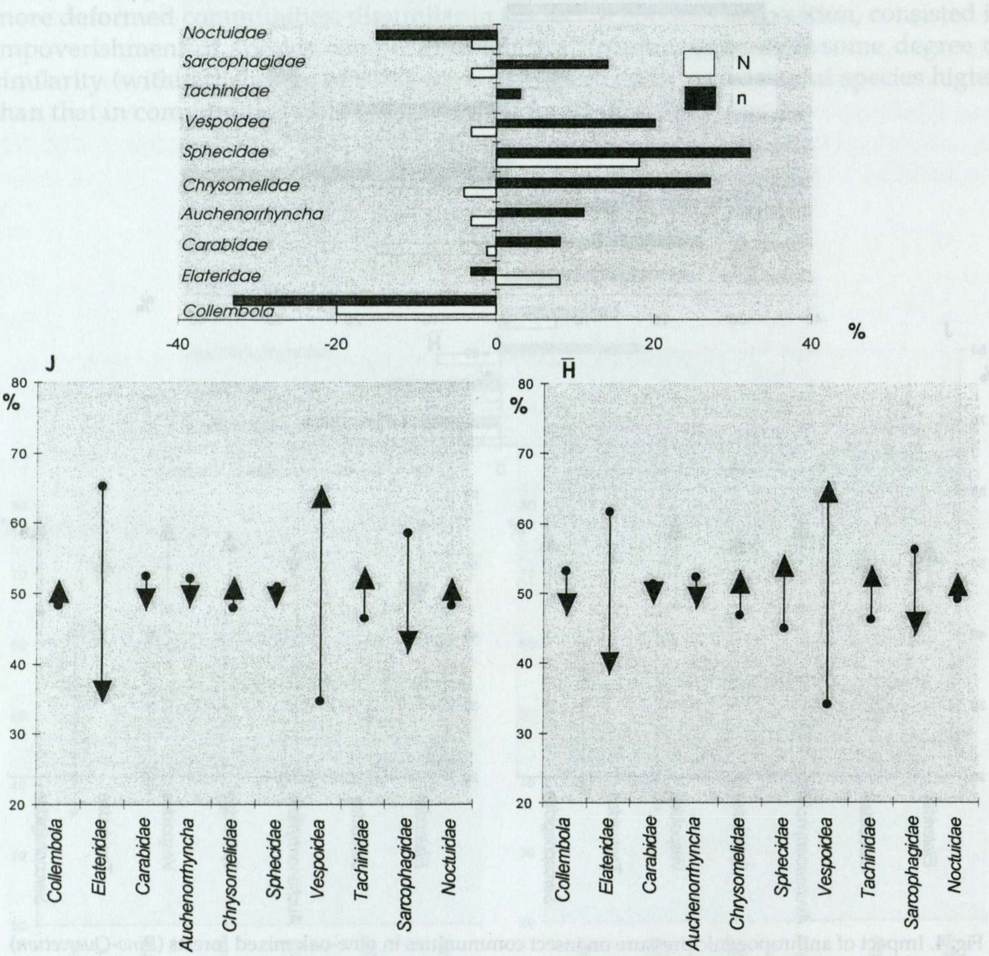

Fig. 5. Impact of anthropogenic pressure on insect communities in linden oak-hornbeam forests (*Tilio-Carpinetum*) (symbols as in Fig. 2).

CONCLUSIONS

Changes which take place in the environment are reflected in the species composition, structure and abundance of faunistic communities. The more a given habitat differs from the natural environment, the more distinct and explicit is the reaction of the fauna. Strong anthropogenic pressure generally causes about habitat degradation and leads to biocoenosis degradation. Regardless of the type of habitat, in restructured and degraded habitats certain animal communities can no longer be said to have a permanent species composition (only aaccidental species are recorded there), whereas other communities are dominated by single species. Occasionally, the composition of a community is limited to just these dominant species.

Reactions of different faunistic communities living in habitats which, although not under strong anthropogenic pressure, have been more or less modified are varied – differently directed and of a different degree of intensity. This is mainly due to the fact that different types of habitat have specific species associated with them and, in consequence, different faunistic complexes characterized by specific origin and habitat requirements. Thus, depending on habitat type and on the character of changes at work there, different taxa and parameters which describe it may be useful as indicators in estimation of the pace of these changes and of their direction. Tendencies in changes in the number of species and in abundance identical for all habitat types were recorded only for three taxa, namely for *Collembola* and *Noctuidae* (a decrease in these values) and for *Sphecidae* (an increase). A similar way of restructuring dominance structure in all habitat types studied was recorded only with respect to *Sarcophagidae*. Thus there is no universal taxon or parameter which would reflect clearly and explicitly all changes and in each type of habitat.

While analysing insect communities from the point of view of their usefulness as indicators of the condition of the environment and of changes occurring there we concluded that a single multispecies community might more or less clearly signal a change and its probable course, but it illustrated neither the depth nor the pace of transformations in the environment. Changes in a particular type of habitat may be recorded by different parameters in different communities. For some communities species composition may be such a parameter, for others abundance or number of species, for others still the character of dominance structure. If the depth and pace of changes taking place in a given habitat are estimated only on the basis of one community, conclusions which are drawn may even be entirely false. It follows from an analysis of the parameters describing the carabid community from a modified pine-oak mixed forest and from a natural one that the degree to which this habitat had been from a natural one is insignificant because the two communities were similar both in respect of species composition and the number of species and also in the character of dominance structure. In this habitat changes which had been brought about by anthropogenic pressure were reflected only in a decrease in the community abundance. Changes in this habitat which had been estimated on the basis of reactions of vespoid communities were more distinct. Indeed, these communities had maintained the same number of species and a similar species composition but in the modified forest their abundance greatly increased, the dominance structure was restructured and the degree of general diversity decreased.

If, however, the degree of transformation of the same habitat is estimated on the basis of changes in leafhopper or noctuid communities, a conclusion may be drawn that this habitat was subject to far-reaching changes, and quite differently directed ones. In a modified pine-oak mixed forest the noctuid community was greatly impoverished, whereas the leafhopper community was far richer both in respect of the number of species and in abundance, and its general diversity had also increased in spite of a decrease in the evenness of the distribution of abundance percentages of particular species.

An analysis carried out on the basis of a greater number of communities, selected as indicatory ones, allows for a more reliable and objective estimate of the condition of habitats and of the changes there.

An analysis of over 30 insect communities occurring in different forest habitats (an ash-alder forest, a linden oak-hornbeam forest, a pine-oak mixed forest and a pine forest) shows that habitat modification generally results in impoverishment of species composition; the number of species decreased in two-thirds of the communities. This tendency was most clearly manifested in the ash-alder habitats compared.

Nearly two-thirds of insect communities from modified habitats were, in comparison with communities from homologous natural habitats, similar in respect of species composition. The most transformed communities were those in a modified ash-alder forest, the least transformed ones in a linden oak-hornbeam forest. Species with a narrower range of tolerance to habitat conditions generally are eliminated from modified habitats and replaced by alien elements. It was recorded in most communities analyzed that forest species disappeared and those associated with open areas appeared.

Changes in the abundance of insect communities occurring in modified habitats were significant but differently directed. A decrease in abundance was recorded for almost half of the communities analyzed, and an increase for the rest of them.

A more explicit tendency was manifested in the restructuring of the dominance structure of communities. This consisted in a decrease in the degree of distribution uniformity of abundance proportions of particular species in the communities from modified habitats (this was recorded for over two-thirds of the communities analyzed). In nearly two-thirds of the communities analyzed an increase in antropopressure brought about a decrease in the degree of general diversity.

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STRESZCZENIE

Różnorodność reakcji zgrupowań owadów na presję antropogeniczną

W opracowaniu zaprezentowano szerokie spektrum zmian, jakie następują w zgrupowaniach owadów pod wpływem presji antropogenicznej. Na podstawie danych dotyczących ponad 30 wielogatunkowych zgrupowań owadów z 10 taksonów przeprowadzono charakterystykę i analizę porównawczą fauny środowisk naturalnych i odkształconych. Opracowanie oparte jest na wynikach szeroko zakrojonych badań Instytutu Zoologii PAN, przeprowadzonych w różnego typu lasach Niziny Mazowieckiej: borze mieszanym (*Pino-Quercetum*), borze świeżym (*Peucedano-Pinetum*), lesie grądowym (*Tilio-Carpinetum*) i lesie łęgowym (*Circaeo-Alnetum*). Środowiska, określone jako odkształcone, były usytuowane w Białołęce Dworskiej – podmiejskiej dzielnicy Warszawy. Ze względu na bliskie sąsiedztwo aglomeracji miejskiej podlegały one stosunkowo silnym wpływom presji antropogenicznej, ale ich roślinność, podobnie jak w środowiskach naturalnych, była zgodna z siedliskiem (nie była kształtowana sztucznie, jak na przykład w parkach). Dane o zgrupowaniach owadów z tych środowisk porównano z danymi dotyczącymi tych samych taksocenów z homologicznych środowisk naturalnych (pozamiejskich), uznanych za wzorcowe. Ocenę zarejestrowanych zmian przeprowadzono na podstawie wykorzystywanych w zoocenologii parametrów, opisujących zgrupowania faunistyczne: składu gatunkowego, liczby gatunków, liczebności, wskaźnika podobieństwa składu gatunkowego Soerensena, wskaźnika dominacji, wskaźnika równomierności Pielou oraz wskaźnika ogólnej różnorodności Shannona i Weavera.

Uzyskane wyniki wskazują, że nie ma jednego uniwersalnego taksonu ani też parametru, który wyraźnie i jednoznacznie odzwierciedlałby wszelkie zmiany w środowiskach różnych typów. Reakcje poszczególnych zgrupowań owadów na odkształcenie środowiska okazały się różnie ukierunkowane i miały różne nasilenie. Każde wielogatunkowe zgrupowanie owadów może jedynie mniej lub bardziej wyraźnie sygnalizować zmianę w środowisku i ewentualnie jej kierunek, samo jednak nie oddaje ani głębokości, ani tempa przekształceń. Dopiero analiza przeprowadzona na większej liczbie zgrupowań pozwala na wiarygodną ocenę stanu środowisk i zmian w nich zachodzących.

Na podstawie przebudowy składu gatunkowego rozważanych zgrupowań owadów stwierdzono, że spośród badanych środowisk podmiejskich najsilniej odkształconymi były łęg i bór sosnowy; w mniejszym stopniu zmieniony był bór mieszany, najmniej zaś grąd.

Wykazano, że odkształcenie środowisk na ogół powodowało ubożenie składu gatunkowego fauny (co najwyraźniej zaznaczyło się w łęgu). Dość jednoznaczna tendencja zarysowała się też w przebudowie struktury dominacyjnej zgrupowań. Polegała ona na zmniejszaniu równomierności rozkładu udziałów poszczególnych gatunków (stwierdzono to dla ponad $^2/_3$ zgrupowań). Wzrost presji antropogenicznej wywoływał też u blisko $^2/_3$ analizowanych zgrupowań zmniejszenie ich ogólnej różnorodności gatunkowej. Zmiany liczebności zgrupowań owadów również były istotne, ale w różnych środowiskach różnie ukierunkowane. Blisko połowa badanych zgrupowań wykazała spadek liczebności, a pozostałe – wzrost.

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