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**Faunistical relationships between *Chilopoda*  
of forest and urban habitats in Mazovia**

**Abstract.** Centipede (*Chilopoda*) communities in Mazovian forests and urban greens of Warsaw differ considerably in composition but contain mainly indigenous species. Urban greens accommodate fewer centipede species, the number decreasing as anthropopression becomes more intense. In both types of habitats, the communities are characterised by a similar model of structure, best preserved in the edaphic component, with one dominant accounting for over 60% of a community. The epigeic components of the communities have less stable compositions and structures, as expressed by changes in potential and actual species diversity.

**1. INTRODUCTION**

The distribution of centipedes (*Chilopoda*) in Europe is described as an increase in the degree of species diversification from north to south (ZALESSKAJA 1990). A number of species are found both in anthropogenic and natural habitats, their range in towns exceeding in the north the limits determined from its range in natural habitats (ENGHOFF 1973, BARBER, KEAY 1988, SCHULTE et al. 1989, ANDERSSON 1983, LEŚNIEWSKA, WOJCIECHOWSKI 1992). Since they are closely associated with soil, centipedes are easily transported even from one continent to another. Prime examples of such introductions are found among species of European or Palaearctic origin such as *Lithobius forficatus*, *Necrophleophagus flavus*, *Pachymerium ferrugineum* or *Schendyla nemorensis*, which have been transferred to certain parts of the New World, where they spread inland by migrating into natural habitats (EASON 1964, ZALESSKAJA 1978, KEVAN 1983). The zoogeographical mobility of *Chilopoda* reaching a transregional or even transcontinental scale is largely due to anthropogenic factors. Anthropogenic habitats, including towns as their most specific examples, may, therefore, serve as a good area for researches on the variability of the *Chilopoda* fauna and disturbances induced by human activities in a broad sense of this term.



Over the last several decades the species composition of *Chilopoda* in towns has been explored by many researchers. ENGHOFF (1973) has provided a list of centipedes from the environs of Copenhagen, and DAVIS (1979) has compiled a similar list of chilopods found in house gardens in London. TISCHLER (1980) has compared the occurrence of chilopods in a park in Kiel and the town's environs. ANDERSSON (1983), in his study on centipedes of the vicinity of Göteborg, also investigated the area of the town. A few chilopod species were also registered in Vienna in a survey of the fauna of urban soils (KUHNELT 1989). *Chilopoda* from urban sites subject to various degrees of anthropopression are described in papers on the biology of soils in Bonn-Bad Godesberg (FRÜND 1989, SCHULTE et al. 1989). The greatest number and diversity of urban localities were included in ZAPPAROLI'S (1992) study on the chilopods of Rome. Some faunistic data referring to *Chilopoda* of a town in Poland have been registered in Poznań lately (LEŚNIEWSKA, in press).

None of the above papers, however, explores the issue of relations between urban fauna and the fauna of natural habitats surrounding the city. The structural features of urban chilopod communities have also been disregarded. In the light of recent studies on urban fauna, the issue of the possibilities of the development of species richness in communities inhabiting urban greens becomes more significant for investigations of circumstances and conditions conducive to the development of the fauna (TROJAN 1994). In order to address this problem, a thorough knowledge of the rules governing the structure of natural communities is needed.

Forest litter is considered the most favourable habitat for the centipedes of our zone (BLOWER 1955, KACZMAREK 1979, LEWIS 1981). Forests are the land biocenoses least transformed by anthropopression in Central Europe and that is why forests have been chosen to study the faunistical relations in *Chilopoda*. Forest communities of *Chilopoda* were thus considered a reference plane for the fauna entering urban regions to be modified by anthropopression in limited areas of urban green. Since structural features of animal communities exhibit also natural variations resulting from the effect of homoeostatic mechanisms operating within competitive associations in ecosystems (TROJAN 1984), forest chilopod communities were considered in three plant association types: linden-oak-hornbeam forests, oak forests and pine forests.

The present paper attempts to answer the following questions: does the forest fauna of *Chilopoda* have certain common features? If so, can these features be preserved in urbanised habitats, in other words, to what extent is the *Chilopoda* fauna of urban greens derived from the fauna of forest habitats?

The following issues were analysed in this regard:

- What is the species capacity of *Chilopoda* in various types of forest and urban greens?
- What is the degree of species composition similarity between forest and urban communities?
- Do forest and urban *Chilopoda* communities develop according to the same model of structure?
- How do the species richness and diversity of *Chilopoda* change in different forest habitats and urban greens?
- What ecofaunistical features can be seen in individual *Chilopoda* species of forest and urban habitats?



## 2. AREAS OF STUDY

### 2.1 FOREST HABITATS

The *Chilopoda* fauna of forest habitats was studied at 9 sites (Fig. 1), which, in phytosociological terms, represent three types of natural plant associations. The study sites were situated in well-preserved forests, characteristic of the habitat types they represent, mostly within nature reserves.

#### Linden-oak-hornbeam forests (*Tilio-Carpinetum*)

1. „**Modrzewina**” forest reserve in Mała Wieś near Belsk. Typical linden-oak-hornbeam forest with 200-year-old larch trees in the first layer of the stand.
2. „**Dębina**” reserve (I) near Klembów. Typical linden-oak-hornbeam forest with one-layered stand, about 150 years old.
3. „**Dębina**” reserve (II) near Klembów. The wet variety of the typical linden-oak-hornbeam forest; two-layered stand with oaks more than 140 years old and hornbeam trees more than 120 years old
4. **Radziejowice I**. Tall linden-oak-hornbeam forest; stand is about 75 years old; multi-layered with an admixture of pine and spruce.
5. „**Cyganka**” reserve in Kampinos National Park. Typical linden-oak-hornbeam forest, the ground cover layer slightly degraded, 130-year-old forest stand.

#### Oak forests (*Potentillo albae-Quercetum*)

6. **Radziejowice II**. The majority of the stand are 55-year-old trees, the oldest oaks are 80 years old.
7. **B. Hryniewiecki** reserve in Podkowa Leśna, 165-year-old stand with drying up oak trees, which is better preserved in the 25-45-year-old undergrowth.

A detailed geobotanical description of the study sites in linden-oak-hornbeam and oak forests is contained in KOTOWSKA, NOWAKOWSKI (1989).

#### Pine forests (*Peucedano-Pinetum*)

8. **Dybki** in Puszcza Biała. About 100-year-old stands near the village of Dybki, representing the Sarmatian variety of the association with a high proportion of juniper in the shrub layer. A detailed description of the site from the viewpoint of phytosociology and soil can be found in MATUSZKIEWICZ, DEGÓRSKI and KOZŁOWSKA (1993).
9. **Łomna** in Puszcza Kampinoska. Situated near the village of Łomna, about 80-year-old stand. A detailed phytosociological and soil description can be found in BAŃKOWSKA, GARBARCZYK (1981).

### 2.2 URBAN GREENS

Studies of *Chilopoda* of urban greens were carried out in 13 areas in Warsaw (Fig. 2). They represent sites subject to anthropopression of various intensity. All of them are located in a potential linden-oak-hornbeam habitat, which is the dominant form of habitat in Warsaw nowadays (MATUSZKIEWICZ 1966, NOWAKOWSKI 1981). However, the sites subject to the most intense anthropopression, i.e. the park and

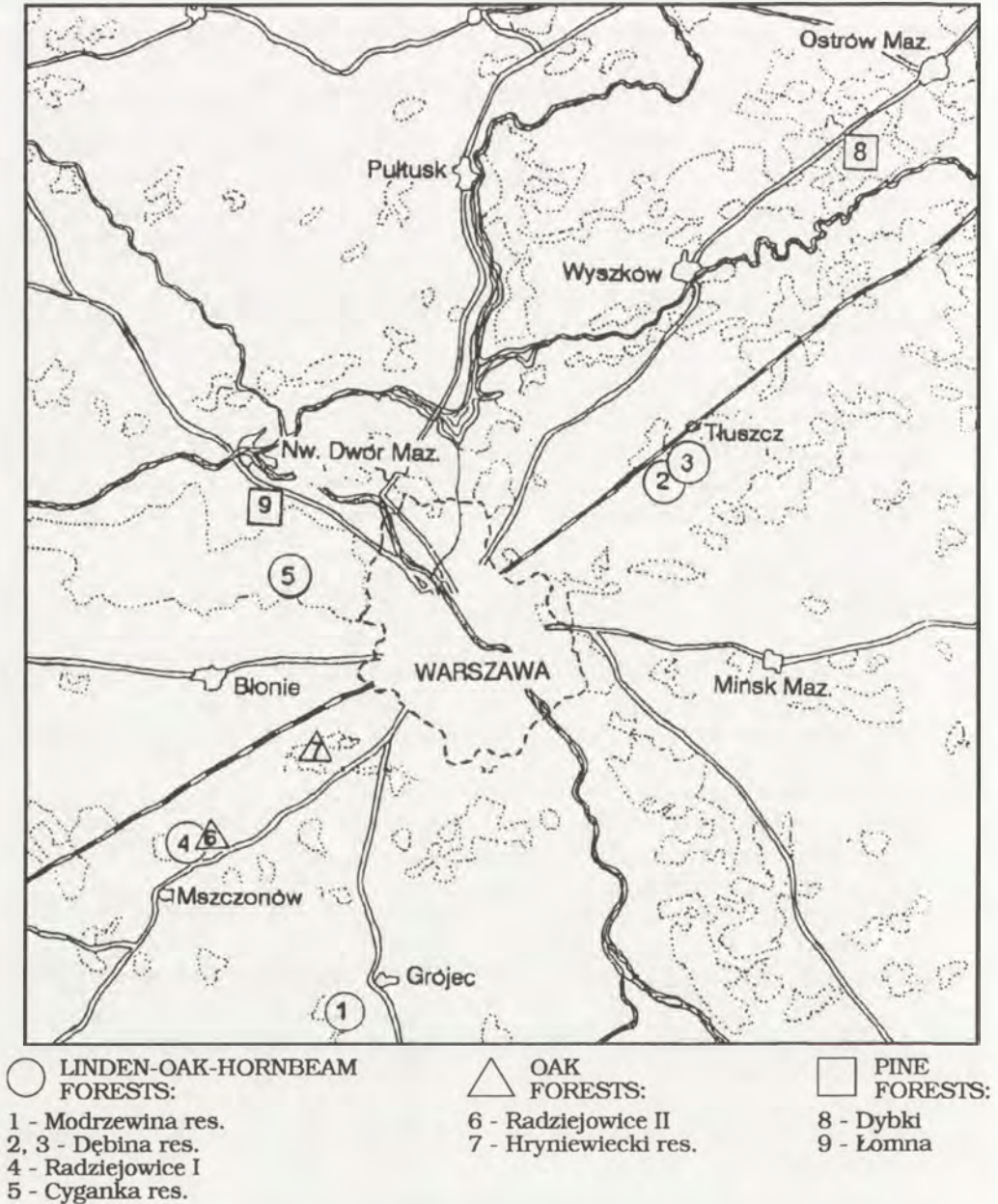
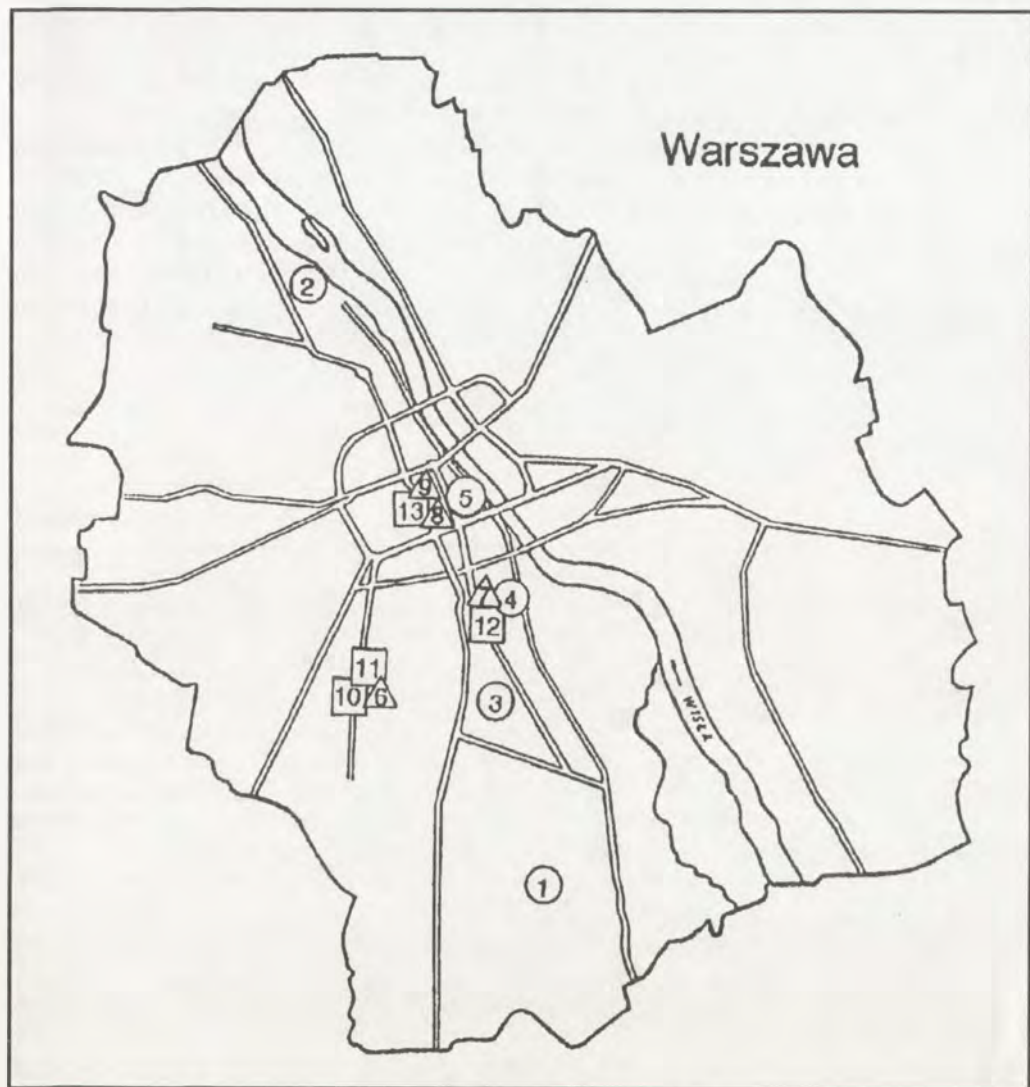


Fig. 1. Location of forest sites

street lawns listed below, are all situated on anthropogenic soil - soil banks with a large amount of rubble (KONECKA-BETLEY 1976, DOBRZAŃSKI et al. 1975, 1977).

On account of the high variety of urban greens and certain features of ground cover that have a particularly significant effect on the chilopod fauna (BLOWER





- |                         |                                 |                                |
|-------------------------|---------------------------------|--------------------------------|
| ○ WOODED AREAS:         | △ PARKS:                        | □ STREET LAWNS:                |
| 1 - Ursynów             | 6 - Cemetery to Soviet Soldiers | 10 - Żwirko & Wigura Avenue I  |
| 2 - Bielany             | 7 - Łazienki-Chopin             | 11 - Żwirko & Wigura Avenue II |
| 3 - Królikarnia         | 8 - Saxon Garden I              | 12 - Ujazdowskie Avenue        |
| 4 - Łazienki-escarpment | 9 - Saxon Garden II             | 13 - Marszałkowska Street      |
| 5 - University          |                                 |                                |

Fig. 2. Location of urban green sites

1955, WALLWORK 1970), cluster analysis of the sites was carried out in order to classify them. The following features of the surface were considered:

1) seminatural wooded areas, parks, street lawns - a nominative variable expressed as the numbers 1, 2, 3.

2) application of horticultural practices - a logical variable assuming the values of 0 (false) or 1 (true).

3) density of the green - an ordinal variable assuming the integer values from 1 to 5, analogous with the Braun-Blanquet scale.

4) shadow, also an ordinal variable, assuming three values: 1, 2, 3, corresponding to a subjective assessment of the amount of shadow on a sunny summer day.

Cluster analyses based on the Euclidean distance and on the Manhattan metric (city-block distance) yielded nearly identical results. The sites are divided into three different clusters at dissimilarity level equalling unity (Fig. 3). On that basis, the *Chilopoda* fauna was examined separately in wooded areas, parks and street lawns.

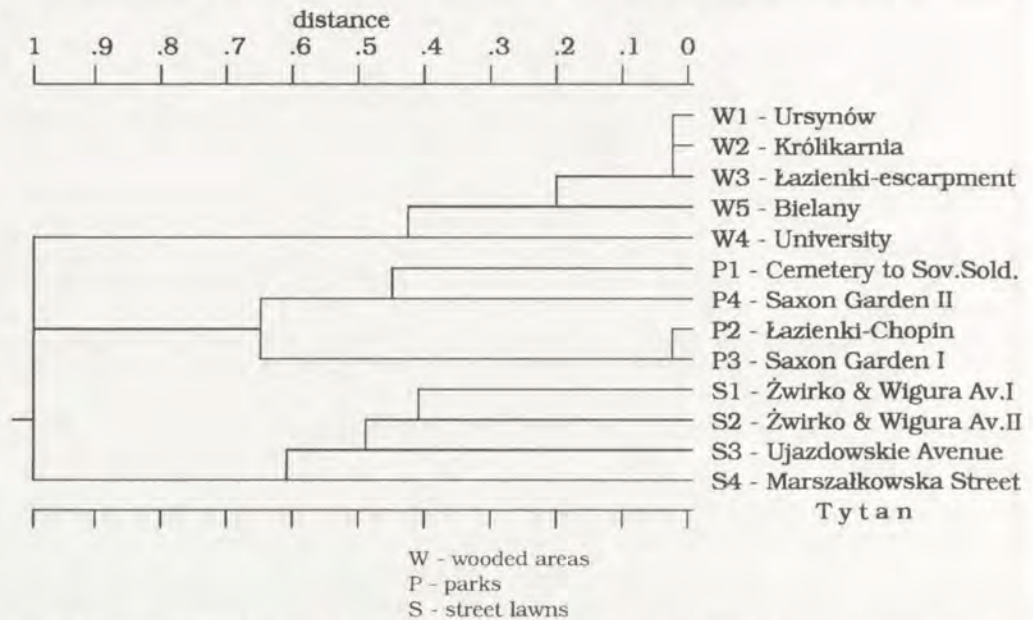


Fig. 3. Classification of urban green study sites according to Euclidean distance (standardised data, average linkage clustering method)

#### Wooded areas

Slightly transformed linden-oak-hornbeam woods and seminatural wooded areas in a linden-oak-hornbeam habitat situated on the Warsaw escarpment were included into the same type of urban green. A geobotanical description of these sites is provided in NOWAKOWSKI (1979). The areas most distant from the city centre are two linden-oak-hornbeam sites situated on the opposite ends of the Warsaw escarpment:

1. **Ursynów** - a site located near southern city limits, within the J.U.Niemcewicz palace park, nowadays the seat of the Agricultural University.
2. **Bielany** - north-western end of Warsaw, within the „Las Bielański” reserve, at the back of the Physical Education Academy campus.

Three further sites in this group are situated on the Warsaw escarpment in the centre of the city. They are seminatural wooded areas in a linden-oak-hornbeam habitat:



3. **Królikarnia.** A maple-hornbeam-elm stand in the Arkadia park next to the Królikarnia palace.
4. **Lazienki-escarpment.** A wooded area with rich undergrowth and relatively poor herb layer at the back of the Frederic Chopin's Monument within the Royal Łazienki park.
5. **University.** At the back of the Warsaw University campus - a maple-linden-robinia stand with poor undergrowth.

#### Park greens

Park greens in the centre of the city are represented by areas inside large parks, at least 50 m away from a street:

6. **Cemetery to Soviet Soldiers.** A large partly shaded lawn situated near Żwirko and Wigura Avenue within the park comprising the Cemetery-Mausoleum to Soviet Soldiers. It is lined with an elm hedge on the side of the street and with coniferous and deciduous shrubs representing a number of species on the south side.
7. **Łazienki-Chopin.** A rather small shaded lawn near Frederic Chopin's Monument in the Łazienki Park on the upper Vistula terrace, with planted oaks, surrounded by a thuja hedge.
8. **Saxon Garden I.** A large shaded lawn in the Saxon Garden, adjacent to Marszałkowska Street, separated by a privet hedge from tram rails.
9. **Saxon Garden II.** An exposed but not intensely insolated lawn, in the heart of Saxon Garden comprising a few tree species and a group of shrubs on the north side.

#### Street lawns

The street lawn group consisted of lawns situated near parks and in the proximity of Warsaw's busiest arterial roads. The following sites were included:

10. **Żwirko & Wigura Avenue I.** A quite wide lawn sandwiched between the lanes of the carriageway, opposite the Cemetery-Mausoleum to Soviet Soldiers, with a line of linden trees running in the middle.
11. **Żwirko & Wigura Avenue II.** A shaded street lawn next to Żwirki i Wigury Avenue, on the same side as the Cemetery, with a line of linden trees.
12. **Ujazdowskie Avenue.** A narrow street lawn in Ujazdowskie Avenue near the Łazienki Park, with linden trees planted in a line.
13. **Marszałkowska.** A large lawn between the lanes of Marszałkowska Street, near Ogród Saski with a few single trees, but well-insolated.

Detailed data concerning the soil and plant cover of the sites in and adjacent to parks may be found in KUBICKA, CHUDZICKA and WYSOCKI (1986).

### 3. METHODS

#### 3.1 COLLECTION OF CENTIPEDES

Due to their strong dependence on moisture conditions in the environment, several years' long development cycle and the relative absence of food preferences in their predacious mode of life, centipedes form a relatively homogeneous group

from the ecological viewpoint (LEWIS 1981, DUNGER 1983). In such groups the separation of ecological niches is accomplished by temporal or spatial division of forms of ecological specialisation (SCHOENER 1974). As a result, the choice of a particular method of material collection, where the output is influenced by the activity patterns of *Chilopoda*, is likely to affect the faunistical data. The intensity of chilopod penetration into the surface layer of soil is reflected in the material obtained with Barber's pitfall traps, while material from siftings or soil samples provides a better insight into the structure of the fauna dwelling in deeper horizons. In further considerations, the two components of the material will be referred to as the epigeon and the edaphon, following the classification of soil fauna accounting for the fact that the fauna inhabits different soil horizons (WALLWORK 1970).

Most soil animals, including centipedes, inhabit mainly the surface layer of soil down to a depth of a dozen or so centimetres, including the humus accumulation horizon, especially litter and humus (GÓRNY 1975). The surface layer has different structures in the habitats studied (Fig. 4). Therefore, in the forest habitat, litter siftings were used as the most efficient method for collection of centipedes representing the edaphic component in the fauna, while soil samples were only used for qualitative analyses. In urban green sites only soil samples were used as loose litter was virtually absent. The thickness of a soil sample was approximately 15 cm.

Barber pitfall traps were used in a continuous manner: traps were emptied every two weeks from April to October.

Deciduous litter siftings were done at regular intervals throughout the vegetational season, while with coniferous litter, siftings were obtained in the spring-

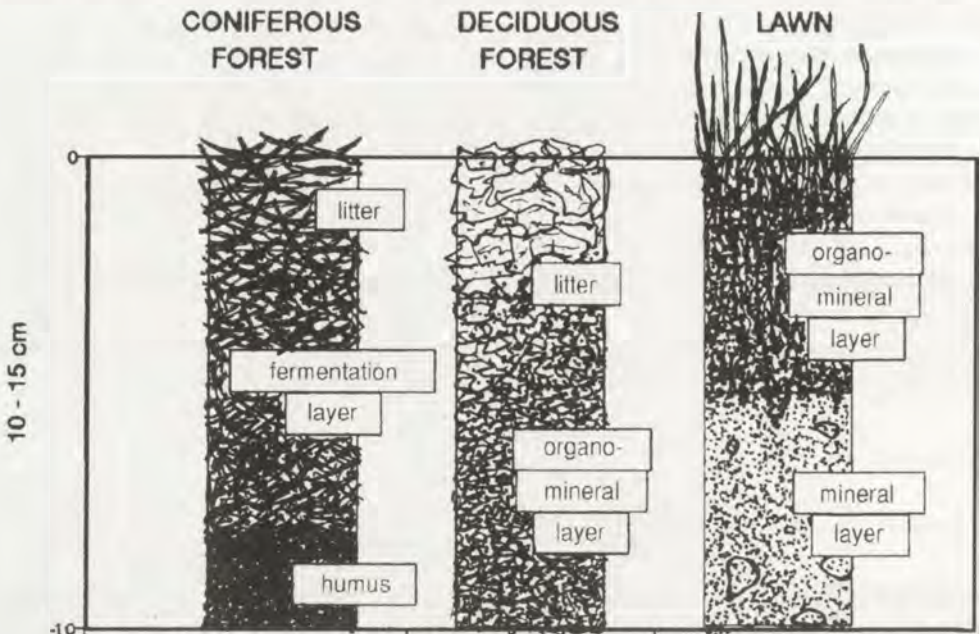


Fig. 4. Schematic diagram of the structure of the surface soil layer in different types of habitats



summer and autumn-winter periods due to heavier desiccation of litter in pine forests in the warmest periods of summer. Seasonal variations in moisture cause intense migrations of centipedes to more humid logs and stumps (AUERBACH 1951). Soil samples were also taken in spring and autumn for the same reasons. In towns they were only taken in May and September.

The study material consists altogether of 3512 specimens collected in the years 1979-1990 at 22 study sites situated in Mazovia and Warsaw (Tab. I).

Table I. Methods, number of samples and size of the *Chilopoda* material

Habitat	Locality	Method	Date of sampling	Number of samples	Size of sample	Number of individuals
1	2	3	4	5	6	7
LINDEN-OAK HORNBEAM FORESTS	Modrzewina	litter siftings	1981	14	10 x 0.1m <sup>2</sup>	113
			1982	12	10 x 0.1m <sup>2</sup>	156
			1984	5	10 x 0.1m <sup>2</sup>	60
		soil samples	1982	12	10 x 0.0017m <sup>2</sup>	73
			1982	2	10 x 0.1m <sup>2</sup>	65
			pitfall traps	1981	7	20traps x 14days
	1982	5		20traps x 14days	40	
	1984	4		30traps x 14days	29	
	Dębina I	litter siftings	1981	14	10 x 0.1m <sup>2</sup>	131
			1984	7	10 x 0.1m <sup>2</sup>	187
		pitfall traps	1980	4	20traps x 14days	38
	1984		8	30traps x 14days	336	
	Dębina II	litter siftings	1981	14	10 x 0.1m <sup>2</sup>	55
		pitfall traps	1980	5	20p. x 14dn.	43
	Radziejowice I	litter siftings	1984	12	10 x 0.1m <sup>2</sup>	55
		pitfall traps	1984	14	30p. x 14dn.	73
Cyganka	litter siftings	1979	3	10 x 0.1m <sup>2</sup>	18	
	pitfall traps	1979	1	10 x 0.1m <sup>2</sup>	65	
		1979	6	20traps x 14days	30	
OAK FORESTS	Radziejowice II	litter siftings	1984	12	10 x 0.1m <sup>2</sup>	33
		pitfall traps	1984	14	30traps x 14days	42
	Hryniewiecki	litter siftings	1983	26	20 x 0.1m <sup>2</sup>	103
		1984	26	20 x 0.1m <sup>2</sup>	101	
		soil samples	1984	2	5 x 0.1m <sup>2</sup>	15
		pitfall traps	1983	12	20traps x 14days	94
1984	16		40traps x 14days	115		
PINE FORESTS	Dybki	litter siftings	1986	12	10 x 0.1m <sup>2</sup>	36
			1987	12	10 x 0.1m <sup>2</sup>	44
		soil samples	1986/88	12	10 x 0.1m <sup>2</sup>	76
			pitfall traps	1986	14	30traps x 14days
	1987	14		30traps x 14days	9	
	Łomna	litter siftings	1986	5	1m <sup>2</sup>	33
			1986	1	10 x 0.1m <sup>2</sup>	10

1	2	3	4	5	6	7	
WOODED AREAS	Ursynów	soil samples	1990	6	0.1m	72	
		pitfall traps	1988	15	10traps x 14days	8	
			1989	9	10traps x 14days	3	
	Królikarnia	soil samples	1990	6	0.1m <sup>2</sup>	12	
		pitfall traps	1988	11	10traps x 14days	0	
			1989	17	10traps x 14days	4	
	Łazienki -escarpment	soil samples	1990	8	0.1m <sup>2</sup>	206	
		pitfall traps	1988	15	10traps x 14days	11	
			1989	17	10traps x 14days	11	
	University	soil samples	1990	6	0.1m <sup>2</sup>	43	
		pitfall traps	1988	13	10traps x 14days	5	
			1989	17	10traps x 14days	2	
	Bielany	soil samples	1990	6	0.1m <sup>2</sup>	60	
		pitfall traps	1988	16	10traps x 14days	4	
1989			17	10traps x 14days	9		
PARKS	Cemetery to Soviet Soldiers	soil samples	1990	8	0.1m <sup>2</sup>	89	
		pitfall traps	1988	15	10traps x 14days	8	
			1989	17	10traps x 14days	4	
	Łazienki-Chopin	soil samples	1990	8	0.1m <sup>2</sup>	36	
		pitfall traps	1988	16	10traps x 14days	2	
			1989	12	10traps x 14days	1	
	Saxon Garden I	soil samples	1990	9	0.1m <sup>2</sup>	24	
		pitfall traps	1988	16	10traps x 14days	7	
			1989	17	10traps x 14days	4	
	Saxon Garden II	soil samples	1990	8	0.1m <sup>2</sup>	40	
		pitfall traps	1988	16	10traps x 14days	1	
			1989	17	10traps x 14days	1	
	STREET LAWNS	Żwirko&Wigura Avenue I	soil samples	1990	8	0.1m <sup>2</sup>	106
			pitfall traps	1988	16	10traps x 14days	9
1989				17	10traps x 14days	17	
Żwirko&Wigura Avenue II		soil samples	1990	8	0.1m <sup>2</sup>	99	
		pitfall traps	1988	16	10traps x 14days	39	
			1989	17	10traps x 14days	27	
Ujazdowskie Avenue		soil samples	1990	8	0.1m <sup>2</sup>	1	
		pitfall traps	1988	15	10traps x 14days	0	
			1989	17	10traps x 14days	2	
Marszałkowska Street		soil samples	1990	8	0.1m <sup>2</sup>	124	
		pitfall traps	1988	16	10traps x 14days	13	
			1989	17	10traps x 14days	21	

### 3.2 METHODS OF ANALYSIS

Our description of *Chilopoda* communities was based on standard methods used in soil zoology (BALOGH 1958, CERNOV 1975, WALLWORK 1976, SOUTHWOOD 1978, GÓRNY, GRUM 1981) and methods of structural analysis described in TROJAN (1992). The following relationships and formulae were used in computations:



1. modified **Arrhenius's formula** (CONNOR, MCCOY 1979):

$$S_i = cN_i^z$$

where:  $S_i$  - number of species in a sample,  
 $N_i$  - number of individuals in a sample,  
 $c, z$  - equation parameters obtained as suggested by the authors  
of the formula;

2. **Jaccard's index**:

$$j = \frac{w}{a+b-w}$$

where:  $a$  - number of species in one habitat,  
 $b$  - number of species in the other habitat,  
 $w$  - number of common species;

3. **constancy** after TISCHLER (1949):

$$c = \frac{i}{k} \times 100\%$$

where:  $i$  - number of sites where a given species occurs,  
 $k$  - total number of sites in the habitat;

4. **index of dominance**:

$$D = \frac{n}{N} \times 100\%$$

where:  $n$  - density (trapability) of a given species,  
 $N$  - density (trapability) of the community;

5. **Morisita's index** modified by HORN (1966):

$$M = \frac{2 \sum_{i=1}^s x_i y_i}{\sum_{i=1}^s x_i^2 + \sum_{i=1}^s y_i^2}$$

where:  $x_i, y_i$  - indices of dominance of species  $i$  at sites X, Y,  $s$  being the total  
number of species;

6. **index of homogeneity**

a) **of dominance** (RIEDL 1963):

$$HD = \sum_{i=1}^s \left( \sum_{j=1}^k \frac{D_{ij}}{k} \right) \frac{D_{\min i}}{D_{\max i}}$$

where:  $D_{ij}$  - index of dominance of the  $i$ th species at the  $j$ th site, there being a total of  $s$  species and  $k$  sites;

b) **of ranks:**

where:  $D_{ij}$  - index of dominance of the  $i$ th species of the  $j$ th rank, there being a total of  $s$  species and  $k$  ranks;

7. **Shannon-Weaver index of diversity:**

$$H' = - \sum_{i=1}^s \frac{n_i}{N} \log_2 \frac{n_i}{N}$$

where:  $n_i$  - abundance of the  $i$ th species,  
 $N$  - abundance of the community;

8. **Pielou's index:**

$$J = \frac{H'}{H_{max}}$$

where:  $H_{max}$  - maximum value of Shannon-Weaver's index;

9. **models of species abundance distribution** described in TROJAN (1992) were calculated for *Chilopoda* communities using a computer programme at the Institute of Zoology P.A.S.

The following measures of dissimilarity (PIELOU 1984) were employed in cluster analyses performed using the TYTAN programme (1990) prepared by A. Batko and I. Moraczewski:

10. **euclidean distance** in an  $s$ -element space:

$$d(A, B) = \sqrt{\sum_{i=1}^s (x_{iA} - x_{iB})^2}$$

11. **city-block distance (Manhattan metric):**

$$d(A, B) = \sum_{i=1}^s |x_{iA} - x_{iB}|$$

12. **Marczewski-Steinhaus distance:**

$$d_M = 1 - \frac{w}{a+b-w}$$

where:  $a, b$  - number of species in sets  $A, B$ ,  
 $w$  - number of common species;

13. **complement of Sørensen's index:**

$$d_s = 1 - 2 \frac{w}{a+b}$$

symbols - see 12.



The average neighbour clustering method (PIELOU 1984) was used in the computer-aided cluster analysis. Cluster analysis based on similarity indices including Jaccard's index, Morisita's index and homogeneity index was performed according to the method described by MOUNTFORD (1962), based on the assumption that the similarity of each new element added to a cluster is equal to that element's average similarity to all the elements already clustered. Thus, the similarity  $s(A, B)$  between an  $m$ -element cluster  $A$  and an  $n$ -element cluster  $B$  is given by:

$$s(A, B) = \frac{1}{mn} \sum_{i=1}^m \sum_{j=1}^n s(A_i, B_j)$$

#### 4. NUMBER OF SPECIES AND SPECIES CAPACITY OF THE STUDY SITES

The number of species recorded at a given site depends to a great extent on the size of study material. In the data concerning *Chilopoda* this relationship was studied on the basis of soil samples and siftings for forest habitats, and soil samples for the urban green. The empirical curve assumes the shape of an Arrhenius's curve. There is a considerable overlap with the theoretical function. When the curves were compared using a chi-square test, the probability of overlap between them turned out to be  $p \geq 0.95$ . The regression of Arrhenius's function thus proves that the empirical data are correct. The number of *Chilopoda* species determined from the curve, i.e. the number dependent on the character of the function, is not much higher than the actual figure obtained with the method used, equalling it when rounded (Tab. II). However, since Arrhenius's curve is not asymptotic, the method does not allow to ultimately determine the species capacity of a habitat. Arrhenius's curve is typical for heterogeneous habitats of a predominantly patchy structure (BALOGH 1958, TROJAN 1992). This suggests considerable diversification of the habitats for centipedes.

Table II. Species capacity for *Chilopoda* of forest habitats in Mazovia and urban greens in Warsaw

Habitat		S	Sp/g	S*(A)	S*(R)
forests	linden-oak-hornbeam forests	14	9	9.421	14.381
	oak forests	8	7	7.441	10.584
	pine forests	8	6	6.032	8.803
urban greens	wooded areas	8	7	7.223	7.746
	parks	9	6	6.387	6.796
	street lawns	7	5	4.591	5.713

S – number of species recorded in the habitat by means of the base and additional methods

Sp/ε – number of species recorded in the habitat by means of litter sifting (forests) or soil samples (urban greens)

S\*(A) – theoretical number of species obtained from the Arrhenius's curve

S\*(R) – theoretical number of species obtained on the base of the negative binomial distribution

Neither siftings nor soil samples alone can assure that all chilopod species from the habitats sampled be present in the material. The application of a greater number of methods may increase the number of species recorded by as much as 30%. Such results were obtained for linden-oak-hornbeam forests, pine forest and park lawns using Barber's pitfall traps as an additional method (Tab. II). On the other hand, the additional soil samples in forest habitats did not increase the number of species identified in the material from soil siftings and Barber's traps.

The species capacity of the habitats for *Chilopoda* was estimated on the basis of structural features of the communities i.e. distribution of species abundance in a community. The empirical distributions based on the material from siftings or soil samples exhibited a high degree of overlap with the negative binomial distribution (Tab. III). The distribution properties (TROJAN 1992) allowed to estimate the theoretically possible number of *Chilopoda* species in the habitats studied. The numbers of species obtained with this method (Tab. II) turned out to be higher than the empirical data and also higher than those determined using Arrhenius's curve. The greatest differences were seen in the case of forest habitats, which are probably more diversified for centipedes than urban greens.

Table III. Probability of overlap between the structures of *Chilopoda* communities and various models of species abundance distribution:

Layer	Habitat	gs	bsd	lgs	lgnd	nbd
edaphon	linden-oak-hornbeam forests	0.000	0.000	0.913	0.000	0.851
	oak forests	0.000	0.000	0.647	0.000	0.615
	pine forests	0.005	0.227	0.341	0.157	0.526
	wooded areas	0.191	0.000	0.890	0.000	0.825
	parks	0.005	0.000	0.967	0.000	0.660
	street lawns	0.000	0.000	0.625	0.000	0.570
epigeon	linden-oak-hornbeam forests	0.000	0.000	0.113	0.000	0.107
	oak forests	0.000	0.000	0.189	0.000	0.129
	pine forests	1.000	1.000	1.000	0.000	1.000
	wooded areas	0.373	0.631	0.444	0.000	0.724
	parks	0.939	0.000	0.552	0.000	0.579
	street lawns	0.000	0.000	0.439	0.000	0.382

gs – geometric series  
 bsd – broken stick distribution  
 lgs – logarithmic series  
 lgnd – lognormal distribution  
 nbd – negative binomial distribution

As for urban greens, empirical data on the numbers of species are higher than theoretical data, even those estimated on the basis of the negative binomial distribution (Tab. II). It follows then that the simultaneous application of two methods (soil samples and Barber's pitfall traps) is sufficient to obtain exhaustive faunistic information from sites located in urban environments.



The numbers of species determined using the negative binomial distribution for siftings and soil samples could be considered to best reflect the actual *Chilopoda* species capacity of the habitats studied. The highest centipede species capacity was recorded in forest habitats (Tab. II), including linden-oak-hornbeam forests, where as many as 82% of *Chilopoda* species identified in all types of forest habitats were found. The wooded areas can accommodate the highest number of centipede species among urban greens. The greatest number of species recorded in parks would rather suggest that *Chilopoda* are sometimes introduced there during horticultural practices such as manuring of peat.

### 5. SPECIES COMPOSITION

25 centipede species have been recorded in Mazovia so far, compared to the total of 38 species known from the Polish Lowland (KACZMAREK 1980, WYTWER 1990, LEŚNIEWSKA, WOJCIECHOWSKI 1992). The data for Mazovia come mostly from forest habitats, while urban areas have not been taken into account to date (W. KACZMAREK 1963, GROŃSKA 1968, WYTWER 1990, 1992). Four species which were recorded in Mazovia for the first time in this study were found in an urban habitat in Warsaw. These are: *Geophilus electricus*, *Brachygeophilus truncorum*, *Clinopodes linearis*, *Strigamia crassipes* (Tab. IV). The above species and two others: *Lithobius crassipes* and *Lithobius microps* account for the distinct character of urban chilopod fauna in relation to the forest habitats studied here, where the species were not registered (Tab. IV).

Only 3 species are common to the three types of forest habitats investigated (Fig. 5): *Lithobius erythrocephalus*, *Lithobius lapidicola* and *Schendyla nemorensis*. Of the three, only *L. lapidicola* is considered a forest species (ZALESSKAJA 1978). However, little is known about its ecological requirements as the species is often mistaken for *L. borealis* (ANDERSSON 1980, EASON 1982). The other two species are typical eurytopes. The fact that only so many common species were registered in an evident proof of high diversification of habitat conditions that *Chilopoda* encounter in various types of forest. Linden-oak-hornbeam and oak forests in this instance accommodate the whole spectrum of *Chilopoda* species in the forest habitats under investigation (Fig. 5). All of the species found in the forest sites studied were also registered in these two plant associations. However, the mutual similarity of species composition in forest *Chilopoda* communities is not high. (Fig. 6). When expressed as Jaccard's index, it reaches a minimum for linden-oak-hornbeam and oak forests (0.294) and a maximum for oak and pine forests (0.454). A middle value (0.375) was obtained for the species composition similarity of *Chilopoda* communities of linden-oak-hornbeam and pine forests. The quite low values of this index are due to the relatively big difference in the number of species between linden-oak-hornbeam forests and the others - the number of species in the former is higher by 75% than in the latter. The number of common species (5 or 6) thus accounts for more than 60% of the species composition of habitats poorer in *Chilopoda* i.e. oak and pine forests (Fig. 5).

Table IV. Occurrence of Chilopoda in the forests of Mazovia and urban greens of Warsaw

No.	Species	Habitat	FORESTS			URBAN GREENS				
			linden- oak- hornbeam	oak	pine	total	wooded areas	parks	street lawns	total
1	<i>Lithobius forficatus</i> (LINNAEUS, 1758)		+		+	+	+	+	+	
2	<i>Lithobius piceus</i> L. KOCH, 1862		+			+				
3	<i>Lithobius tenebrosus fernoscandius</i> LOHMANDER, 1848		+			+				
4	<i>Lithobius agilis</i> C. L. KOCH, 1847		+			+				
5	<i>Lithobius melanops</i> NEWPORT, 1845		+				+		+	
6	<i>Lithobius pelidnus</i> HAASE, 1880		+		+					
7	<i>Lithobius mutabilis</i> L. KOCH, 1862		+	+		+			+	
8	<i>Lithobius calcaratus</i> C. L. KOCH, 1844			+	+	+				
9	<i>Lithobius erythrocephalus</i> C. L. KOCH, 1847		+	+	+	+				
10	<i>Lithobius lapidicola</i> MEINERT, 1872		+	+	+	+				
11	<i>Lithobius muticus</i> C. L. KOCH, 1847			+		+				
12	<i>Lithobius crassipes</i> L. KOCH, 1862					+			+	
13	<i>Lithobius curtipes</i> C. L. KOCH, 1847		+		+	+				
14	<i>Lithobius microps</i> MEINERT, 1868					+	+	+	+	
15	<i>Lamyctes fulvicornis</i> MEINERT, 1868		+			+	+		+	
16	<i>Necrophleophagus flavus</i> (DE GEER, 1778)		+			+	+	+	+	
17	<i>Clinopodes linearis</i> (C. L. KOCH, 1835)						+		+	
18	<i>Geophilus electricus</i> (LINNAEUS, 1758)					+	+	+	+	
19	<i>Brachygeophilus truncorum</i> (BERGSOE et MEINERT, 1867)							+	+	
20	<i>Pachymerium ferrugineum</i> (C. L. KOCH, 1835)			+	+	+				
21	<i>Strigamia acuminata</i> (LEACH, 1814)		+	+		+				
22	<i>Strigamia crassipes</i> (C. L. KOCH, 1835)					+	+	+	+	
23	<i>Schendyla nemorensis</i> (C. L. KOCH, 1837)		+	+	+	+	+	+	+	
	number of species		14	8	8	17	8	9	7	12





Fig. 5. Species composition affinities between *Chilopoda* communities of different types of habitats

Much higher values of Jaccard's index were obtained for the *Chilopoda* communities of urban greens. The numbers of species found there were, however, similar to one another so that with the same number of common species as in forest habitats (Fig. 5) much higher similarity was recorded: from 0.545 for wooded areas and parks to 0.667 for wooded areas and street lawns (Fig. 6).

When comparing urban and forest chilopod fauna, the similarity is always lower than when comparing only the different forest habitats and much lower than when only urban habitats are compared (Fig. 6). However, when species composition is compared in *Chilopoda* communities of linden-oak-hornbeam forests and various types of urban greens, the index of similarity is the highest with as few as 3, 4 and 5 common species, which means that the urban chilopod fauna is the most similar to the fauna of linden-oak-hornbeam forests. The similarity relations between *Chilopoda* communities in the habitats under study, as resulting from values of Jaccard's index, are illustrated in a dendrogram obtained using the method proposed by MOUNTFORD (1962) (Fig. 7).

The affinity of a species to a given habitat is determined by the notion of constancy i.e. the occurrence of a species at various sites representing a given habitat (TISCHLER 1949). Data on the constancy of the occurrence of various species of *Chilopoda* in linden-oak-hornbeam as well as in forest habitats and urban greens

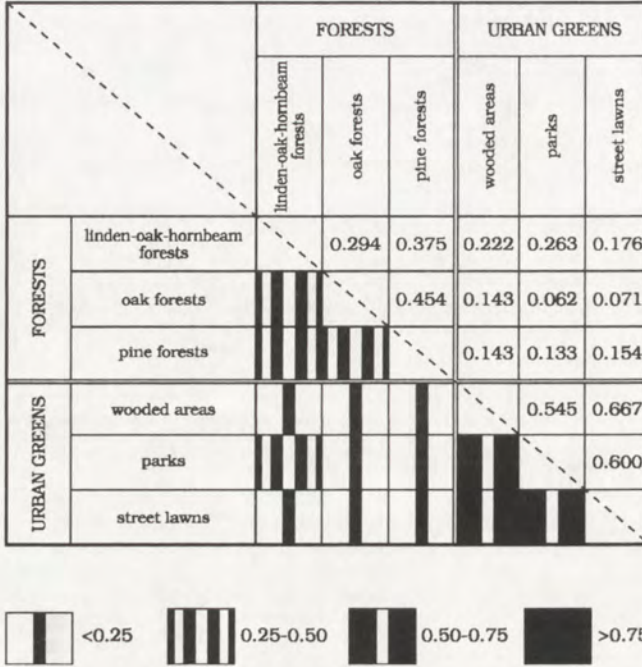


Fig. 6. Values of Jaccard's index for *Chilopoda* communities of forest and urban habitats

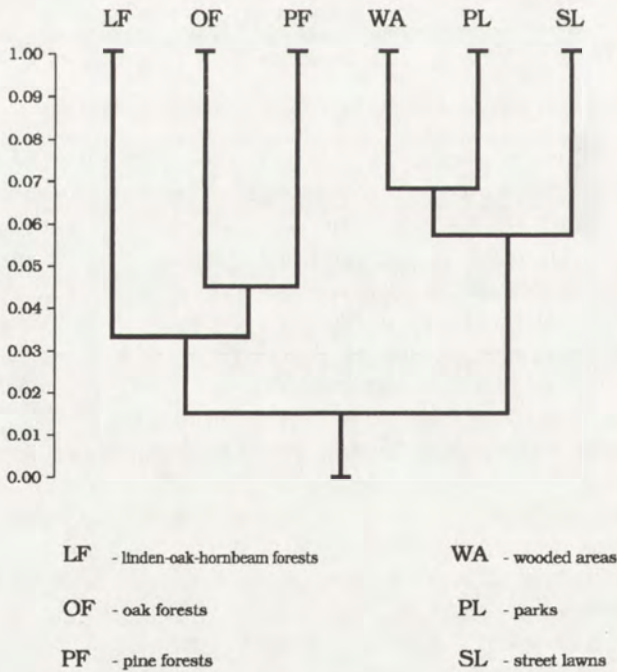


Fig. 7. A diagram of species composition similarity of *Chilopoda* communities of forest and urban habitats based on Jaccard's index



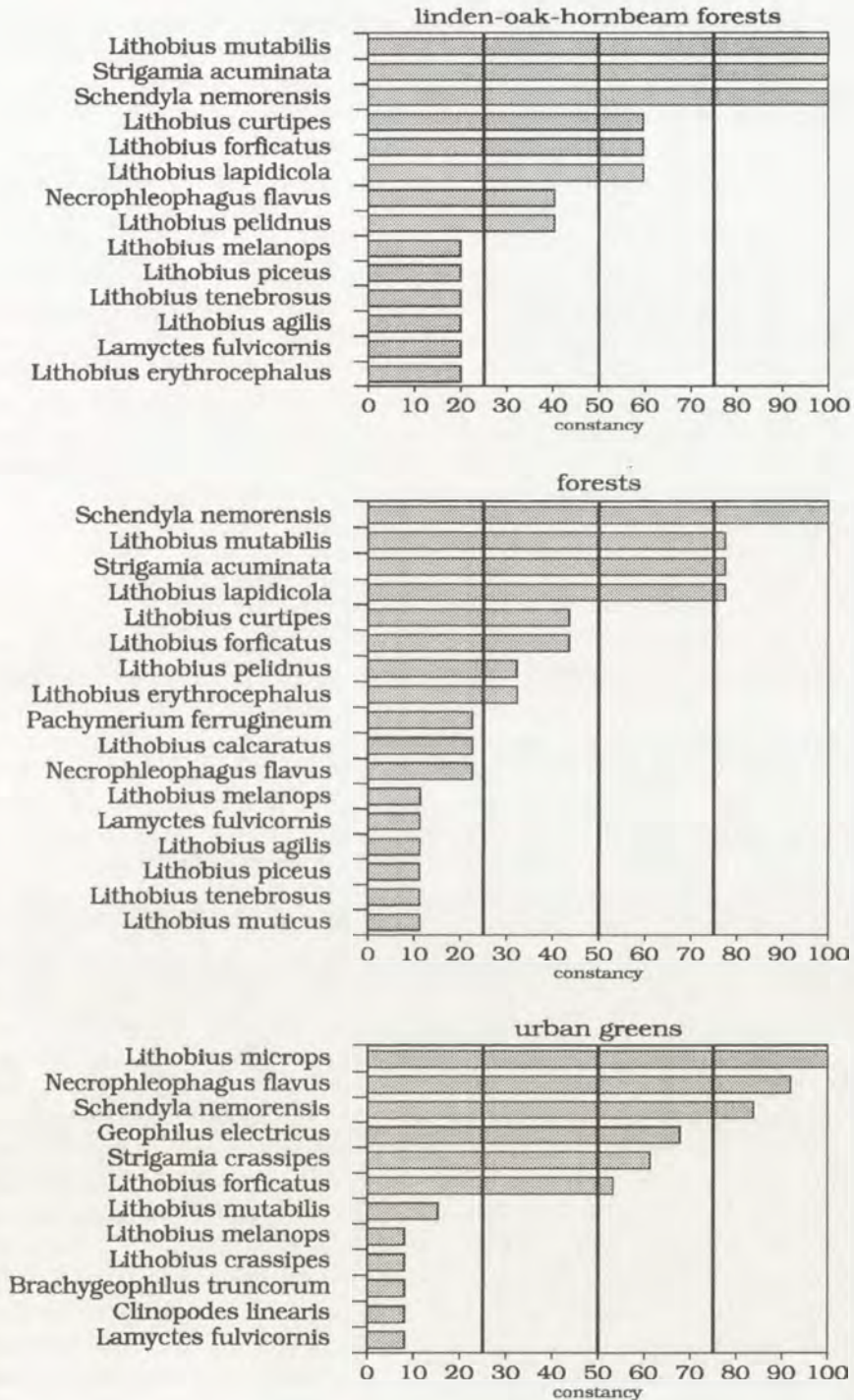


Fig. 8. Constancy of occurrence of *Chilopoda* species in various types of habitats.

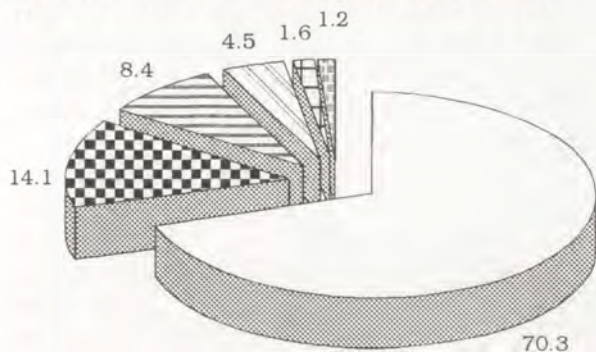
allow to trace changes in the intensity of the link between centipedes and these habitats (Fig. 8). The only absolutely constant species in every habitat studied here, according to TISCHLER'S scale (1949), is *Schendyla nemorensis*, a soil eurytope. Two other species: *Lithobius mutabilis* and *Strigamia acuminata*, which occur as an integral component of the litter fauna in linden-oak-hornbeam forests, are replaced by other species in urban greens. *Lithobius mutabilis* is replaced by *Lithobius microps*, while *Strigamia acuminata* is completely superseded by other species of *Geophilomorpha*: *Necrophleophagus flavus*, *Geophilus electricus* and *Strigamia crassipes*. It should be noted here that species that are absolutely constant and constant in urban greens i.e. *Lithobius forficatus*, *Lithobius microps*, *Necrophleophagus flavus*, *Geophilus electricus*, *Strigamia crassipes* and *Schendyla nemorensis* are also common to the three types of urban greens distinguished in this paper, accounting for about 2/3 of the species composition of the *Chilopoda* community in each of them. They thus form a clear-cut core of those communities. The other species occurred sporadically at individual sites, functioning as accessory elements in the *Chilopoda* communities of urban greens.

#### 6. STRUCTURE OF DOMINANCE

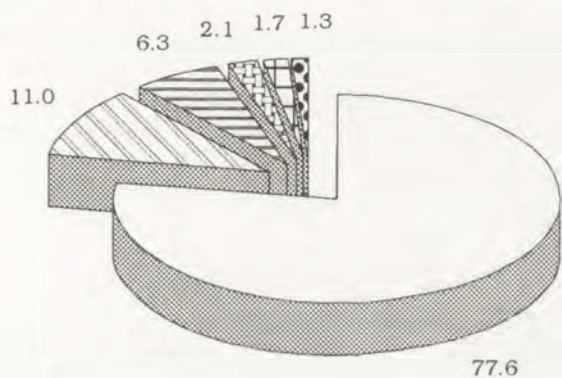
Of all the forest habitats examined in this paper, linden-oak-hornbeam forests are the most abundant in centipedes, both in the number of species and the number of individuals (WYTWER 1990, 1992). *Chilopoda* communities in this habitat are characterised by a quite uniform structure of dominance. The percentages of the dominant species do not change significantly from site to site (WYTWER 1990). Three species of the dominant group in that type of forests i.e. *Lithobius mutabilis*, *Strigamia acuminata* and *Schendyla nemorensis* occur in similar proportions in centipede communities of oak forests (Figs. 9, 10). Dominance structure similarity, expressed as Morisita index, reaches very high values when sites representing each of the two association types are compared (Figs. 11, 12). The epigeic components of the *Chilopoda* communities are nearly identical - the values of Morisita's index are never lower than 0.98, which is due to the nearly identical proportions of *L. mutabilis* (above 90%) (Figs. 10, 12). The similarity of the edaphic components of the *Chilopoda* communities of these two habitats is also relatively high, the figures ranging from 0.56 to 0.99 (Fig. 11). The lowest values (0.56-0.76) were obtained for the oak forest site in Radziejowice, where the structure of dominance of the edaphic component of the community is equally similar to that of *Chilopoda* communities of linden-oak-hornbeam forest *Chilopoda* communities and of oak forests. Pine forest *Chilopoda* communities, on the other hand, have low dominance structure similarity in comparison with those of linden-oak-hornbeam forests, both in the edaphic and epigeic components (Figs. 11, 12). This is due to the dominants being replaced, although the same species are found there which also occur in pine and linden-oak-hornbeam forests or oak forests (Fig. 5). *Schendyla nemorensis* - the chief dominant of the edaphic component of the pine forest *Chilopoda* communities, exhibits sharp variations in its proportion (from 55 to about 40%) (Fig. 9). In linden-oak-hornbeam forests, ac-



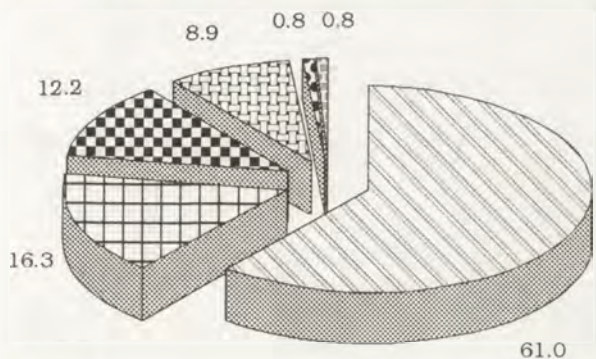
**LINDEN-OAK-HORNBEAM FORESTS**



**OAK FORESTS**



**PINE FORESTS**



**LEGEND:**










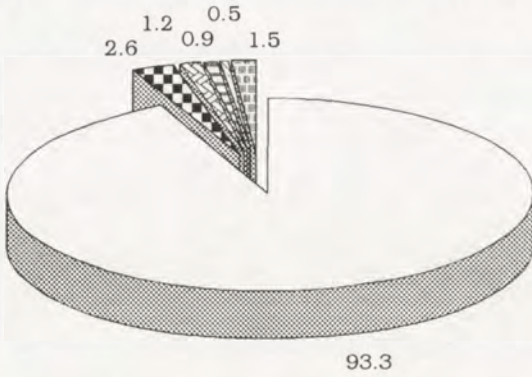
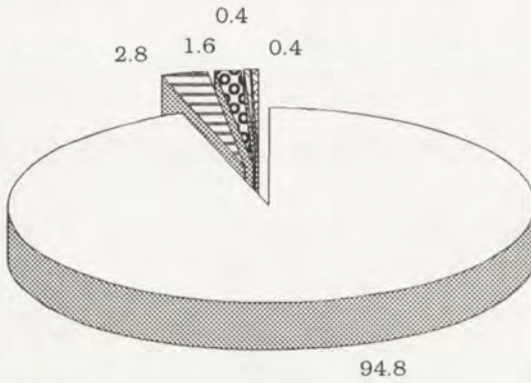
-  *Lithobius mutabilis*
-  *Lithobius curtipes*
-  *Strigamia acuminata*
-  *Schendyla nemorensis*
-  *Lithobius lapidicola*
-  *Lithobius calcaratus*
-  *L.forf. + L.mel. + L.mutab.*
-  *Pachymerium ferrugineum*
-  *Lithobius forficatus*

Fig. 9. Dominance structures of the edaphic component of forest *Chilopoda* communities

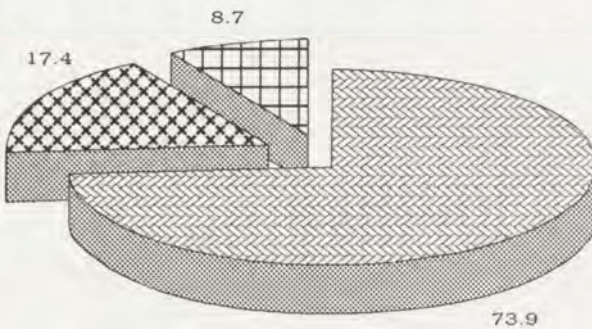
**LINDEN-OAK-HORNBEAM FORESTS**



**OAK FORESTS**



**PINE FORESTS**



**LEGEND:**










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-  Lithobius curtipes
-  Strigamia acuminata
-  Schendyla nemorensis
-  Lithobius lapidicola
-  L. pic.+L.tenebr.+L. agilis+L.crythr.+L.lapid.
-  Lithobius pelidnus
-  Lithobius forficatus
-  Lithobius erythrocephalus

Fig. 10. Dominance structures of the epigeic component of forest Chilopoda communities



ording to the dominance criteria adopted for *Chilopoda* (WYTWER 1990), it is merely an influent species, with an under-10% share in the community. Epigeic dominants in *Chilopoda* of pine forests include: *L. pelidnus* and *L. forficatus*, which are subprecedents (less than 2% of the community) in linden-oak-hornbeam forests (Fig. 10).

The structures of dominance in communities of different types of urban greens exhibit relatively high similarity. In these communities, the group of dominant species remains quite constant (Wytwer, in press). In the edaphic component, the first three dominant species always appear in the same order, namely *Lithobius microps*, *Necrophleophagus flavus* and *Schendyla nemorensis*. Together they make up 90% of the community abundance (Fig. 13). On the other hand, the structure of dominance of the epigeic component varies with the type of urban green. The structural change is mainly due to a decrease in the proportion of *Lithobius forficatus* in park and street lawns, the species being gradually replaced by *Lithobius microps* (Fig. 14). As a result, the values of Morisita's index for the edaphic component of the communities never drop beyond 0.96 (Fig. 15), while the similarity of dominance structures of the epigeic components of communities of different types of urban greens is lower: 0.55-0.79 (Fig. 16).

The replacement of dominants that can be observed in *Chilopoda* communities when forest and urban habitats are considered (Figs. 9, 10 and 13, 14) is the

		LINDEN-OAK-HORNBEAM FORESTS					OAK FORESTS		PINE FORESTS	
		Modrzewina res.	Dęblna res. I	Dęblna res. II	Radziejowice I	Cyganka res.	Radziejowice II	Hryniewiecki res.	Dybkł	Lomna
LINDEN-OAK-HORNBEAM FORESTS	Modrzewina res.		0.88	0.97	0.99	0.98	0.68	0.99	0.08	0.09
	Dęblna res. I			0.96	0.88	0.87	0.56	0.88	0.13	0.00
	Dęblna res. II				0.97	0.97	0.69	0.97	0.17	0.11
	Radziejowice I					0.98	0.70	0.99	0.10	0.14
	Cyganka res.						0.76	0.98	0.21	0.20
OAK FORESTS	Radziejowice II							0.64	0.70	0.20
	Hryniewiecki res.								0.07	0.73
PINE FORESTS	Dybkł									0.85
	Lomna									

Fig. 11. Similarity of dominance structures of edaphic components of forest *Chilopoda* communities based on Morisita's index

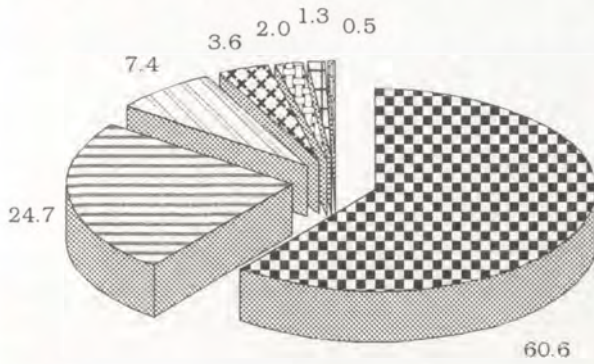
		LINDEN-OAK-HORNBEAM FORESTS					OAK FORESTS		PINE FORESTS
		Modrzewina res.	Dębina res. I	Dębina res. II	Radziejowice I	Cyganka res.	Radziejowice II	Hryniewiecki res.	Dybkł
LINDEN-OAK-HORNBEAM FORESTS	Modrzewina res.		1.00	0.98	1.00	0.99	1.00	1.00	0.02
	Dębina res. I			0.98	1.00	0.99	0.99	1.00	0.00
	Dębina res. II				0.98	0.98	0.98	0.97	0.00
	Radziejowice I					0.99	1.00	1.00	0.00
	Cyganka res.						0.99	0.99	0.12
OAK FORESTS	Radziejowice II							0.99	0.00
	Hryniewiecki res.								0.00
PINE FORESTS	Dybkł								

Fig. 12. Similarity of dominance structures of epigeic components of forest *Chilopoda* communities based on Morisita's index

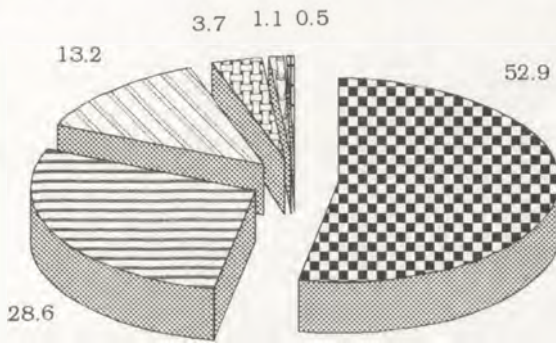
reason for the very low values of Morisita's index obtained for urban and forest communities (Figs. 15, 16). The maximum values, which, however, never exceeded 0.2, were obtained for centipede communities of urban greens and pine forests, especially in the edaphic component, where *Sch. nemorensis*, the dominant in pine forests, contributes significantly to the communities of the three types of urban greens, accounting for 7%-10%. The communities of *Chilopoda* of pine forests are thus structurally similar, at least to the same extent, both to communities from urban greens and to those from linden-oak-hornbeam and oak forests. A graphic representation of dominance structure similarity, generated after MOUNTFORD'S (1962) method and based on Morisita's index reveals that there is even higher similarity between centipede communities in pine forests and urban greens than between pine forests and the other two types of forest habitats (Fig. 17). Owing to the specific properties of the index, the degree of structural overlap is most influenced by species with the highest percentages, while the dominance „tail” (low-abundance species) is ignored. As a result, the urban and forest communities of chilopods can hardly be considered similar, which in the light of the relations between species compositions discussed above, is not the best measure of the affinity between these structures. A homogeneity index was used to determine the importance of influent and accessory species for dominance structure similarity. As a measure of overlap of dominance structures, this index accounts more proportionally for low-abundance species (RIEDL 1963). The representation



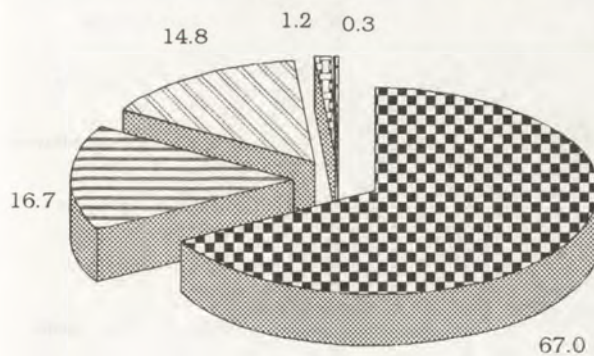
**WOODED AREAS**



**PARKS**



**STREET LAWNS**

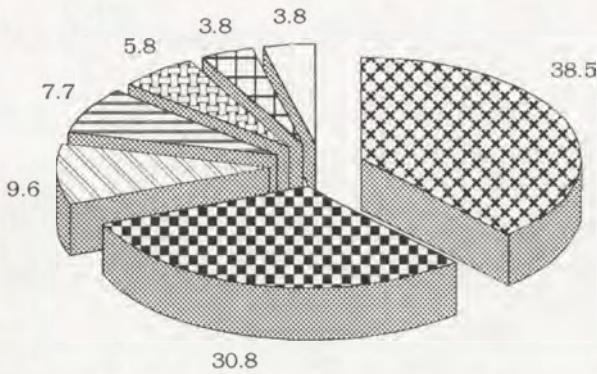


**LEGEND:**

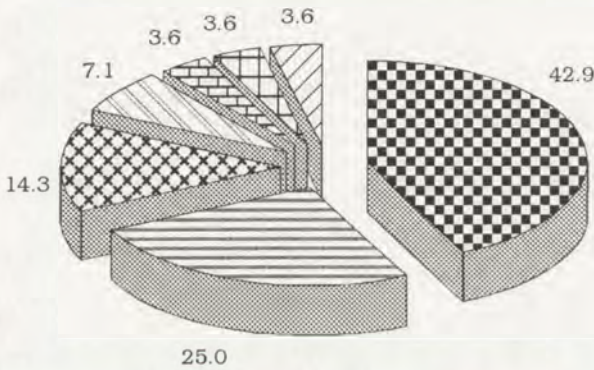
-  *Lithobius forficatus*
-  *Lithobius microps*
-  *Necrophlephagus flavus*
-  *Geophilus electricus*
-  *Strigamia crassipes*
-  *Schendyla nemorensis*
-  *Lithobius crassipes*
-  *Clinopodes linearis*
-  *Brachygeophilus truncorum*

Fig. 13. Dominance structures of the edaphic component of urban *Chilopoda* communities

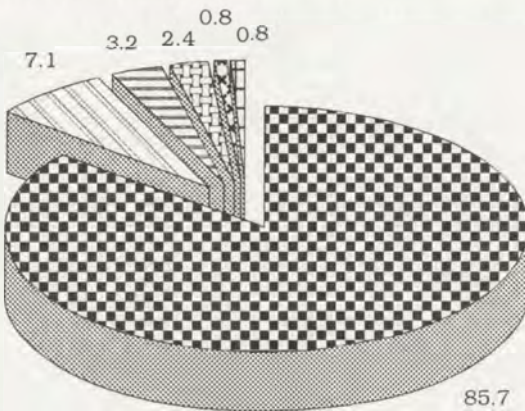
**WOODED AREAS**



**PARKS**



**STREET LAWNS**



**LEGEND:**










-  *Lithobius forficatus*
-  *Lithobius melanops*
-  *Lithobius mutabilis*
-  *Lithobius microps*
-  *Lamycetes fulvicornis*
-  *Necrophlephagus flavus*
-  *Geophilus electricus*
-  *Strigamia crassipes*
-  *Schendyla nemorensis*

Fig. 14. Dominance structures of the epigeic component of urban *Chilopoda* communities



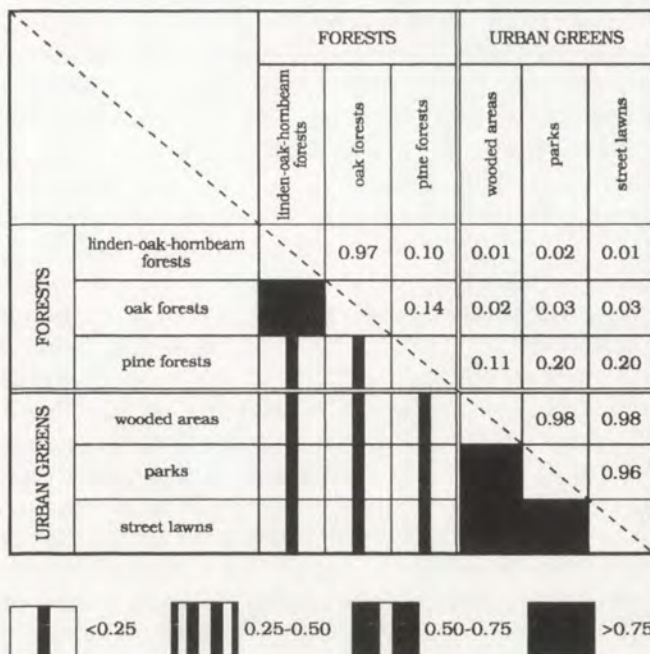


Fig. 15. Similarity of dominance structures of edaphic components of forest and urban *Chilopoda* communities based on Morisita's index

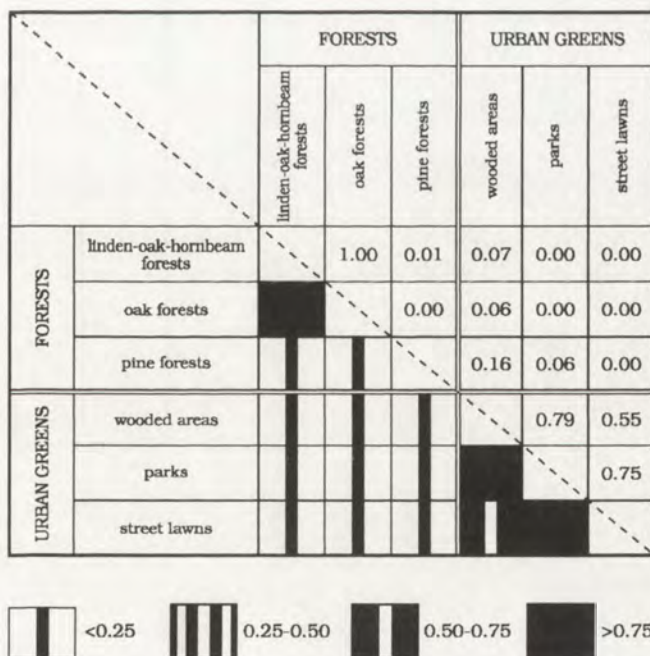


Fig. 16. Similarity of dominance structures of epigeic components of forest and urban *Chilopoda* communities based on Morisita's index

of relationships between dominance structures based on the index of homogeneity show that pine forest *Chilopoda* communities are more similar to other forest communities as far as the edaphic component is concerned (Fig. 18). In the epigeic component, the arrangement based on Morisita's index is still largely preserved. The general relationship between urban and forest *Chilopoda* communities is equally insignificant in both cases.

The values of both indices of dominance structure similarity depend on the number of common species. If species are replaced within a community, as is the case with urban and forest communities of chilopods, the question of the degree of similarity of the model of structure cannot be resolved. The similarity is low although the arrangement of proportions between species' shares remains the same while the species composition changes, which happens e.g. in communities of pine forests and street lawns (Figs. 9, 13 and 10, 14). The degree of overlap of structures was, therefore, determined with a modified index of homogeneity, where a system arranged according to ranks corresponding to percentages of species in the community provided the basis for the analysis. That allowed to analyze dominance relations irrespective of the communities' species composition. The cladogram that resulted reveals relatively high (75%) similarity between dominance structures for the edaphic components of the chilopod communities in all the habitats studied, and 40% similarity for the epigeic component (Fig. 19). In both

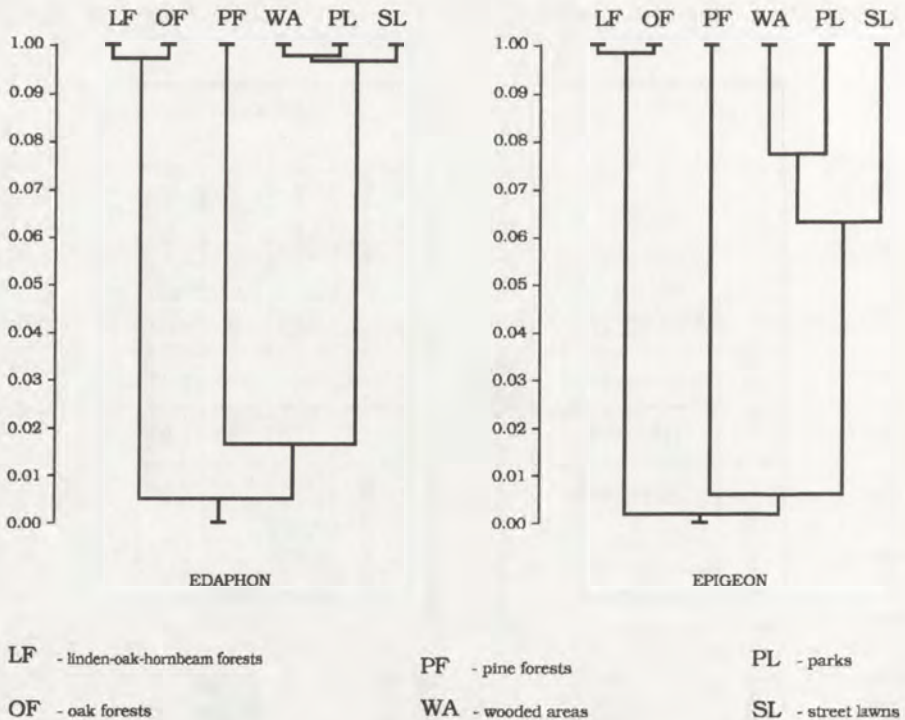


Fig. 17. Diagrams of similarity of dominance structures of forest and urban *Chilopoda* communities based on Morisita's index



components, the lowest similarity was observed for *Chilopoda* communities of wooded areas and parks in town. However, the model of dominance identified in the *Chilopoda* communities of street lawns bears definite similarity to the model represented by *Chilopoda* communities of forests, particularly pine forests.

The high structural similarity of edaphic components of the communities has also been demonstrated by studies on the distribution of abundance of individual species of *Chilopoda* in the faunal material from the habitats studied. The results of a chi-square test giving data on the probability of overlap between these distributions and the five theoretical models constructed so far for analysis of the structure of the fauna (i.e. the geometrical progression series, broken stick distribution, the logarithmic series, the lognormal series and the negative binomial distribution) (TROJAN 1992), suggest that there exists a structural model of *Chilopoda* communities similar both to the logarithmic distribution and the negative binomial distribution (Tab. III). This feature is also outlined in the material comprising the epigeic component of the centipede communities from wooded areas and park lawns, which, in turn, reaffirms the presence of certain structural differences between the chilopod fauna of the above two habitats and of other habitats. The logarithmic distribution describes cases where a small number of species occurs in a community but where low-abundance species are a relatively numerous group. This is a case where the occurrence of species in the habitat is

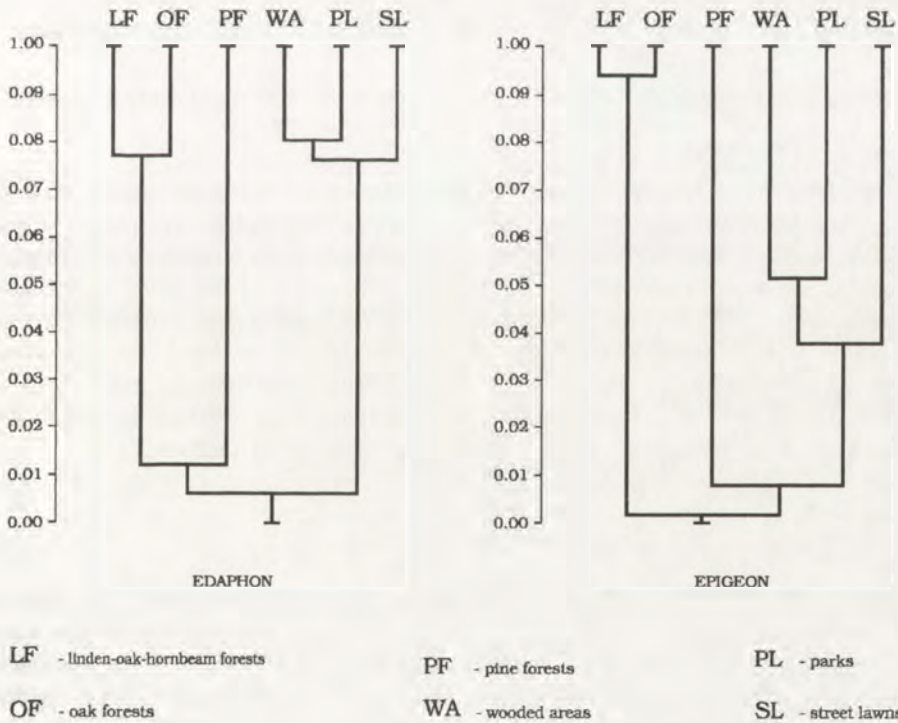


Fig. 18. Diagrams of similarity of dominance structures of forest and urban *Chilopoda* communities based on the index of dominance homogeneity

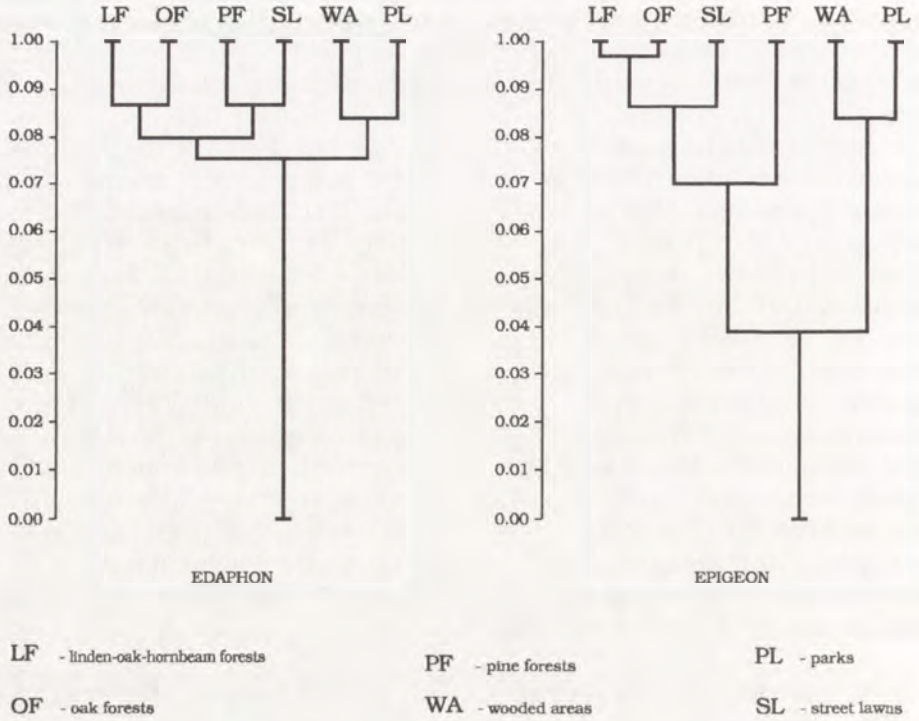


Fig. 19. Diagrams of similarity of dominance structures of forest and urban *Chilopoda* communities based on the index of rank homogeneity

influenced by one or few factors (MAY 1975, MAGURRAN 1988). It seems to reflect properly the character of the occurrence of centipedes in the habitats investigated in this paper. Undoubtedly, the factor which influences the communities the most strongly is ambient moisture, the situation being best reflected by the structural model obtained for the edaphic components of the communities. The surface of soil is a habitat less friendly for the most of centipedes and the structure of the epigeic component depends chiefly on the activity patterns of individual species. As a result, the structural model of the epigeic components is much more dependent on the random effect of diverse environmental factors.

## 7. SPECIES DIVERSITY

Both species composition and abundance undergo marked changes in both components of *Chilopoda* communities: edaphic and epigeic. This weighs considerably on the values of species diversification measured with Shannon-Weaver's index (actual species diversity:  $H'$ ). However, the studied habitats have the different species capacity which determine the maximum value of species diversity (potential species diversity:  $H'_{max}$ ). Animal communities can realize this diversity on a different scope and the Pielou's index is a measure of the state (TROJAN 1994).



Table V. Species diversity of Chilopoda communities of forests and urban habitats

Layer	Type of forests	H'	Hmax	J	Type of urban green	H'	Hmax	J
edaphon	linden-oak-hornbeam forests	1.470	3.170	46.372	wooded areas	1.643	2.807	58.532
	oak forests	1.245	2.807	44.353	parks	1.710	2.585	66.151
	pine forests	1.708	2.585	66.074	street lawns	1.350	2.322	58.140
	total	1.772	3.585	49.428	total	1.599	3.170	50.442
epigeon	linden-oak-hornbeam forests	0.578	3.459	16.710	wooded areas	2.409	2.807	85.821
	oak forests	0.424	2.322	18.260	parks	2.341	2.807	83.399
	pine forests	1.132	1.585	71.420	street lawns	0.980	2.585	37.911
	total	0.674	3.459	19.485	total	1.864	3.170	58.801

H' - Shannon and Weaver's index

Hmax - maximum value of Shannon and Weaver's index

J - the degree of realization of potential species diversity

The potential species diversity of *Chilopoda* in the forest habitats studied is higher in oak forests, especially linden-oak-hornbeam forests, than in pine forests (Tab. V). This trend, however, does not hold true for changes in actual diversity in the forest communities studied. The highest values of that index were recorded in *Chilopoda* communities of pine forests, both in the edaphic and epigeic components. Centipede communities of oak and linden-oak-hornbeam forests had relatively low actual species diversity. These habitats represent the case where only one of a large number of well-adapted species is particularly abundant. In the habitats investigated it is *Lithobius mutabilis*. Its tolerance to drought (ALBERT 1983, FRÜND 1987), higher than in other relatively abundant species of the communities from oak and linden-oak-hornbeam forests, namely *Lithobius curtipes* and *Strigamia acuminata*, allows it to penetrate the surface layer of litter more intensely. At the same time the constant moisture of the deeper layer of mull litter provides optimal conditions for younger developmental stages of this species, which are more sensitive to that environmental factor. It also allows older, more mobile and larger individuals to compensate for water loss (FRÜND 1987). The mor and moder types of litter, which occur in pine forests, often become dry down to the mineral layer in summer and probably that is the reason why the litter does not create favourable conditions for the development of *L. mutabilis*. However, species dwelling in the deeper layer of humus are still able to survive. According to FRÜND (1987), this group of species includes *L. curtipes*, which was registered in every type of forests examined. Species pursuing a more euedaphic mode of life are less dependent on litter desiccation. These comprise most *Geophilomorpha* (AUERBACH 1951, BLOWER 1955, WALLWORK 1970, DUNGER 1983) including also *Schendyla nemorensis*, which is dominant in the edaphic component of *Chilopoda* communities in the pine forests investigated (Fig. 9). On the other hand, the epigeic component of the communities in pine forests can be formed mainly of those centipede species that probably only penetrate the litter in search of food. They hide mainly in other shelters more capable of preserving moisture, such as spaces under the bark of trees, around trunks and decaying logs. Such behaviour is known for *Lithobius forficatus* (LEWIS 1981). The practice of *Lithobius pelidnus* - the species most often caught into Barber's pitfall traps in pine forests - of seeking shelter in and around tree trunks, described by FRÜND (1987), also suggests a similar mode of life. Greater variability of moisture relations in mor and moder types of litter, therefore, lowers the species capacity of the habitat for *Chilopoda* (Tab. II) and also the potential species diversity of the communities (Tab. V). Despite relatively similar dominance structures (Fig. 19), species diversity is most fully realized in pine forests, Pielou's index (J) reaching 66% in the edaphon and as much as 71% in epigeon, while oak and linden-oak-hornbeam forests are characterized by values of this index lower than 50% for the edaphon and 20% for the epigeon (Tab. V).

The values of Shannon-Weaver's index indicate a similar degree of species diversity in the edaphic components of *Chilopoda* communities in forests and urban greens. Despite the complete replacement of the forest dominant species by synanthropic and eurytopic forms in towns, the respective distributions of species abundance exhibit similar skewness, and the proportion of the eudominant



*Lithobius microps* oscillates slightly around 60% (Fig. 14), which is not a much lower value than the share *Lithobius mutabilis* in oak and linden-oak-hornbeam forests and approximately the same as the percentage of *Schendyla nemorensis* in pine forests (Fig. 9). All the types of urban green are, however, potentially poorer in centipedes (Tab. II). Potential species diversity of centipede communities of these habitats thus assumes somewhat lower values than in forest *Chilopoda* communities (Tab. V). The degree of realisation of potential diversity, expressed as Pielou's index (J), is, therefore, relatively high, being the closest to the figure obtained for forest *Chilopoda* communities (Tab. V). The scope of changes in the edaphic components, however, is relatively small when compared with the degree of species diversity realisation in the epigeic components of *Chilopoda* communities. The highest actual diversity was recorded for the epigeic *Chilopoda* fauna in wooded areas and urban parks. Almost 70% of community abundance, usually „allocated to" one species in other communities, is divided between two species, namely *Lithobius forficatus* and *Lithobius microps*, owing to which the skewness of the distribution is reduced remarkably and the index of diversity increases. As a result, the realisation of potential species diversity reaches maximum values - about 85%. In the epigeic component of *Chilopoda* communities of street lawns, *Lithobius forficatus* is almost completely replaced by *Lithobius microps*, which takes over the whole 85% of the community. As a result, the value of actual species diversity decreases considerably leading to a reduction in the realisation of potential species diversity, which equals approximately the average of values obtained for deciduous and coniferous forests.

#### 8. ECOFAUNISTICAL ANALYSIS OF CHILOPODA SPECIES

The ecological success of a species in its habitat is expressed by its abundance, the most objective measure of which, also in the case of centipedes, is found in density. Trapability, being dependent on the abundance of the species and the level of activity, may be considered a separate attribute in ecological description of species. Cluster analysis allows to make use of both parameters: density and trapability that describe a species in its habitat. 12 attributes (density and trapability in each of the 6 habitat types distinguished) were thus used to describe each of the 23 species of *Chilopoda* from an ecofaunistical viewpoint. The complement of Sørensen's or Marczewski-Steinhaus's index was adopted as a systematical distance for classifying the *Chilopoda* species. The two methods produced almost identical results. The species was divided into 5 completely dissimilar groups (Fig. 20).

The largest 10-element group comprises species which were only registered in forest habitats. The only exception in this group and also the most different species from the rest (similarity lower than 5%) is *Lithobius mutabilis*, which was also registered in scarce numbers at wooded areas in Warsaw. However, due to the quantitative parameters which this species revealed in oak and linden-oak-hornbeam forests, it was assigned to the forest species group. This result corresponds fully both to the opinions of many authors (VERHOEFF 1937, MATIC 1966, ZALESKAJA 1978, KACZMAREK 1980) and the results of studies showing the species' undisputa-



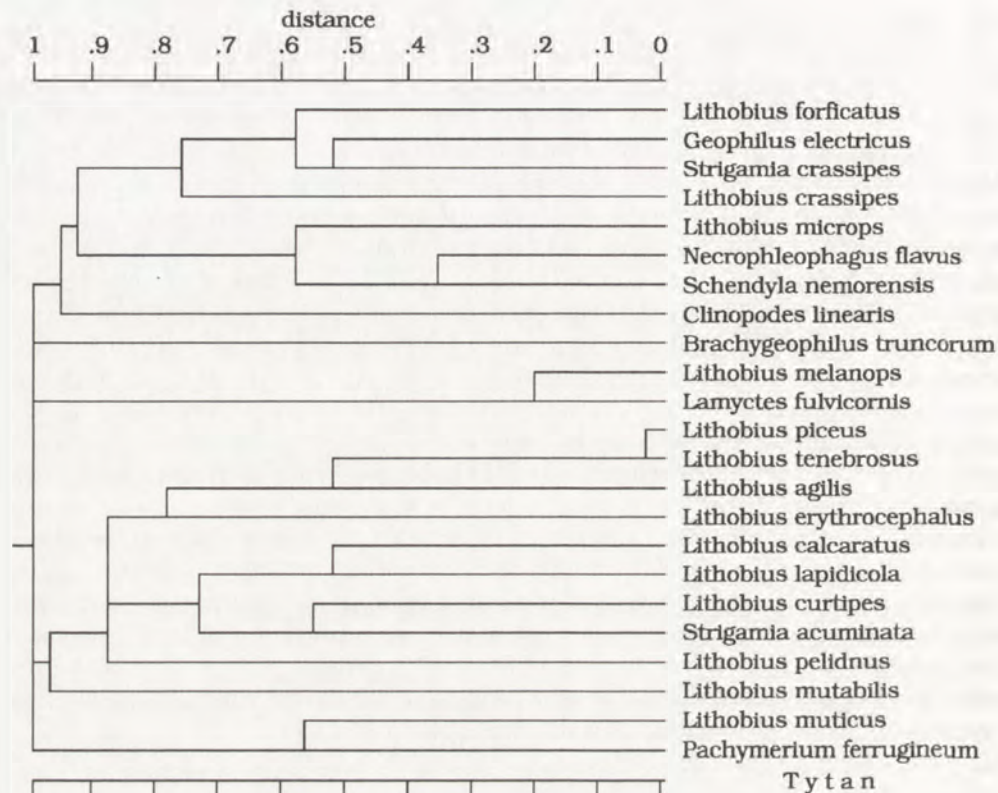


Fig. 20. Ecofaunistical classification of *Chilopoda* species resulting from cluster analysis based on species density and trapability in forest and urban green habitats (using the complement of Sørensen index, average linkage clustering method)

ble links with Central European deciduous forests (THIELE 1956, ALBERT 1979, KACZMAREK 1977, 1989). Its presence in wooded areas provides further evidence that the assignment was correct as the species was only registered at two sites located in the city outskirts (Bielany, Ursynów), both of which are still linden-oak-hornbeam forests despite noticeable traces of anthropogenic transformation. Nearly 100% similarity, on the other hand, was obtained for *L. piceus* and *L. tenebrosus*. *L. agilis* is the most similar to the two (nearly 50%). The three species were only found in linden-oak-hornbeam forests. Data from literature point to a number of ecological attributes which make them forest species (MATIC 1966, KACZMAREK 1979, BARBER 1985). BECKER (1982) stresses the lack of tolerance of *L. piceus* to open area habitats, and so does ANDERSSON (1985) for *L. tenebrosus*. ZALESKAJA (1978) lists *L. agilis* as an exclusively forest species, while THIELE (1956) considers it an accompanying species in the *Querceto-Carpinetum polytrichetosum* plant association. The forest species group comprises also *L. erythrocephalus*, known to be eurytopic from literature (ZALESKAJA 1978, KACZMAREK 1980). Still, it was not found in any of the types of urban greens examined, though such possibility could suggest the data from Sweden, where *L. erythrocephalus* is no-



ted more frequently in areas transformed by man than in natural habitats (ANDERSSON 1985). In Poland it is only exceptionally reported from synanthropised areas (KACZMAREK 1980). There are two other pairs of species characterised by relatively high similarity of occurrence and also included into the forest species group: *Lithobius curtipes* and *Strigamia acuminata* on the one hand and *Lithobius calcaratus* and *Lithobius lapidicola* on the other (Fig. 20). The former two are species occupying important positions in the structure of *Chilopoda* communities in linden-oak-hornbeam forests (Figs. 9, 10). Both are known to be typical of forest biocenoses and avoid urbanised areas (ANDERSSON 1985, MATIC 1966, 1972, BARBER, KEAY 1988). *S. acuminata* is a European species introduced into North America (EASON 1964). *L. curtipes* has a wider geographical range, occurring in 3 biomes in the Palaearctic: the taiga, deciduous forests and steppe. On the background of data from literature, the nearly 50% similarity between the species in the other pair (*L. calcaratus* and *L. lapidicola*) stands out as very important as it is indicative of the ecological requirements of *L. lapidicola*. The literature data on this species are hardly reliable as it is often mistaken for *L. borealis* (EASON 1982). *L. calcaratus* was recorded in oak and pine forests, while *L. lapidicola* occurred in every type of forest habitats, but it occupied the highest ranks in the structure of dominance of *Chilopoda* communities also in oak and pine forests. As can be seen, the ecological requirements of both species are similar. However, *Lithobius calcaratus* is known to be asynanthropic but it is a eurytope inhabiting forest litter as well as open well-insolated areas, even xerothermic carrs (VERHOEFF 1937, EASON 1964, BECKER 1982, BARBER, KEAY 1988). The type and manner of the spread of *L. lapidicola* in Poland needs further studies because the objective taxonomic characters of this species have only recently stated precisely (EASON 1982). The forest species group comprises also *L. pelidnus* (Fig. 20), which was not abundant in linden-oak-hornbeam forest while it dominated the epigeic component of pine forest *Chilopoda*. Its „forest” pattern of occurrence, noted by researchers (MATIC 1966, KACZMAREK 1980), may be quite unique as the species dwells mainly in shelters in and around tree trunks (FRÜND 1987). With coniferous litter drying in summer, the shelters function as reservoirs of moisture and the species occupying these microhabitats increase in rank. All the species classified as forest forms in this paper are European elements (EASON 1964, MATIC 1966, 1972, KACZMAREK 1979).

The following two species were singled out of the forest species group as they occurred only in these habitats and bore 50% similarity: *Lithobius muticus*, recorded only in oak forests, and *Pachymarium ferrugineum*, registered in oak and linden-oak-hornbeam forests (Fig. 5). Both species are still related to each other by virtue of their relatively well-documented eurytopic nature, low sensitivity to variations in moisture and their ability to survive in dry and insolated plots of soil (VERHOEFF 1925, PALMEN, RANTALA 1954, EASON 1964, LOKSA 1966, BECKER 1982, BARBER, KEAY 1988). A certain preference for man-transformed habitats was only noted for *P. ferrugineum* in Scandinavian countries, Germany (PALMEN 1949, JEEKEL 1964, ANDERSSON 1985) and Poland (GRONSKA 1968). Geographically, *L. muticus* is confined to Central Europe, while *P. ferrugineum* rates among the most widespread species in the world (Europe, North Africa, both Americas, Japan), although EASON (1964) supposes that it was originally a Palaearctic species.



The group of forest species is only slightly more large than the group comprising species which occur only in urban greens or which are characterised by much higher values of the quantitative parameters in that habitat (Fig. 20). The core of the group is certainly formed of three main urban dominants: *Lithobius microps*, *Schendyla nemorensis* and *Necrophleophagus flavus*. Marked similarities concerning the choice of sites by these species were also reported by ANDERSSON (1985) in Sweden. *L. microps* is known from the whole Europe, occurring both in natural and synanthropic habitats, owing to which it was considered for a long time to be an indigenous species showing natural preferences for microhabitats created by human activities (EASON 1964). JEEKEL (1964) nevertheless classified it as a Western European species and DUNGER (1966), as an Atlantic-Mediterranean element. The species was not registered in the forest habitats studied in Mazovia, although GROŃSKA (1968) found it in the Łódź Highland in Central Poland (including a Mazovian locality in Lipce Reymontowskie) in several types of forest as well as arable land. However, at the northernmost limits of its range, *L. microps* used to be known only from synanthropised sites, evidence coming from Scotland (EASON 1964), Finland (PALMEN 1949) and Sweden (LOHMANDER 1923). In the latter country the species has increased its abundance considerably over the last few decades and has been penetrating natural habitats more intensely (ANDERSSON 1983). Although the earlier records in Poland mention both natural and synanthropic sites (e.g. KARLIŃSKI (1883a, b) in the Tatras and the Botanical Garden in Cracow, and then in Poznań and the Great Polish Lowland (KACZMAREK 1952) and the seaside spa of Międzyzdroje and the forest of the Wolin Island (KACZMAREK 1954)), it seems more likely that the species has been spreading in Poland from synanthropic to natural habitats rather than in the reverse direction.

Among eurytopes occurring at equal frequencies in natural and urbanised habitats are also two further urban dominants: *Schendyla nemorensis* and *Necrophleophagus flavus* (GROŃSKA 1968, KACZMAREK 1980, ANDERSSON 1985, BARBER, KEAY 1988). These species are of European origin and belong to the indigenous fauna although, owing to their broad scope of ecological tolerance, they have now spread throughout the Holarctic (Eason 1964). The presence of *N. flavus* in linden-oak-hornbeam forests and of *Sch. nemorensis* in every type of forest habitats studied indicates that urban communities of *Chilopoda* preserve to a certain extent the character of natural communities. It is even easier for the two species as they belong to the order *Geophilomorpha* and inhabit deeper soil horizons thus being less sensitive to changes in ground cover than the more epigeic *Lithobiomorpha* (BLOWER 1955, LEWIS 1981, DUNGER 1983).

A distinct subgroup of urban species, distinguished already by its low similarity (less than 10%) (Fig. 20), comprises four species, of which only *Lithobius forficatus* was also recorded at forest sites. It is, after all, the most common and widely spread eurytopic species in our climatic zone, commonly occurring in forests, open areas and habitats influenced by man (EASON 1964, KACZMAREK 1979). This surface species does not show any microhabitat preferences (BARBER, KEAY 1988). Its wide habitat tolerance has allowed it to achieve an almost cosmopolitan distribution (ZALESSKAJA 1978). While it was relatively rare in the communities inhabiting the three types of forest habitats investigated in this paper, it turned



out to be a co-dominant in the epigeic component of *Chilopoda* communities of wooded areas and parks. In regularly mowed and raked street lawns it gives up its position to *L. microps*, which, owing to the smaller size of his body, is more likely to find adequate moisture in the small spaces forming in the soil layer overgrown with numerous grass roots. *L. forficatus* as a larger and more surface-oriented species looks for shelters such as litter, logs, stones or another kind of ground cover that will provide suitable moist spaces. The position of this species in the structure of dominance in the habitats studied in the present paper proves that it is the first epigeic centipede to replace species withdrawing from the forest habitat following anthropogenic transformation. However, it gives up to less epigeic species such as *L. microps* later.

The other three species of the subgroup were only found, like *L. microps*, at urban sites. Two of them: *Geophilus electricus* and *Strigamia crassipes* are more characteristic as they occur in urban greens at higher constancies and more numerously (Figs. 13, 14). Both were registered in Mazovia for the first time. They are known to occur both in forest and synanthropic habitats (KACZMAREK 1979, BARBER, KEAY 1988). ANDERSSON (1983) has noted a significant increase in the abundance of *S. crassipes* in Sweden over the last 50 years. LOHMANDER (1923) registered it as a species new to Sweden at a site to which - he guessed - it had spread from a garden. Nowadays the species is encountered equally frequently in natural habitats in Sweden. *S. crassipes* and *G. electricus* are European species (ATTEMS 1929, EASON 1964) so they may also have been preserved from natural communities that, however, inhabit different types of forests than those described in this paper.

Over-20% similarity was registered between the above three species and *Lithobius crassipes*, a species known from the whole of Europe and North Africa (EASON 1964). ZALESSKAJA (1978) has even reported it from Siberia. *L. crassipes* is also a eurytope not fastidious about his microhabitat (JEEKEL 1964, LOKSA 1966, KACZMAREK 1980), known also from caves in Romania (MATIC 1966). It has been reported from towns by EASON (1964) and TISCHLER (1980). According to British data, however, it prefers non-urbanised but rather man-made habitats (BARBER, KEAY 1988). This is compatible with the observation that its occurrence has been increasing in Sweden over the last few decades (ANDERSSON 1983). In the urban greens of Warsaw, the species seems to function as an element of natural communities as it has been reported many times from Mazovia and the environs of Warsaw (ŚLÓRSARSKI 1883, GROŃSKA 1968), also from Puszcza Kampinoska outside Warsaw, where it was found in a young stand of pine (W. KACZMAREK 1963).

The species least similar to other urban species is *Clinopodes linearis* recorded in Mazovia for the first time. It is a Southern European species occurring as a synanthropic one in the northern part of the continent, including Poland (ARTEMS 1929, BRÖLEMANN 1930, JEEKEL 1964, MATIC 1972, KACZMAREK 1979, BARBER, KEAY 1988). The species was only registered in the park lawn in the Łazienki Park, where it could get owing to horticultural practices.

*Brachyogeophilus truncorum* alone constitutes a separate class of species (Fig. 20). It was recorded as new to Mazovia at a street lawn in Marszałkowska Street. The species is known from the Mediterranean region and Western countries with a sea border (ATTEMS 1929, BRÖLEMANN 1930, EASON 1964, JEEKEL 1977),



including Scandinavian countries (MEIDELL 1979, ANDERSSON 1983) and Poland (KACZMAREK 1980). It occurs mainly in natural habitats throughout its geographical range, but it does not avoid synanthropic habitats (JEEKEL 1964, BARBER, KEAY 1988). A significant increase in its frequency has been noted in Sweden over the last several decades, but no habitat preferences have been observed (ANDERSSON 1983).

Another group of species that appear to be equally associated with forests and urban greens comprises a pair of species bearing 80% similarity to one another: *Lithobius melanops* and *Lamyctes fulvicornis*. Both are known to be eurytopes in natural habitats, but are as frequently reported from synanthropic habitats (JEEKEL 1964, ZALESSKAJA 1978, ANDERSSON 1985, BARBER, KEAY 1988). However, while *L. melanops*, which prefers wet and warm sites, is an indigenous species, known only from Europe (EASON 1964, MATIC 1966), *L. fulvicornis* that occurs nearly in the whole Holarctic, has spread by means of parthenogenetic populations, probably from the Canary Islands and the Azores (EASON 1964, ZALESSKAJA 1978). Many authors have mentioned its preferences for inundated habitats at the banks of rivers, lakes, streams (LATZEL 1880, CHAMBERLIN 1912, SUMMERS, UETZ 1979, ANDERSSON 1985, ZULKA 1992) or even irrigated plantations (NEGREA 1989), although there are doubts concerning this characteristic (EASON 1964). On the other hand most authors did mention cultivated land when discussing the species' occurrence. The species is also frequently found in greenhouses (KACZMAREK 1980). Thus, this kind of human activity must have helped *L. fulvicornis* substantially in its spread in Europe where it became an element of many natural biocenosis so that in this connection the species may also be considered a natural element in urban greens.

Table VI. Ecological classification of Chilopoda species occurring in the forests of Mazovia and/or the urban greens of Warsaw

Forest polytopes	Eurytopes		
	asynanthropic	indifferent	synanthropic
<i>Lithobius mutabilis</i> *	<i>Lithobius calcaratus</i>	<i>Lithobius erythrocephalus</i>	<i>Lithobius microps</i> *
<i>Lithobius piceus</i>	<i>Lithobius lapidicola</i>	<i>Pachymerium ferrugineum</i> *	<i>Schendyla nemorensis</i> *
<i>Lithobius tenebrosus</i>	<i>Lithobius muticus</i>	<i>Lithobius forficatus</i> *	<i>Necrophleophagus flavus</i> *
<i>Lithobius agilis</i>		<i>Geophilus electricus</i> **	<i>Lamyctes fulvicornis</i> *
<i>Lithobius curtipes</i>		<i>Strigamia crassipes</i> **	<i>Lithobius melanops</i> *
<i>Strigamia acuminata</i>		<i>Brachygeophilus truncorum</i> **	<i>Clinopodes linearis</i> **
<i>Lithobius pelidnus</i>		<i>Lithobius crassipes</i> *	

\* - species recorded in the urban greens of Warsaw

\*\* - species recorded in the urban greens of Warsaw as new to Mazovia



The analysis-based ecofaunistical classification of *Chilopoda* species corresponds also to the associations distinguished by ANDERSSON (1983) using FAGER'S (1957) method. The method is based upon the frequency of simultaneous occurrence of species in samples. Negative associations were found for species regarded in this paper as forest species and eurytopes with an affinity or indifference to urbanised areas, as is the case with *L. curtipes* and *L. microps* or *L. forficatus* (Tab. VI). Positive associations may not only be revealed for species belonging to one of the four groups distinguished here but also „adjacent” species that can occur together in one type of habitat. This type of relationships refers to such examples as noted by ANDERSSON (1983), e.g. *L. erythrocephalus* and *L. calcaratus* or *L. erythrocephalus* and *Sch. nemorensis* or *Sch. nemorensis* and *P. ferrugineum* or *L. melanops* and *L. crassipes*.

In the light of the data on occurrence and ecological connections of centipedes from forest and synanthropised habitats it may be stated that *Chilopoda* communities of urban greens in Warsaw are based on indigenous fauna occurring in natural plant associations of Central Europe. The communities are only completed by accidental introductions (Fig. 21). Urbanisation-induced changes in the centipede fauna manifest themselves chiefly as species adapting to the changing environmental conditions.

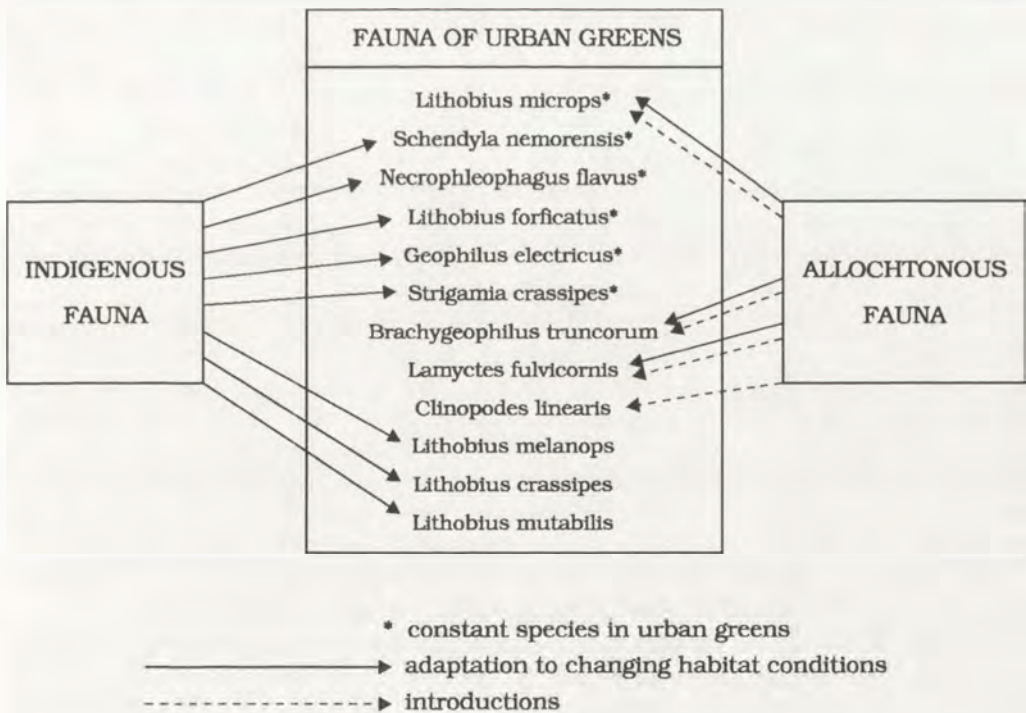


Fig. 21. Hypothetical course of development of the chilopod fauna of urban greens in Warsaw



## 9. SUMMARY

The dependence of the number of *Chilopoda* species on the size of the material collected as litter siftings or soil samples is represented as an Arrhenius's function that characterises non-homogeneous, habitats of a considerably patchy structure so that an unlimited number of species can occur in them theoretically. Nevertheless, the structural features of the communities attest the presence of a definite number of *Chilopoda* species in the habitats under investigation. The analysis of these features suggests that simultaneous application of several methods (litter siftings, soil samples and Barber's pitfall traps) usually suffices to provide a comprehensive list of species inhabiting the forest and urban habitats studied. The data obtained in this study show that although species capacity for centipedes varies between different types of forests, more species can generally occur in the forest habitat than in urban greens. Of the three types of forest investigated, the linden-oak-hornbeam forests are characterised by the greatest species capacity for *Chilopoda*, with 14 species. At least 8 centipede species can settle in a pine forest. The same number of species could be expected to inhabit urban wooded areas, compared to only 6 in street lawns. An increase in the number of *Chilopoda* species in urban greens may result from periodical introduction of species in during horticultural practices.

In total, 23 chilopod species were registered in the habitats studied in Mazovia, including 17 in forest habitats and 12 in urban greens. Diversified habitat conditions in forest habitats are the cause of both changes in the number of species and partial replacement of elements in a community. Only 3 species: *Lithobius erythrocephalus*, *Lithobius lapidicola* and *Schendyla nemorensis* were recorded as common to the forest habitats under investigation. However, all of the species occurring in pine forests were registered in either linden-oak-hornbeam or oak forests. Species composition similarity, measured with Jaccard's index, is not high (varying between 0.30-0.45), but this is due mainly to the high differences between habitats in the number of species - more than 60% common species were found for each pair of habitats compared.

In the course of synurbisation of *Chilopoda* communities, species composition is radically restructured in comparison to the forest fauna. The cluster analysis of the species composition of centipede communities revealed that the communities are sharply divided into two groups corresponding to forest and urban habitats. The values of Jaccard's index referring to the similarity of species compositions of forest and urban communities of *Chilopoda* reached a very low level (0.06-0.26), the highest numbers being recorded when urban communities were compared to communities from linden-oak-hornbeam forests. The affinity between linden-oak-hornbeam and urban green *Chilopoda* communities is largely due to the relatively broad poole of centipede species that is found in that type of forest.

The similarity of the species composition of urban green *Chilopoda* communities was relatively high (the values of the Jaccard's index fall within 0.55-0.67 for each pair of habitats compared). The urban green centipede communities were characterised by constant occurrence of at least 6 species that accounted for at least 2/3 of the community species composition and occurred in urban greens at



a constancy higher than 50%. These are: *Lithobius forficatus*, *Lithobius microps*, *Necrophlephagus flavus*, *Geophilus electricus*, *Strigamia crassipes* and *Schendyla nemorensis*.

The following indices were employed to analyze structures of dominance: Morisita's, dominance homogeneity, rank homogeneity. The analysis also consisted in comparing the actual structures to 5 theoretical distribution models. It showed that the structure of *Chilopoda* communities is considerably transformed, mostly by means of species being supplanted. *Chilopoda* communities of linden-oak-hornbeam and oak forests are nearly identical, while what makes the structure of pine forest centipede communities different is the replacement of dominants, especially in the epigeic component. A marked change in the structure of that component was also observed in urban greens where *Lithobius forficatus* is supplanted by *Lithobius microps*. As for the edaphic component, all the communities of *Chilopoda* turned out to be more conservative with high similarity of ranks recorded despite differences in species composition (even in the case of forest and urban communities). The preservation of a similar model of structure in the edaphic component is confirmed by species abundance distributions of all the communities which bear similarity to the same theoretical distributions, namely the logarithmic series and the negative binomial distribution. Their overlap with the former theoretical model indicates that there is one dominant factor, probably humidity, determining the occurrence of centipedes.

Depending on the type of forest or urban habitat, *Chilopoda* communities exhibit variations in the degree of species diversity, both actual, calculated according to Shannon-Weaver's index, and potential, i.e. that which may be theoretically achieved by a community consisting of the expected number of species. As a result, the communities reach different degrees of realisation of species diversity, as measured with Pielou index. In forest communities, the highest potential diversity was observed in linden-oak-hornbeam forests, while wooded areas head the list in towns; the lowest values were recorded for pine forests and street lawns respectively. Pine forest communities of *Chilopoda* are, however, characterised by higher actual diversity, which results from the community reacting to greater variability of relevant environmental factors, including humidity. High actual diversity are seen mostly in the epigeic component, which is the most exposed to environmental changes, and, besides pine forests, were noted in wooded areas and parks. Thus, the degree of realisation of potential species diversity depends not only on the habitat itself, but chiefly on the layer analysed. The figures are quite similar in the edaphon (44-66%) in both forest and urban communities. In the epigeon the highest values were recorded in wooded areas and park (83-86%) and the lowest in linden-oak-hornbeam and oak forests (16-18%).

The cluster analysis based on density and trapability of individual species recorded in each habitat studied and data from literature made it possible to distinguish 4 groups of *Chilopoda* species: forest polytopes, asynanthropic eurytopes, neutral eurytopes and synanthropic eurytopes. While the fauna of forest habitats may contain species representing any of these groups, species forming the urban green fauna subject to constant anthropopression belong to the latter two groups only. Communities of urban green *Chilopoda* are thus formed of eury-



topic species that are at least neutral to synanthropic habitats, which allows them to spread with the help of human activities. The formation of the chilopod fauna of urban greens in Warsaw depends to a great extent on indigenous species associated with the natural habitat in Central Europe. These species account for the majority of the species composition of urban green centipede communities. There is only one alien species, namely *Lithobius microps*, that is particularly expansive and occupies a major position in the *Chilopoda* communities of urban greens, especially those subject to especially intense anthropopression as in street lawns. Forest species, such as *Lithobius mutabilis*, only have a chance to survive in practically undisturbed habitats in the outskirts.

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#### STRESZCZENIE

[Tytuł: Powiązania faunistyczne *Chilopoda* środowisk leśnych i miejskich Mazowsza]  
Zależność liczby gatunków *Chilopoda* od wielkości zbieranego materiału metodą przesiewek bądź prób glebowych ma postać krzywej Arrheniusa charakteryzującej środowiska niejednolite, o dużej mozaikowatości tak, iż teoretycznie z badanych środowisk można wykazać nieograniczoną liczbę gatunków. Niemniej, strukturalne cechy zgrupowań są świadectwem ustalonej liczby gatunków *Chilopoda* żyjących w badanych środowiskach. Analiza tych cech wskazuje, iż jednoczesne stosowanie kilku metod (przesiewki, próby glebowe i pułapki Barbera) na ogół wyczerpuje listę gatunków żyjących w badanych środowiskach leśnych i miejskich. Uzyskane wyniki świadczą o tym, że różne typy lasów wykazują zmienną pojemność gatunkową dla *Chilopoda*, lecz generalnie, może występować tam więcej gatunków niż w zieleni miejskiej. Spośród trzech typów lasów największą pojemnością gatunkową dla *Chilopoda* charakteryzują się grądy (14 gatunków). Co najmniej 8 gatunków *Chilopoda* może żyć w środowisku borów świeżych. Takiej samej liczby gatunków można spodziewać się w środowisku miejskich zadrzewień a tylko 6 na trawnikach przyulicznych. Większa liczba gatunków parczników w środowisku zieleni miejskiej może być związana z okresowym wprowadzaniem gatunków w czasie zabiegów ogrodniczych.



W sumie, w badanych środowiskach Mazowsza wykazano 23 gatunki Chilopoda, w tym 17 w środowiskach leśnych i 12 w zieleni miejskiej. Zróżnicowane warunki siedliskowe w środowiskach leśnych prowadzą zarówno do zmian liczby gatunków jak i ich częściowej wymiany. W badanych środowiskach leśnych wykazano tylko 3 gatunki wspólne: *Lithobius erythrocephalus*, *Lithobius lapidicola* i *Schendyla nemorensis*, lecz wszystkie gatunki występujące w borach zostały stwierdzone w grądach bądź dąbrowach. Podobieństwo składu gatunkowego mierzone liczbą Jaccarda nie jest wprawdzie wysokie (zawiera się w przedziale wartości 0.30 - 0.45), ale wynika to głównie z dużej różnicy liczby gatunków w poszczególnych środowiskach, gdyż w każdym przypadku stwierdzano ponad 60% gatunków wspólnych.

W procesie synurbizacji zgrupowań *Chilopoda* zachodzi głęboka przebudowa składu gatunkowego w stosunku do fauny leśnej. Analiza klastyczna zgrupowań pareczników pod względem składu gatunkowego wykazała wyraźny rozdział zgrupowań według dwóch typów środowisk: leśnych i zieleni miejskiej. Wartości liczby Jaccarda wyrażającej podobieństwo składów gatunkowych zgrupowań leśnych i miejskich *Chilopoda* osiągały bardzo niski poziom (0.06 - 0.26), przy czym największe odnosiły się do porównań ze zgrupowaniami z grądów. To powinowactwo pomiędzy zgrupowaniami pareczników z grądów i zieleni miejskiej w znacznej mierze wynika jednak ze stosunkowo szerokiej puli gatunków *Chilopoda*, jaka zasiedla ten typ lasu.

Podobieństwo składu gatunkowego zgrupowań *Chilopoda* zieleni miejskiej było stosunkowo wysokie (liczba Jaccarda obliczona dla każdej z par porównywanych zgrupowań osiągała wartości: 0.55 - 0.67). Zgrupowania pareczników zieleni miejskiej charakteryzowały się stałą obecnością 6 gatunków stanowiących co najmniej 2/3 składu gatunkowego zgrupowań i występujących w zieleni miejskiej ze stałością powyżej 50%. Są to: *Lithobius forficatus*, *Lithobius microps*, *Necrophleophagus flavus*, *Geophilus electricus*, *Strigamia crassipes* i *Schendyla nemorensis*.

Analiza struktur dominacyjnych, którą przeprowadzono w oparciu o współczynniki: Morisity, homogeniczności dominacji i homogeniczności rang oraz poprzez przyrównywanie struktur do 5 teoretycznych modeli rozkładów, wykazała iż, struktura zgrupowań *Chilopoda* podlega wyraźnej przebudowie, przede wszystkim ze względu na wymianę gatunków. Zgrupowania *Chilopoda* z grądów i dąbrów wykazują niemal całkowite podobieństwo, zaś zgrupowania z borów odróżniają się swą strukturą głównie z powodu wymiany dominantów, zwłaszcza w części epigeicznej. Wyraźną zmianę modelu strukturalnego tej części zaobserwowano też w obrębie zieleni miejskiej w związku z wypieraniem *Lithobius forficatus* przez *Lithobius microps*. Wszystkie zgrupowania *Chilopoda* w swej części edaficznej okazały się bardziej konserwatywne, gdyż pomimo różnego składu gatunkowego (nawet dla zgrupowań leśnych i miejskich) wykazują wysokie podobieństwo rang. Potwierdzeniem zachowania zbliżonego modelu struktury w części edaficznej jest podobieństwo rozkładów liczebności gatunków jednocześnie do tych samych rozkładów teoretycznych, tj. szeregu logarytmicznego i rozkładu dwumianowego ujemnego. Podobieństwo do pierwszego z modeli ujawnia dominujący wpływ jednego czynnika oddziałującego na występowanie pareczników, jakim najprawdopodobniej jest wilgotność.



W zależności od typu środowiska leśnego jak i miejskiego zgrupowania *Chilopoda* wykazują zmienny poziom różnorodności gatunkowej tak aktualnej, według współczynnika Shannona i Weavera, jak i potencjalnej, która może być osiągnięta w zgrupowaniu przy oczekiwanej liczbie gatunków. Dlatego też według wskaźnika Pielou zgrupowania osiągają inny stopień realizacji różnorodności gatunkowej. Najwyższą potencjalną różnorodność wśród leśnych zgrupowań stwierdzono w łąkach, a wśród zgrupowań miejskich - w zadrzewieniach; analogicznie: najmniejszą w borach i na trawnikach przyulicznych. Borowe zgrupowania *Chilopoda* charakteryzują się jednak podwyższoną różnorodnością aktualną, osiągniętą wskutek reakcji zgrupowania na zwiększoną zmienność istotnych dla pareczników czynników środowiska, do których należy wilgotność. Zmienność tej cechy widoczna jest przede wszystkim w epigeicznej części zgrupowań, najbardziej narażonej na zmiany środowiska i oprócz borów dotyczy również zadrzewień i parków. Stopień realizacji różnorodności potencjalnej zależy więc nie tylko od środowiska ale głównie od rozpatrywanej warstwy. W edafonie kształtuje się on na stosunkowo zbliżonym poziomie (44-66%) tak w zgrupowaniach leśnych jak i miejskich. W epigeonie najwyższy jest w zadrzewieniach i parkach (83-86%), najniższy zaś w łąkach i dąbrowach (16-18%).

Analiza klastyczna oparta na parametrach zagęszczenia i lowności poszczególnych gatunków stwierdzonych w każdym z uwzględnionych w badaniach środowisk oraz dane z piśmiennictwa pozwoliły na wyróżnienie 4 grup gatunków *Chilopoda*: politopy leśne, eurytopy asynantropijne, eurytopy obojętne i eurytopy synantropijne. O ile fauna środowisk leśnych może zawierać gatunki zaliczone do każdej z tych grup, to gatunki wchodzące w skład fauny zieleni miejskiej pozostającej pod silną presją antropogeniczną rekrutują się tylko z dwóch ostatnich grup. Zgrupowania *Chilopoda* zieleni miejskiej ukształtowane są więc przez gatunki eurytopowe o stosunku co najmniej obojętnym do środowisk synantropijnych, który umożliwia im rozprzestrzenianie również z pomocą ludzkiej aktywności. W kształtowaniu się chilopodofauny zieleni Warszawy ważne znaczenie mają gatunki rodzime, związane ze środowiskiem naturalnym w Europie Środkowej. Stanowią one większość składu gatunkowego zgrupowań zieleni miejskiej. Wśród gatunków obcych tylko jeden *Lithobius microps* jest szczególnie ekspansywny i zajmuje naczelną pozycję w zgrupowaniach *Chilopoda* zieleni miejskiej, szczególnie takiej, która pozostaje pod bardzo silną presją antropogeniczną jak trawniki przyuliczne. Gatunki leśne, jak np. *Lithobius mutabilis*, mają szanse przetrwania tylko w niewiele zmienionym środowisku na obrzeżach miasta.

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