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WOJCIECH CZECHOWSKI

OCCURRENCE OF CARABIDS (*COLEOPTERA, CARABIDAE*) IN THE URBAN GREENERY OF WARSAW ACCORDING TO THE LAND UTILIZATION AND CULTIVATION

ABSTRACT

The work describes comprehensively the carabid fauna of the urban environment (Warsaw) and presents its specific features when compared with the carabid fauna of the region (Mazovian Lowland). It defines the dependence of carabid occurrence on the ways of cultivating and utilizing urban greens, and determines these anthropogenic factors which are of primary significance in deciding on the structure and the specific features of urban carabid communities. Furthermore, the paper indicates the basic tendencies of the re--structuring of the communities affected by the progressing human settlement. It provides a bioindicational assessment of the quality of various town green habitats with respect to the characteristics shown by their respective carabid communities, and puts forth suggestions as to the methods of cultivating and utilizing town greens, which would allow for the optimum functioning of faunistic associations. This has been arrived at through by analyzing and comparing the species composition, size and structure of carabid communities from urban, suburban, rural and natural habitats (habitats homologous to lime-oak-hornbeam forest), the seasonal dynamics of these communities and the zoogeographical and ecological composition of carabid fauna. The research was done in the years 1974—1978; 16000 adult carabids (122 species) were collected in its course, mainly with the use of Barber's pitfall traps.

INTRODUCTION

The town is an area which has been shaped by spatially intermixing and mutually interacting elements of three environments: social, technological and natural. The urban natural environment is a remnant of the primeval environment of a given area and at present it is dominated by the influences of other constituents of an agglomeration. It plays, however, an important role for the creating of the optimum living conditions in great centres. Therefore it is necassary to take into account ecological values of the environment in an economic calculation when planning urban investments [21, 76].

The green areas of contemporary towns, considered as a living habitat of organisms, are, to an unusual extent, influenced by direct or indirect, purposeful or unintentional human activities. Some physical and chemical factors which do not occur in natural environments at all or which are of no greater importance there, become basic ecological conditions in the town. The most significant transformations of the natural environment in the town are of geomechanical, hydrological, chemical, thermic [74] and horticultural [75, 77] nature. All basic elements of the environment undergo modification: the air, soil, water and energy relations, food supply, etc. These changes result in the formation of a specific urban climate and a radical reconstruction of the plant cover and the animal world [23].

The properties of the urbanized environment are usually unfavourable for its fauna. However, apart from the negative pressures, the town creates favourable conditions for many animals, not only for obligatory synanthropes but also for species occurring in free nature. This causes a significant modification of species composition and quantitative relations in urban faunistic associations. The number of taxa and numbers of many systematic groups are markedly smaller in towns as compared to undeveloped areas. At the same time, however, the animals which have adapted to new conditions, often having no enemies or competitors, considerably increase their numbers. This results in wide-range changes in the structure of zoocoenoses [54, 55].

Recently urban environments have been more and more often the focus of attention of researchers, especially ecologists. The reason for this increasing interest in urban ecology has been the change of urban planners'and inhabitants' views on the functions of urban green areas. Town greens, formerly treated only as a decorative element, have now gained the status of a basic environment-forming factor [11]. The subsequent enlargement of green areas have caused the increase of importance of free living fauna. Attention has been paid to the problems of proper functioning of biocoenoses in the conditions of strong athropogenization, the bioindication of the state of the environment, etc.

The knowledge of the fauna of towns is still insufficient. Most of the data compiled so far is fragmentary and comes from peripheral regions, where the greenery, unlike typical managed urban greenery, is relatively close in its character to that of undeveloped areas. This situation may well be illustrated by a review of literature concerning carabids, one of the best known families of *Coleoptera*. Problems connected with the carabids of towns, described in an ecological aspect, are to be found in a few papers only and the data included in them are usually fragmentary or sketchy [44, 58, 67, 69, 70].

The carabids of Warsaw are relatively well known; the tradition of studies goes back to the end of the 19th century [30, 40, 41, 63]. The papers listed above comprise the first stage of studies on the carabids of Warsaw. In their character, they were qualitative faunistic research works, carried out (almost exclusively) in seminatural suburban environments. Then there was a break in the studies, which (apart from single reports) lasted until recent years when they have been resumed in a quantitative aspect and mainly in city centre environments [16—18].

The present study has been carried out within the subject "Effect of the settlement pressure upon the fauna, as exemplified by the Warsaw agglomeration". The objectives of the study were as follows: 1) possibly comprehensive description of the carabid fauna in urbanized environment (Warsaw) and presentation of its specificity against the background of the regional fauna (Mazovian Lowland); 2) determination of the dependence of the occurrence of carabids on the methods of utilizing and cultivating urban greens, and, at the same time, an attempt to indicate those anthropogenic factors connected with urbanization which are decisive in determining the pattern and specificity of the urban communities of carabids; 3) establishment of the basic tendencies of the structuring of carabid communities, which accompany the gradual transformation of the natural environment under the influence of intensifying human settlement; 4) bioindicational assessment of the quality of various habitats of city greens on the basis of the state of carabid communities inhabiting them; 5) possible presentation of suggestions concerning the ways of management and utilization of urban greenery, which would render possible the optimum functioning of faunistic associations.

In order to carry out these tasks, the species composition, numbers and structure of carabid communities in urban, suburban and non-urban environments, the seasonal dynamics of these communities, and also the zoogeographical and ecological composition of fauna were studied and compared.

STUDY AREA

GENERAL DESCRIPTION OF URBAN GREENERY

The Warsaw agglomeration lies in the Warsaw Basin within the Mazovian Lowland (physiographical data on this area are contained in the paper by Nowakowski [46]). Potential plant communities of most of Warsaw's area are made up of subcontinental lime-oak-hornbeam forests (*Tilio--Carpinetum*) of a poor, and in some places rich type [42] (Fig. 1). In the course of urbanization the primeval plant cover was nearly completely destroyed. Within the city boundaries only small parts of the old forests have remained, mainly in suburban areas, and, changed to a smaller or greater extent, in separate patches within built-up areas.

Grasslands, set up and maintained with the decisive help from man, are substitute communities. Their vegetation consists of ca 70 species of vascular herbaceous plants. Grasses dominate: *Poa pratensis* L., *Lolium perenne* L., *Agrostis vulgaris* With., *Festuca rubra* L., and others. Frequent among dicotyledonous plants are: *Trifolium repens* L., *Achillaea millefolium* L., *Taraxacum officinale* Web., and *Medicago lupulina* L. On the phytosociological

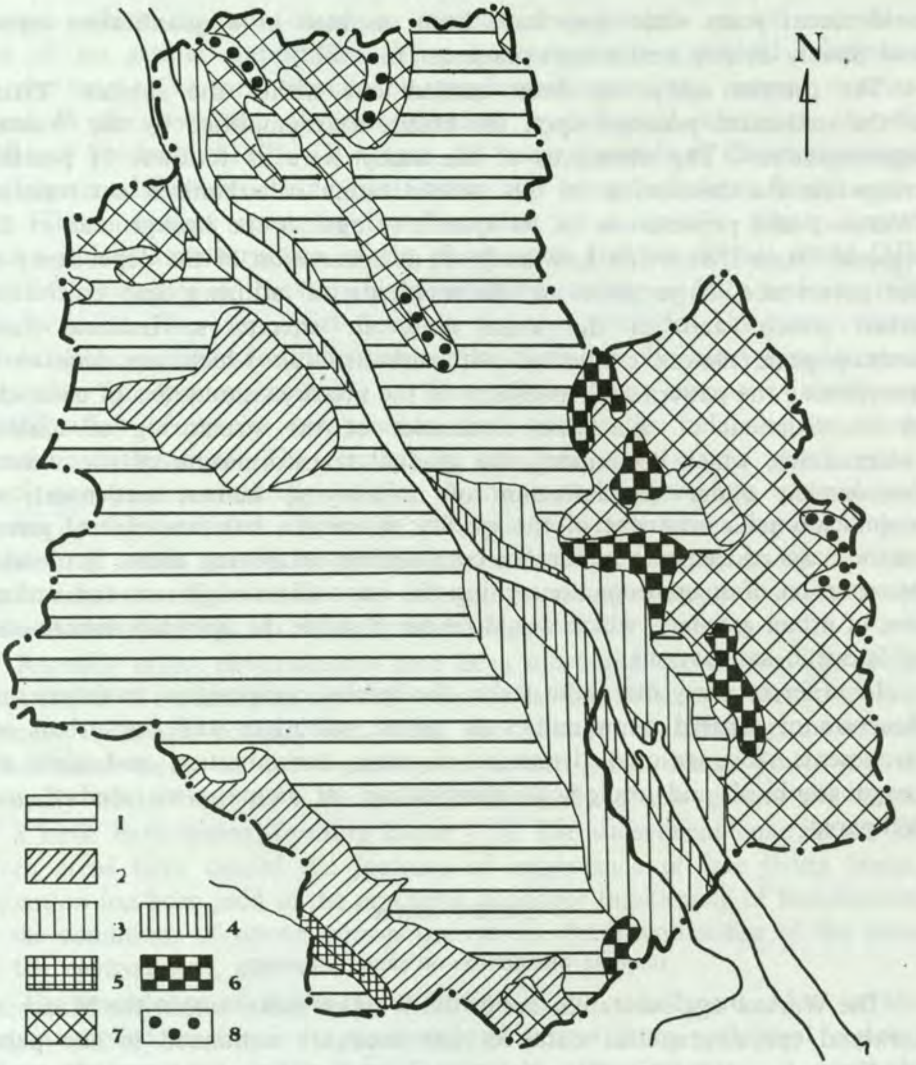


Fig. 1. The potential vegetation of Warsaw (according to Matuszkiewicz [42]). 1 — subcontinental lime-oak-hornbeam forest in the Mazovian variety (*Tilio-Carpinetum*); 2 — xerothermic oakwood (*Potentillo albae-Quercetum*); 3 — ash-elm carr (*Fraxino-Ulmetum*); 4 — willow-poplar carr (*Salicetum albo-fragilis*); 5 — alder-ash carr (*Circaeo-Alnetum*); 6 — wet alderwood (*Carici elongatae-Alnetum*); 7 — oak-pine forest (*Pino-Quercetum*); 8 — subcontinental moist pine forest (*Peucedano-Pinetum*)

score, cultivated lawns resemble pasture communities (*Cynosurion* alliance) or wet meadows of the *Arrhenatherion* alliance (*Arrhenatheretalia* order). The richest lawns are to be found in parks; they usually consist of 20—25 species of plants (including 7—10 species of grasses). The poorest are roadside lawns, composed of 8—10 species (including 5—6 species of grasses). Neglected lawns (e.g. in back-yards) or spontaneous communities, forming in newly-built housing estates, take the form of ruderal associations of the *Onopordetalia* order [75, 77].

The city greenery of Warsaw is composed mainly of more or less open lawns, which constitute 60—70% of green areas. The rest are all forms of woodlands, thickets, allotment gardens etc. The total area of Warsaw's urban greenery amounts to ca 12000 hectares [37].

In this study five main types of town greens have been distinguished and investigated: park greens, the greenery of housing estates, street greens, wooded areas and allotments. In the first three habitats the more or less carefully cultivated lawns dominate. There may occur single trees or scrubs, however open areas prevail. The term "wooded areas", as opposed to lawns, denotes parts of usually old stands of trees of a high canopy density, which tend to form forest herb layer. Wooded areas occur often within parks, nevertheless, due to their specific nature (and the nature of their fauna) they have been classified as a separate type of greenery.

The soil in parks is relatively little polluted by toxic substances and it is not salinized. It is usually anthropogenic soil, though in some cases, the profiles are natural in their character. The rich vegetation of the *Cynosurion* or *Arrhenatherion* alliances is dominant. The lawns are usually frequently mowed and the hay is removed. Periodically, mineral fertilizers and herbicides are applied. Single and often old trees grow usually on park lawns, and so do numerous clusters of bushes. Urban parks are large areas of greenery covering sometimes dozens of hectars. The homogenous way of park landscaping makes them relatively similar.

Wide differentiation is a characteristic of housing estates' greens, on the score of both the size of particular parts and the type of vegetation. The set-up of these areas largely depends on the ingenuity of the people living there. Into this category of habitats all lawns within housing developments have been included, both in isolated back-yards within built-up areas and also in the vast spaces of modern housing estates. The soil in these areas is seriously changed, and usually strewed. The turf is composed of wet pasture communities (of the *Cynosurion* alliance), and ruderal associations of the *Onopordetalia* order grow in neglected sites. Trees, usually young (man-planted), grow separately, far between.

Street greens consist of narrow long lawns stretching along roads or in the middle of main dual carriage-way thoroughfares, and of isolated greens in squares and roundabouts. The soil is seriously degraded, polluted and dried. The vegetation is relatively homogenous; it is also cultivated, as in parks, but it is heavily destroyed and qualitatively impoverished, with poor pasture association dominating. The roadside parts of lawns often become similar to xerophilous sandy grasslands of the *Sedo-Sclerantea* class, sometimes with an addition of mesohalophytes.

Urban wooded areas have remained in relatively unchanged shape only in the Warsaw peripheries. Those fragments of wooded areas which have survived in the central quarters have been considerably transformed. The amount of, formerly numerous, oaks (*Quercus* sp.) and hornbeams (*Carpinus betulus* L.) is now much smaller. In their place, maples (especially *Acer negundo* L.), robinias (*Robinia pseudoacacia* L.), and limes (*Tilia* sp.) appear. The herb layer has also considerably changed. Apart from the generally negative influence of urbanization, horticultural and clean-up manipulations (raking the litter) are also contributing to it. Some places are nearly completely deprived of herbaceous vegetation.

The habitats of urban greenery which undergo the most intensive horticultural treatment are allotment gardens their vegetation composition is very unstable. The herbaceous vegetation is nearly exclusively composed of cultivated decorative plants and vegetables. The higher layer usually consists of densely growing fruit-trees and shrubs. Artificial fertilizers and pesticides of all sorts are commonly used.

DESCRIPTION OF STUDY AREAS

41 study areas in Warsaw's urban greenery have been covered by the study: 8 parks, 10 housing estates, 10 street greens, 12 wooded areas, and 1 allotment garden (Fig. 2). All these areas are situated in the habitats of the potential lime-oak-hornbeam forest. They were selected to reflect the variety of every given type of greenery in the fullest possible way (only allotments were treated marginally). According to the degree of the environment variety of each study area, 1—3 study plots were chosen within it.

Park greenery

P 1. A.P.E. Park area near the Academy of Physical Education, at the border of the town's closely built-up regions, adjacent to Bielański Forest. One plot was studied, in an uncultivated part of the park, where the herbaceous vegetation turned wild.

P 2. Ursynów. An old palace garden at the border of the town's closely built-up regions. The site of the Warsaw Agricultural Academy. A small area (a few hectares), with carefully maintained lawns, dense clusters of shrubs, and an old, carefully cultivated wooded area.

P 3. Culture and Leisure Park. (Plots I, and II). The largest public park in Warsaw, visited by great numbers of people; established in 1951. The park, until recently neglected, is now intensively cultivated. Lawns of luxuriant, rich vegetation; diversified tree cover, compact in some places.

P 4. Łazienki Park. (Plots I, II, and III). Warsaw's oldest park, established on the territory of the former prince's zoological gardens. In the 18th century it finally assumed its shape of a French-style landscape park. A vast area (86 hectares) containing ponds and a network of channels. Lawns undergo intensive agrotechnical treatment.

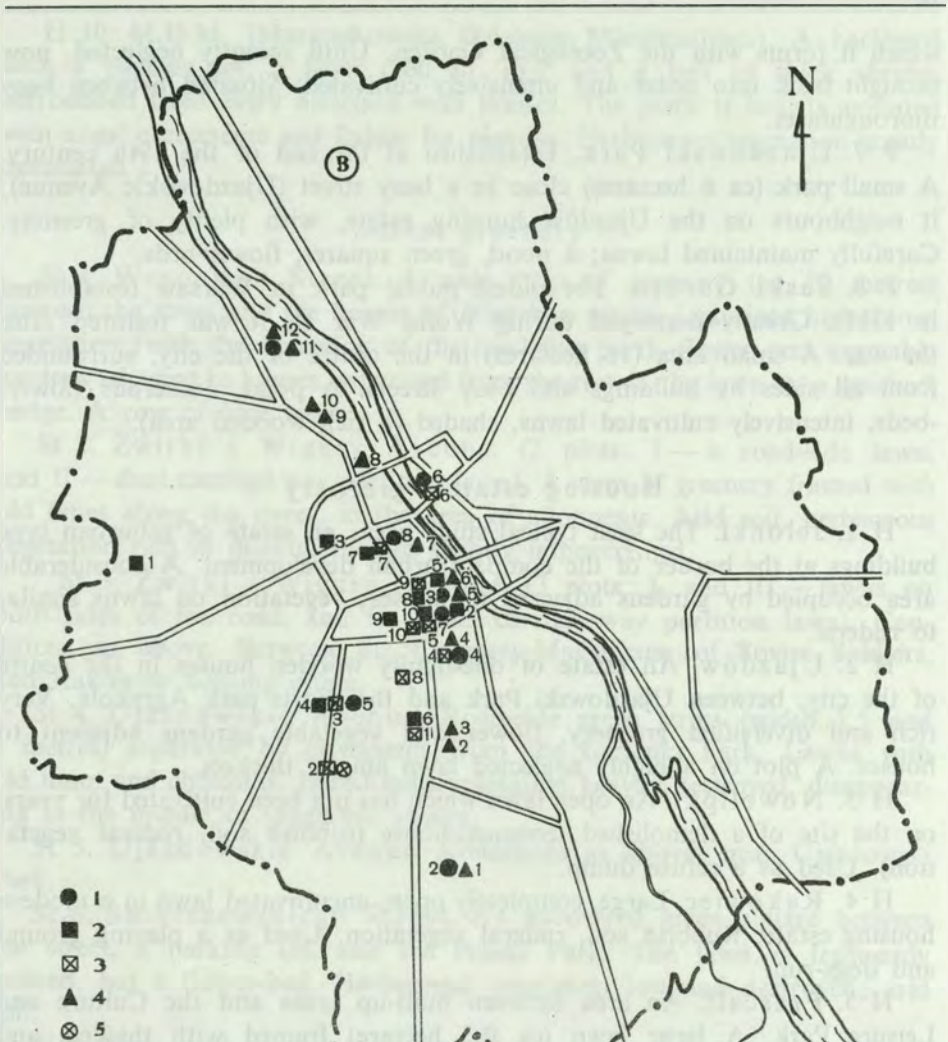


Fig. 2. The sites of the study of urban greenery in Warsaw.
1 — park greenery; 2 — housing estates' greenery; 3 — street greenery; 4 — wooded areas; 5 — allotments; 6 — suburban quarter (Białołęka Dworska). (The numbers for the study areas of particular types of greenery as in the text)

P. 5. Cemetery-Mausoleum of Soviet-Soldiers. (The surrounding area; plots I, and II). A park of 20.5 hectares, established in the years 1949—1950 on arable lands. Carefully maintained lawns, in some places thickly covered with shrubs and trees. The front of the park adjoins a busy thoroughfare (Żwirki i Wigury Avenue), the back is a complex of allotments.

P 6. Praski Park. (Plots I, II, and III). Established in 1865; since 1928 it has been a part of a complex of greenery (ca 90 hectares), which it forms with the Zoological Garden. Until recently neglected, now brought back into order and intensively cultivated. Situated between busy thoroughfares.

P 7. Ujazdowski Park. Established at the end of the 19th century. A small park (ca 6 hectares) close to a busy street (Ujazdowskie Avenue); it neighbours on the Ujazdów housing estate, with plenty of greenery. Carefully maintained lawns; a pond, green squares, flower-beds.

P 8. Saski Garden. The oldest public park in Warsaw (established in 1713). Greatly destroyed during World War II, it was restored after the war. A small area (16 hectares) in the centre of the city, surrounded from all sides by buildings and busy streets. A pond, numerous flower-beds, intensively cultivated lawns, shaded (a rich wooded area).

Housing estates' greenery

H 1. Jelonki. The least typical study area; an estate of suburban type buildings at the border of the compact urban development. A considerable area occupied by gardens adjacent to houses; vegetation on lawns similar to ruderal.

H 2. Ujazdów. An estate of one-family wooden houses in the centre of the city, between Ujazdowski Park and the sports park Agrykola. Very rich and diversified greenery, flower and vegetable gardens adjacent to houses. A plot on a highly neglected lawn among thickets.

H 3. Nowolipki. An open lawn which has not been cultivated for years, on the site of a demolished tenement-house (rubbish soil, ruderal vegetation). Used as a refuse dump.

H 4. Rakowiec. Large, completely open, uncultivated lawn in a modern housing estate. Rubbish soil, ruderal vegetation. Used as a playing ground and dogs-run.

H 5. Frascati. An area between built-up areas and the Culture and Leisure Park. A large lawn (ca 0.3 hectare) framed with thickets and densely planted trees. Dogs-run and a place of constant feeding of pigeons.

H 6. Wierzbno. (2 plots: I — a large and open lawn, and II — a small, shaded lawn between buildings). An estate established in the years 1960—1965, with rich and well maintained greenery.

H 7. Za Żelazną Bramą. A modern estate of big, separate tower-blocks. Between the blocks large frequently mowed and trodden down lawns.

H 8. Piękna. A lawn of ca 0.1 hectare, restricted by houses and parking lot, opened towards the street. A dogs-run.

H 9. Institute of Zoology. An isolated lawn within built-up area (300 sq. m.), open towards the street (the yard of the Institute of Zoology, P.A.S.). Herbaceous vegetation luxuriant and of very rich species composition; numerous shrubs and young trees. Rubbish soil, defiled with dogs' and cats' excrements.

H 10. M.D.M. (Marszałkowska Dzielnica Mieszkaniowa). A backyard with a parking lot, a lawn (200 sq. m.), and a belt of thick shrubs, surrounded from every direction with houses. The place is heavily polluted with dogs' excrements and fodder for pigeons. Herbaceous vegetation greatly devastated.

Street greenery

St 1. Woronicza Street. A wide strip of greenery (ca 20 metres) between the street and the houses of Wierzbno estate. Luxuriant herbaceous vegetation (with the exception of the road-side part), flower and vegetable gardens adjacent to houses, separated from the rest of the lawn by a quickset hedge. A row of lime trees.

St 2. Żwirki i Wigury Avenue. (2 plots: I — a road-side lawn, and II — dual carriage-way partition lawn). A strip of greenery framed with old limes along the street, in the area of allotments. Arid soil, herbaceous vegetation rich in quality, though slightly impoverished.

St 3. Żwirki i Wigury Avenue. (3 plots: I, and III — lawns on both sides of the road, and II — dual carriage-way partition lawn). Conditions as above. Between the Cemetery-Mausoleum of Soviet Soldiers, and Rakowiec housing estate.

St 4. Ujazdowskie Avenue. Road-side green strips (width 1.5 and 2 metres) separated by pavements from the Łazienki Park. Lawns with old limes and chestnuts. Herbaceous vegetation heavily destroyed, disappearing in the middle of vegetative season.

St 5. Ujazdowskie Avenue. Conditions as above; near Ujazdowski Park.

St 6. Świerczewskiego Street. An uncovered green square between the street, a parking lot, and the Praski Park. The lawn is frequently mowed, has a flower-bed. Herbaceous vegetation low and destroyed; arid soil.

St 7. Marszałkowska Street. A large (ca 0.3 hectare) open lawn in a wide dual carriage-way partition, between Saski Garden and Za Żelazną Bramą housing estate.

St 8. Niepodległości Avenue. A narrow (ca 3 metres) dual carriage-way partition lawn with a quickset hedge and devastated, low grassy vegetation.

St 9. Trzech Krzyży Square. (Plots I, and II: lawns of 500 and 300 sq. m.). The area is surrounded by streets, near Frascati housing estate and the Culture and Leisure Park. Lawns framed by a quickset hedge.

St. 10. Zbawiciela Square. A round lawn (ca 500 sq. m). in the centre of the city, intersected by tram tracks. The area is completely cut off (by streets and buildings) and away from any sizeable green areas.

Wooded areas

W 1. Ursynów. Relatively little changed lime-oak-hornbeam forest on clay soil. In the neighbourhood: meadows and the park of the Warsaw Agricultural Academy.

W 2. Arkadia. A stand of maples, hornbeams, and elms on humic-clay soil. Herbaceous vegetation badly devastated. Arkadia Park area.

W 3. Królikarnia. Also within the Arkadia Park. The stand similar to the former one, however, considerably thinned.

W 4. Łazienki. A stand with a rich shrubs layer, and very poor herbaceous vegetation; clay-humic soil. Within the Łazienki Park.

W 5. Sejm. A stand with the maple, lime, and robinia; herbaceous vegetation completely destroyed in places; humic-clay soil. Within the Culture and Leisure Park.

W 6. Culture Park. Also within Culture and Leisure Park. The stand density considerably thinned, grassy herb layer.

W 7. University. A wooded area with maples, limes, and robinias; poorly developed shrubs layer, herbaceous vegetation intensively transformed into lawn turf. A large complex of open lawns, and the buildings of the University of Warsaw in the vicinity of the study area.

W 8. Citadel. A wooded area with maples and limes, rich shrubs layer and poor herbaceuos vegetation; humic-clay, rubble soil. The study area located on the ramparts of the Warsaw Citadel.

W 9. Gdańska Street. Relatively thin wooded area with old oak trees and also hornbeams, limes, and maples; well developed shrub layer, and luxuriant herbaceous vegetation; sandy soil.

W 10. Kaskada. Settlement conditions as above; within Kaskada Park. Differs from the former in greater density of trees and less developed herbaceous vegetation.

W 11. Bielany. A lime-oak-hornbeam forest on sandy soil on the Vistula escarpment which forms the edge of Bielański Forest.

W 12. Bielański Forest. A lime-oak-hornbeam stand deep within the "Bielański Forest" nature reserve; sandy soil.

The only allotment garden studied was in the centre of a complex of allotments (ca 45 hectares) situated nearby Żwirki i Wigury Avenue.

In order to describe the changes resulting from human settlement respective (i.e. also situated in the habitat of *Tilio-Carpinetum*) non-urban and suburban environments of Mazovia were studied as well (Fig. 3).

Natural (control) environment. Lime-oak-hornbeam forest (*Tilio-Carpinetum*) near Hamernia (Skierniewice voivodship).

Rural environments. Old parks in Młochów (Warsaw voivodship) and Radziejowice (Skierniewice voivodship). The manor park in Młochów lies among arable lands, has not been cultivated for many years, and its vegetation has turned wild; lawns with many dicotyledonous plants; study areas: "forest" — a wooded area (no operations whatsoever); "lawn" — an open part (mowed once or twice a year). The palace park in Radziejowice, situated at the skirt of the village among meadows and forests, is maintained in a condition similar to that of typical urban parks; closed to the public; study areas: "forest" — a wooded part with carefully cultivated trees and systematically raked litter; "lawn" — an open, representative part of the park.

Suburban environment. Białołęka Dworska — a peripheral quarter of Warsaw with detached one-family houses; study areas: "forest" — a remnant patch of lime-oak-hornbeam forest (ca 0.4 hectare), surrounded by arable lands; "meadow" — a meadow community of the *Arrhenatherion* alliance on a large area amidst fields and farm buildings (Fig. 2).

THE TYPE OF URBAN GREENERY AND ANTHROPOGENIC INFLUENCE

Urbanization pressure consists of a number of factors. In various urban habitats different groups of factors determine the nature of this pressure. It seems that the factors which determine the type of pressure are also

Fig. 3. Poland, Mazovian Lowland, Warsaw and non-urban study areas. 1 — Młochów; 2 — Radziejowice; 3 — Hamernia

these which mostly influence the structure of local biocoenoses. In order to define these "leading factors" in every type of urban greenery studied, maps of the distribution of the intensity of urbanization pressure in Warsaw prepared by Biuro Planowania Rozwoju Warszawy (the Office for Planning Warsaw Development) [4] were applied. An 8-degree scale of the pressure intensity is used there, describing the pressure summarily and its particular components, the most important of which are the pollution of the environment with fumes, and direct human influence. Human pressure is measured by the density of inhabitants and the intensity of their mobility. The symptoms of this pressure most important for the environment are: an increased quantity of organic substance (discarded bits of food, the excess of pigeon feed, uncovered dust bins, the excrements of dogs and cats), the watering of lawns — usually not employed elsewhere, and the treading, permanent in many places on the greenery.

The available materials [4] lack information on the methods of land utilization from the agrotechnical point of view. Therefore, the approximate scale here has been worked out individually on the basis of systematic observations of the study areas lasting several years. The tabulation of the resultant data (Tab. 1) shows that horticultural treatments are decisive in allotments, park greens, and wooded areas, human influence in housing estates' greenery, and traffic influence in street greenery. Within urban wooded areas the influence of particular factors is minor. These habitats are best suited for the studies on the general influence of urbanization upon fauna, discussed in a previous paper [17].

The quantity of grass and litter remaining after the vegetation season indirectly demonstrates the intensity of mechanical cultivation treatments in various types of urban greenery. In parks the average quantity is 214 g

Tab. 1. Intensity of main anthropogenic factors, and urban pressure in general,[1] influencing particular types of urban greenery in Warsaw (according to the adapted 8-degree scale)

Type of greenery \ Type of pressure	horticultural	inhabitants'	transport	urban in general
park greenery	6	4	3	3
housing estates' greenery	4	7	4	4
street greenery	5	5	7	5
wooded areas	3	2	2	3
allotment gardens	8	5	1	2

[1] The value of general intensity of urban pressure is not directly derived from the values of the above listed particular anthropogenic factors. It is a resultant of the whole complex of direct and indirect anthropogenic influences. It consists e.g. of the size of hardened area in a given region as well as climatic changes (the Office for Planning Warsaw's Development 1976).

of dry weight per 1 sq. m., in housing estates — 244 g, in street greens — 219 g (more than in parks!), in wooded areas — 660 g (in the lime-oak-hornbeam forest in Hamernia it is 1132 g).

METHODS

THE TECHNIQUE OF CATCHES AND THE DURATION OF RESEARCH

The type of area seriously restricted the choice of study methods. The only possible catches to be carried out on a large scale were those with Barber's pitfall traps. The biocoenometric method was also used as well as a number of auxiliary methods.

Glass cylinders 4 cm in diameter and 10 cm deep were used as traps. They were put into holes in soil made with a soil sampler. Thanks to this method the traps were placed efficiently and neither the soil nor vegetation surrounding them was disarranged. In particular study plots, depending on their size, 10 — 25 traps were placed in a row, 1 m apart each. Each catch lasted for 2 weeks. During the first year of studies (1974) catches were carried out throughout the whole season without breaks. In the following years there was one series of catches every month of the season (from April to October). Ethylene glycol was used as a preservative agent in the traps. The way trap catches were made fulfilled most of the particular requirements for this method [1, 66].

The data on the number of animals caught into Barber's pitfall traps are bound to include some approximations resulting from the differences in activity of various species [43, 62], and also the dependence of this activity upon local habitat conditions [24, 61]. The results obtained with the use of this method are thus suitable mainly for the comparisons of fauna in different study areas of similar nature [1]. Therefore they may be successfully used while comparing carabid fauna in more or less homogenous lawns. Some approximation occurs only in comparisons between open and wooded areas, where the difference lies, on the one hand, in the degree of density of herbaceous vegetation and the structure of soil surface, and, on the other, in the composition of carabid communities itself. The seasonal changes of activity did not affect the comparability of results because the catches were carried out everywhere at the same periods of time.

Square frames of 0.25 sq. m. were used for biocoenometric catches; there were 10 repetitions in a series, several times during a season. The biocoenometric method is not particularly useful for studies on carabids because of their relatively small density [65]. As the method's time and labour consumption is incommesurable to its effectiveness, biocoenometric catches were made in a few study plots only. They yielded a relatively small amount of data, however they enabled — through the comparison of their results with those of the trap catches carried out at the same time, and by determining an appropriate conversion rate — an estimated assessment of the density of carabids directly from the data obtained from Barber's pitfall traps [15].

In the studies by the Institute of Zoology of the Polish Academy of Sciences on the fauna of Warsaw, catches were also carried out by other methods, specific for the faunas of soil, herb layer, and tree canopy [20]. They yielded some fortuitous material of carabids, of which that has been used which broadens the knowledge of the fauna of carabids in particular study areas.

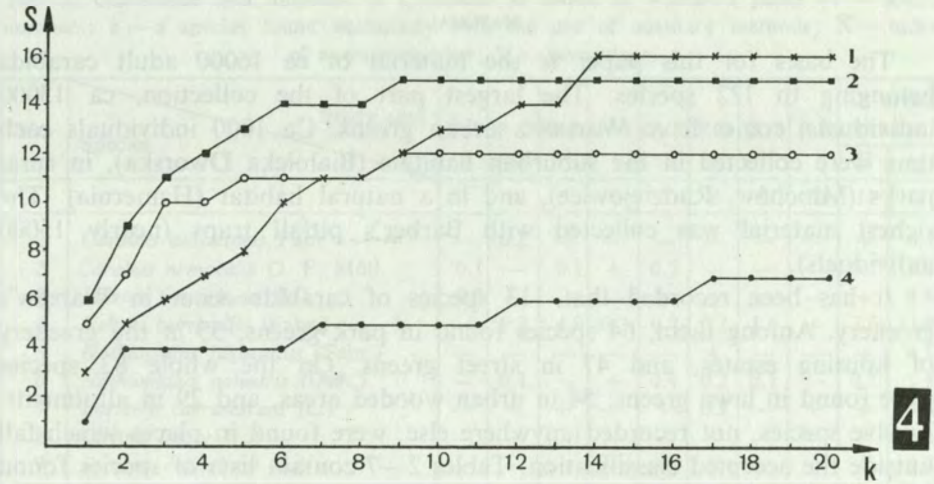
The studies were carried out in the years 1974—1978. Every study area of urban greenery was studied for 1—5 seasons. The longer cycle of catches (4—5 years) was carried out in places especially representative of a given type of greenery. Those few study areas where research met particularly serious obstacles (permanently destroyed traps) were studied only for one year. In suburban and non-urban environments material was collected in 2—3-year periods.

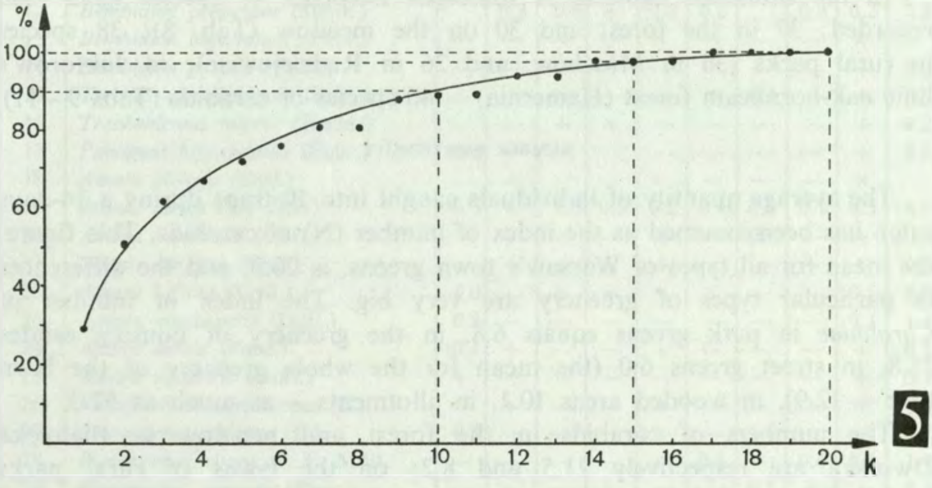
THE REPRESENTATIVENESS OF THE METHOD

The number of traps laid during studies usually considerably exceeded the minimum necessary for obtaining proper quantitative data [7, 39, 47]. The chosen methodology warranted representative material also in the qualitative aspect. The analysis has been conducted on the basis of the data from 4 properly selected study plots of urban greenery (1974). These study plots (P 4 II, H 6 II, H 9, H 10) constitute a sequence of growing species diversity of carabid communities, considerably differing in numbers. Twenty traps were laid in each plot. It has been ascertained that in order to get a full number of species in a given season, 9 to 17 traps had been necessary in particular cases, while usually 15 traps may be considered sufficient (Fig. 4). The smallest number of traps that was used during the studies in some plots, i.e. 10, was usually enough to reveal 90% of the species occurring at a study plot. In practice, that means the omission of 1—2 accessory species (Fig. 5).

On the basis of the data from the same plots, the results obtained in catches made without intervals (2 series in a month) have also been compared with those with intervals (1 series in a month). It has been concluded that the decrease in the frequency of catches caused a fall in their effectiveness of, on the average, 19% at a plot. On the average it corresponds to 2 unrevealed species in a season.

At particular study plots systematic catches were carried out in a different number of seasons. At plots considered the most typical of urban greenery, a cycle of at least 4 years was applied. With respect to the data obtained during 4 years, 1-year catches revealed ca 75% of local species, 2-year catches —





Figs 4 and 5. The representativeness of material from a varying number of traps — detailed data (Fig. 4) and generalized data (Fig. 5).
k — number of traps; S — number of species found; % — percentage of species found; 1 — 4 study plots: 1 — H 6 1; 2 — H 9; 3 – H 10; 4 — P 4 II

90%, 3-years catches — 95%. This is equivalent to the omission of respectively: 3, 2, and 1 species.

As in most of the study areas more than 10 traps were laid and the catches lasted more than one season, the conclusion that possible inadequacies were trivial, or even completely eliminated in the course of the consecutive years, seems to be well founded. It should also be taken into consideration that in some study areas flying by accidental species often appeared, whose sporadic catches seemingly decreased the effectiveness of tests.

MATERIAL

The basis for this paper is the material of ca 16000 adult carabids belonging to 122 species. The largest part of the collection, ca 13000 individuals, comes from Warsaw's urban greens. Ca 1000 individuals each time were collected in the suburban habitats (Białołęka Dworska), in rural parks (Młochów, Radziejowice), and in a natural habitat (Hamernia). The richest material was collected with Barber's pitfall traps (nearly 15000 individuals).

It has been recorded that 113 species of carabids occur in Warsaw's greenery. Among them, 64 species found in park greens, 55 in the greenery of housing estates, and 47 in street greens. On the whole 83 species were found in lawn greens, 54 in urban wooded areas, and 29 in allotments. Twelve species, not recorded anywhere else, were found in places which fall outside the accepted classification. Tables 2—7 contain lists of species found in particular study areas and types of urban greenery.

In the suburban habitats of Białołęka Dworska 47 species have been recorded: 37 in the forest and 30 on the meadow (Tab. 8); 38 species in rural parks (30 in Młochów, and 26 in Radziejowice); in Jaktorów's lime-oak-hornbeam forest (Hamernia) — 40 species of carabids (Tabs 9—11).

NUMBER AND DENSITY

The average quantity of individuals caught into 10 traps during a 14-days catch has been assumed as the index of number (N) of carabids. This figure, the mean for all types of Warsaw's town greens, is 20.3, and the differences in particular types of greenery are very big. The index of number of *Carabidae* in park greens equals 6.8, in the greenery of housing estates 25.8, in street greens 6.0 (the mean for the whole greenery of the lawn type — 12.9), in wooded areas 10.1, in allotments — as much as 52.3.

The numbers of carabids in the forest and meadow in Białołęka Dworska are respectively 21.5 and 8.2; on the lawns of rural parks in Młochów and Radziejowice: 8.0 and 4.9, and in the wooded areas of those parks — 6.6 and 20.9. In the lime-oak-hornbeam forest near Hamernia the number of the community is 15.3.

In order to determine an approximate number of individuals occurring in a unit of area, another conversion rate has been used, obtained through the comparison of the data from traps and from the biocoenometric catches carried out in some study areas [15]. In the light of these data the density of adult carabids in Warsaw's park greens is estimated at ca 0.7 individuals per 1 sq. m., in housing estates — ca 2.6/1 sq. m. and in street greenery — ca 0.6/1 sq. m. Therefore, on the average, assuming the equal participation of park greens, housing estates' greens, and street greenery in the town's area, the density of carabids in Warsaw's lawns is 1.3 individuals per 1 sq. m. This figure nears the lower limit of the number of carabids in non-urban habitats [65].

Tab. 2. Occurrence and numbers of *Carabidae* in lawns in Warsaw's parks (+ — scarce numbers; x — a species found exclusively with the use of auxiliary methods; $\overline{N}$ — index of average number; % — percentage)

No.	Species / Study area	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	All areas, average	
										$\overline{N}$	%
1	2	3	4	5	6	7	8	9	10	11	12
1	*Carabus auronitens* Fabr.	—	0.2	—	—	—	—	—	—	+	0.5
2	*Carabus nemoralis* O. F. Müll.	0.1	—	0.1	+	0.5	—	—	—	0.1	1.4
3	*Leistus ferrugineus* (L.)	0.3	—	—	—	+	—	—	—	+	0.6
4	*Nebria brevicollis* (Fabr.)	—	0.2	4.9	0.3	0.7	0.2	1.6	+	1.0	13.9
5	*Nothiophilus biguttatus* (Fabr.)	—	—	—	—	—	+	—	—	+	0.1
6	*Nothiophilus palustris* (Duft.)	—	0.1	—	+	0.1	0.2	0.1	—	0.1	1.4
7	*Loricera caerulescens* (L.)	—	—	+	—	+	0.1	—	+	+	0.3
8	*Clivina fossor* (L.)	—	—	0.1	—	—	—	—	—	+	0.2
9	*Broscus cephalotes* (L.)	—	—	—	—	+	—	—	+	+	0.2
10	*Asaphidion flavipes* (L.)	—	—	—	+	+	—	—	—	+	0.2
11	*Bembidion lampros* (Herbst)	—	—	0.1	—	—	—	—	+	+	0.2
12	*Bembidion properans* (Steph.)		0.3	0.6	+	0.2	0.2		0.3	0.2	2.8
13	*Bembidion biguttatum* (Fabr.)	—	—	—	—	×	—	—	—	×	—
14	*Bembidion guttula* (Fabr.)	—	—	—	+	—	—	—	—	+	0.1
15	*Trechus quadristriatus* (Schrank)	—	+	—	—	—	—	0.1	—	+	0.2
16	*Trechoblemus micros* (Herbst)	—	—	+	+	—	—	—	—	+	0.2
17	*Panageus bipustulatus* (Fabr.)	0.1	—	—	—	—	—	—	—	+	0.2
18	*Amara plebeja* (Gyll.)	—	—	—	—	×	—	—	—	×	—
19	*Amara aenea* (De Geer)	0.5	×	1.5	0.3	0.2	0.4	0.8	0.1	0.5	6.9
20	*Amara familiaris* (Duft.)	—	—	+	—	+	×	0.1	—	+	0.3
21	*Amara similata* (Gyll.)	+	+	+	×	+	×	—	+	+	0.3
22	*Amara bifrons* (Gyll.)	4.0	—	+	+	+	×	—	—	0.5	6.9
23	*Amara municipalis* (Duft.)	0.8	—	—	—	—	—	—	—	0.1	1.4
24	*Amara aulica* (Panz.)	0.1	+	—	—	+	—	—	—	+	0.1
25	*Amara equestris* (Duft.)	+	—	—	—	—	—	—	—	+	0.1
26	*Pterostichus caerulescens* (L.)	—	+	—	—	+	—	—	+	+	0.2
27	*Pterostichus cupreus* (L.)	0.1	—	—	—	+	—	—	—	+	0.2
28	*Pterostichus virens* O. F. Müll.	—	—	—	—	+	0.1	—	0.4	0.1	1.4
29	*Pterostichus vernalis* (Panz.)	—	—	—	+	+	—	0.1	+	+	0.3
30	*Pterostichus oblongopunctatus* (Fabr.)	—	0.2	—	—	—	—	—	—	+	0.5
31	*Pterostichus niger* (Schall.)	0.2	0.6	—	+	0.1	+	—	—	0.1	1.4
32	*Pterostichus vulgaris* (L.)	—	1.2	1.6	0.4	3.5	0.5	0.2	1.8	1.2	16.7
33	*Pterostichus nigrita* (Fabr.)	0.1	—	—	—	×	—	—	—	+	0.2
34	*Calathus ambiguus* (Payk.)	0.1	—	—	+	—	—	—	—	+	0.2
35	*Calathus erratus* (C. R. Sahlb.)	0.6	—	—	+	—	—	—	+	0.1	1.4
36	*Calathus fuscipes* (Goeze)	5.1	0.1	2.1	0.9	0.6	0.8	0.1	0.2	1.2	16.7
37	*Calathus melanocephalus* (L.)	3.9	—	0.3	0.4	—	0.1	—	0.1	0.6	8.3
38	*Synuchus nivalis* (Panz.)	0.1	—	0.1	0.1	+	+	0.1	+	0.1	1.4
39	*Agonum sexpunctatum* (L.)	—	+	—	—	×	—	0.1	—	+	0.2
40	*Agonum assimile* (Payk.)	—	—	0.1	0.1	—	—	—	—	+	0.5
41	*Agonum dorsale* (Pont.)	—	—	0.2	—	—	—	—	—	+	0.5
42	*Badister bipustulatus* (Fabr.)	—	—	0.1	0.2	+	—	0.1	—	0.1	1.4
43	*Badister dilatatus* Chaud.	—	—	—	—	—	—	—	+	+	0.1
44	*Anisodactylus binotatus* (Fabr.)	—	0.1	—	—	0.1	×	—	+	+	0.5

Tab. 2 (contd)

1	2	3	4	5	6	7	8	9	10	11	12
45	*Harpalus seladon* Schaub.	—	—	—	+	—	—	–	–	+	0.1
46	*Harpalus griseus* (Panz.)	–	–	–	+	+	–	–	–	+	0.2
47	*Harpalus rufipes* (De Geer.)	0.9	–	0.3	0.2	0.2	0.2	0.1	0.1	0.3	4.2
48	*Harpalus affinis* (Schrank)	0.1	–	1.0	+	–	0.3	–	0.2	0.2	2.8
49	*Harpalus anxius* (Duft.)	0.1	–	–	–	–	–	–	–	+	0.2
50	*Harpalus latus* (L.)	–	–	+	–	–	–	–	–	+	0.1
51	*Harpalus smaragdinus* (Duft.)	0.2	–	–	–	–	–	–	–	+	0.5
52	*Harpalus tardus* (Panz.)	0.1	–	–	+	–	–	–	–	+	0.2
53	*Harpalus vernalis* (Fabr.)	+	–	–	0.1	–	+	–	–	+	0.3
54	*Harpalus winkleri* Schaub.	–	–	–	+	–	–	–	–	+	0.1
55	*Acupalus exiguus* Dej.	–	–	–	–	–	–	–	×	×	–
56	*Acupalpus teutonus* (Schrank)	–	–	–	+	–	–	–	–	+	0.1
57	*Acupalpus brunnipes* (Sturm)	–	–	–	+	–	–	–	–	+	0.1
58	*Acupalpus dorsalis* (Fabr.)	–	–	–	–	+	–	–	–	+	0.1
59	*Dromius laeviceps* Motsch.	–	+	–	–	–	–	–	–	+	0.1
60	*Dromius quadraticollis* A. Mor.	–	×	–	–	–	–	–	×	×	–
61	*Dromius quadrimaculatus* (L.)	–	–	–	–	×	–	–	×	×	–
62	*Bradycellus harpalinus* (Aud.-Serv.)	0.1	–	–	–	–	–	–	–	+	0.2
63	*Metabletus foveatus* (Fourcr.)	+	–	–	–	–	–	–	–	+	0.1
64	*Metabletus truncatellus* (L.)	–	–	–	0.1	+	–	–	–	+	0.2
	Total	17.8	3.2	13.3	3.5	6.6	3.3	3.5	3.4	6.8	

Tab. 3. Occurrence and numbers of *Carabidae* in the greenery of Warsaw's housing estates (+ — scare numbers; × — a species found exclusively with the use of auxiliary methods; N̄ — index of average number; % — percentage)

No.	Species \ Study area	H 1	H 2	H 3	H 4	H 5	H 6	H 7	H 8	H 9	H 10	All areas, average	
												N̄	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	*Cicindela germanica* L.	0.1	–	–	+	–	–	–	–	–	–	+	+
2	*Carabus cancellatus* Ill.	0.1	1.5	–	–	–	–	–	–	–	–	0.2	0.8
3	*Carabus nemoralis* O. F. Müll.	0.6	1.0	–	–	0.1	0.3	–	–	–	–	0.2	0.8
4	*Nebria brevicollis* (Fabr.)	–	20.4	–	–	1.1	0.1	–	–	+	+	2.2	8.5
5	*Nothiophilus aquaticus* (L.)	–	–	–	–	–	–	0.1	–	–	–	+	+
6	*Nothiophilus palustris* (Duft.)	–	0.1	–	–	–	–	0.1	–	0.1	0.1	+	0.3
7	*Loricera caerulescens* (L.)	–	0.3	–	–	–	–	–	–	–	–	+	0.2
8	*Clivina fossor* (L.)	–	–	–	–	–	0.1	–	–	–	0.4	0.1	0.4
9	*Broscus cephalotes* (L.)	–	–	1.0	–	–	+	0.2	–	–	–	0.1	0.4
10	*Asaphidion flavipes* (L.)	0.1	–	–	–	–	0.2	–	–	–	–	+	0.2
11	*Bembidion ampros* (Herbst)	–	–	0.1	0.1	–	–	–	0.2	0.4	+	0.1	0.4
12	*Bembidion properans* (Steph.)	–	0.2	0.4	0.9	4.9	7.7	0.6	3.5	0.3	16.6	3.5	13.5
13	*Epaphius secalis* (Payk.)	–	–	–	–	–	–	–	–	+	–	+	+
14	*Trechus austriacus* Dej.	–	–	–	–	–	–	–	–	0.1	–	+	+
15	*Trechus quadristriatus* (Schrank)	–	–	–	–	0.1	–	–	–	–	–	+	+

1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	*Trechoblemus micros* (Herbst)	–	–	–	+	–	–	–	–	–	–	+	+
17	*Amara aenea* (De Geer)	–	0.4	0.6	2.5	2.0	1.7	1.0	0.7	2.3	3.2	1.4	5.4
18	*Amara famelica* Zimm.	0.1	–	–	0.1	–	–	–	–	–	–	+	0.1
19	*Amara similata* (Gyll.)	0.1	0.1	0.1	–	–	0.1	–	0.1	+	–	0.1	0.4
20	*Amara bifrons* (Gyll.)	0.2	–	4.0	0.1	–	0.1	–	0.4	0.7	0.6	0.6	2.3
21	*Amara apricaria* (Payk.)	–	–	–	+	–	×	–	–	–	–	+	+
22	*Amara consularis* (Duft.)	0.1	–	–	–	–	–	–	–	–	–	+	+
23	*Amara aulica* (Panz.)	–	0.3	5.6	0.2	–	–	–	–	0.6	–	0.7	2.7
24	*Amara equestris* (Duft.)	0.8	–	–	–	–	–	–	–	–	–	0.1	0.4
25	*Pterostichus caerulescens* (L.)	0.4	0.1	0.1	–	–	0.2	–	–	0.3	–	0.1	0.4
26	*Pterostichus cupreus* (L.)	–	–	0.1	–	–	–	–	–	–	–	+	+
27	*Pterostichus virens* (O. F. Müll.)	2.9	–	4.4	3.3	–	0.9	0.7	–	0.4	–	1.3	5.0
28	*Pterostichus vernalis* (Panz.)	–	–	0.1	–	–	–	–	–	×	–	+	+
29	*Pterostichus niger* (Schall.)	–	0.8	0.4	–	0.1	0.1	–	–	–	–	0.1	0.4
30	*Pterostichus vulgaris* (L.)	6.1	25.6	16.1	0.1	2.0	5.4	0.5	–	–	0.1	5.6	21.5
31	*Calathus ambiguus* (Payk.)	–	–	0.3	0.4	–	–	–	–	–	–	0.1	0.4
32	*Calathus erratus* (C. R. Sahlb.)	–	–	–	0.2	–	–	–	–	–	–	+	0.1
33	*Calathus fuscipes* (Goeze)	5.4	4.7	7.6	2.6	2.8	3.9	1.1	0.7	0.9	5.2	3.5	13.5
34	*Calathus melanocephalus* (L.)	–	0.1	3.3	0.7	1.5	0.2	0.1	0.9	1.5	–	0.8	3.1
35	*Dolichus halensis* (Schall.)	0.1	0.7	0.1	–	–	–	–	–	–	–	0.1	0.4
36	*Synuchus nivalis* (Panz.)	–	0.1	0.2	0.1	–	–	–	–	0.1	–	0.1	0.4
37	*Agonum gracilipes* (Duft.)	–	–	0.1	–	–	+	–	–	–	–	+	+
38	*Agonum sexpunctatum* (L.)	–	–	0.1	–	–	–	–	–	+	–	+	+
39	*Agonum assimile* (Payk).	–	0.1	–	–	–	–	–	–	–	–	+	+
40	*Agonum dorsale* (Pont.)	–	0.9	–	0.1	–	0.1	–	–	–	0.3	0.1	0.4
41	*Badister bipustulatus* (Fabr.)	–	0.1	–	–	–	+	–	–	0.1	–	+	0.1
42	*Anisodactylus binotatus* (Fabr.)	0.3	1.2	–	0.2	0.1	–	–	–	+	–	0.2	0.8
43	*Harpalus griseus* (Panz.)	1.6	–	–	–	–	–	–	–	–	–	0.2	
44	*Harpalus rufipes* (De Geer)	3.5	9.4	2.6	1.2	–	0.2	0.2	0.3	1.5	5.5	2.4	9.2
45	*Harpalus affinis* (Schrank)	0.4	–	1.4	1.5	1.0	0.7	–	0.3	1.9	8.7	1.6	6.2
46	*Harpalus progrediens* Schaub.	–	0.1	–	–	–	–	–	–	–	–	+	+
47	*Harpalus psittaceus* (Fourcr.)	–	–	–	0.1	–	–	–	–	–	–	+	+
48	*Harpalus rubripes* (Duft.)	0.3	–	0.1	0.4	–	–	–	–	–	–	0.1	0.4
49	*Harpalus tardus* (Panz.)	–	–	0.1	0.1	–	–	–	–	–	–	+	0.1
50	*Harpalus vernalis* (Fabr.)	–	–	–	–	–	–	–	–	0.1	–	+	+
51	*Harpalus winkleri* Schaub.	–	0.4	–	–	–	–	–	–	–	–	+	0.3
52	*Bradycellus harpalinus* (Aud.-Serv.)	–	–	–	–	–	–	–	–	+	–	+	+
53	*Zabrus tenebrioides* (Goeze)	–	–	–	–	–	–	–	–	–	+	+	+
54	*Metabletus foveatus* (Fourcr.)	–	–	0.1	–	–	–	–	–	–	–	+	+
55	*Metabletus truncatellus* (C. R. Sahlb.)	–	–	–	–	–	–	–	–	0.1	–	+	+
	Total	23.2	68.6	49.6	14.8	15.7	22.1	4.6	7.1	11.5	40.8	25.8	

Tab. 4. Occurrence and numbers of *Carabidae* in Warsaw's street greenery (+ — scarce numbers; × — a species found exclusively with the use of auxiliary methods; $\bar{N}$ — index of average number; % — percentage)

No.	Species / Study area	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	All areas, average	
												$\bar{N}$	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	*Cicindela germanica* L.	–	–	0.3	–	–	–	–	–	–	–	+	0.5
2	*Carabus cancellatus* Ill.	–	0.1	–	–	–	–	–	–	–	–	–	0.2
3	*Carabus nemoralis* O. F. Müll.	0.1	0.3	+	–	–	–	–	–	–	–	+	0.7
4	*Nebria brevicollis* (Fabr.)	1.7	0.6	0.2	+	–	–	+	–	–	–	0.3	5.0
5	*Nothiophilus aquaticus* (L.)	–	–	+	–	–	–	–	–	0.1	–	+	0.2
6	*Nothiophilus biguttatus* (Fabr.)	–	+	–	–	–	–	–	–	–	–	+	+
7	*Nothiophilus palustris* (Duft.)	–	+	+	–	–	–	–	–	+	–	+	0.2
8	*Loricera caerulescens* (L.)	0.1	–	–	–	0.1	–	+	–	–	+	+	0.3
9	*Broscus cephalotes* (L.)	–	+	+	–	–	–	–	–	–	–	+	0.2
10	*Asaphidion flavipes* (L.)	–	–	+	×	–	–	–	–	–	–	+	+
11	*Bembidion lampros* (Herbst)	–	–	–	–	0.1	–	–	–	–	–	+	0.2
12	*Bembidion properans* (Steph.)	0.7	–	0.6	0.6	–	0.1	0.1	1.5	–	1.2	0.5	8.3
13	*Bembidion ustulatum* (L.)	–	+	–	–	–	–	–	–	–	–	+	+
14	*Bembidion guttula* (Fabr.)	–	–	×	+	–	–	–	–	+	–	+	0.2
15	*Amara plebeja* (Gyll.)	–	–	×	–	–	–	–	–	–	–	×	–
16	*Amara aenea* (De Geer)	0.4	+	1.1	0.7	–	2.0	0.4	1.8	0.5	0.5	0.7	11.7
17	*Amara familiaris* (Duft.)	–	–	+	–	–	–	–	–	–	–	+	+
18	*Amara similata* (Gyll.)	–	–	–	–	–	–	+	–	–	–	+	+
19	*Amara bifrons* (Gyll.)	–	–	+	0.1	0.1	×	+	0.1	–	–	+	0.5
20	*Amara apricaria* (Payk.)	0.1	–	0.2	+	–	–	+	–	–	0.1	+	0.7
21	*Amara aulica* (Panz.)	0.1	–	–	–	–	–	–	–	–	–	+	0.2
22	*Pterostichus caerulescens* (L.)	0.4	–	–	–	–	–	–	–	–	–	+	0.7
23	*Pterostichus virens* (O. F. Müll.)	1.6	+	1.2	–	–	0.3	2.3	0.1	–	–	0.6	10.0
24	*Pterostichus vernalis* (Panz.)	–	–	+	–	–	–	–	–	–	×	+	+
25	*Pterostichus vulgaris* (L.)	1.8	2.6	0.6	+	–	–	+	–	–	–	0.5	8.3
26	*Calathus erratus* (C. R. Sahlb.)	–	–	+	–	–	0.1	0.9	–	–	–	0.1	1.7
27	*Calathus fuscipes* (Goeze)	7.6	2.3	0.8	–	0.3	0.8	0.1	0.9	0.3	0.1	1.3	21.7
28	*Calathus melanocephalus* (L.)	0.1	–	0.1	–	–	×	0.1	–	–	+	+	0.5
29	*Agonum gracilipes* (Duft.)	–	–	–	–	–	0.1	–	–	–	–	+	0.2
30	*Agonum obscurum* (Herbst)	–	–	+	–	–	–	–	–	–	–	+	+
31	*Agonum fuliginosum* (Panz.)	–	+	–	–	–	–	–	–	+	–	+	0.2
32	*Badister bipustulatus* Fabr.	0.1	–	0.1	–	–	×	0.1	–	–	–	+	0.5
33	*Badister dilatatus* Chaud.	–	–	–	–	–	–	+	–	–	–	+	+
34	*Chlaenius nigricornis* Fabr.	–	–	–	–	–	–	–	–	–	+	+	+

Tab. 4 (contd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
35	*Anisodactylus binotatus* (Fabr.)	×	+	+	+	–	–	–	–	–	–	+	0.2
36	*Harpalus griseus* (Panz.)	–	+	–	–	–	–	0.1	0.1	–	+	+	0.5
37	*Harpalus rufipes* (De Geer)	0.6	2.0	0.3	0.1	0.2	0.3	0.4	1.1	0.3	1.2	0.7	11.7
38	*Harpalus affinis* (Schrank)	1.0	+	0.8	0.9	0.2	0.8	+	1.0	0.1	0.6	0.5	8.3
39	*Harpalus psittaceus* (Fourcr.)	–	–	+	–	–	–	–	–	–	+	+	0.2
40	*Harpalus rubripes* (Duft.)	–	–	–	–	–	0.2	–	–	–	–	+	0.3
41	*Harpalus servus* (Duft.)	–	–	–	–	–	–	–	–	–	+	+	+
42	*Harpalus tardus* (Panz.)	0.1	–	–	–	–	0.3	–	–	–	–	+	0.7
43	*Harpalus vernalis* (Fabr.)	–	–	–	–	–	3.1	+	–	–	–	0.3	5.0
44	*Harpalus winkleri* Schaub.	–	–	–	–	–	0.1	–	–	–	–	+	0.2
45	*Acupalpus dorsalis* (Fabr.)	–	–	+	–	–	–	–	–	–	–	+	+
46	*Acupalpus teutonus* (Schrank)	–	–	–	–	–	–	+	–	–	–	+	+
47	*Metabletus truncatellus* (L.)	–	–	+	–	–	–	–	–	–	–	+	+
	Total	16.5	8.3	6.6	2.5	1.0	8.2	4.7	6.6	1.4	3.9	6.0	

SPECIES COMPOSITION AND STRUCTURE OF CARABID FAUNA IN URBAN GREENERY

PARK GREENERY

Park greenery is the urban habitat richest in species of carabids in Warsaw. On the whole, 77% of species recorded in the greenery of the lawn type occur there as well as 57% of species found in the whole of urban greenery. On the average, 22 species occur in every study area — more than in other types of greenery. The richest species composition was shown by the community in the park at the Cemetery--Mausoleum of Soviet Soldiers (P 5) (32 species), while the poorest in the Ujazdowski Park (P 7) (12 species) (Tab. 2).

The dominant species in parks are (the average for all study areas) *Pterostichus vulgaris* and *Calathus fuscipes* (16.7% of the whole number of carabids each), *Nebria brevicollis* (13.9%), *Calathus melanocephalus* (8.3%), as well as *Amara aenea* and *A. bifrons* (6.9% each). (These species have been included into the group of dominants whose participation in the total number of carabids is at least 5%). The species of the greatest number at particular study areas are *Pterostichus vulgaris* (P 2, P 5, P 8), *Calathus fuscipes* (P 1, P 6), and *Nebria brevicollis* (P 3, P 7).

Tischler's scale [71] has been applied in order to determine the degree of constancy (C) of species at particular study areas in park greens. The scale defines the species of 100—76% frequency as constant, 75—51% — relatively constant, 50—26% — accessory, nad below 25% — accidental. constant species in park greenery (i.e. occurring in all, or nearly all

Tab. 5. Occurrence and numbers of *Carabidae* in Warsaw's wooded areas (+ — scarce numbers; × — a species found exclusively with the use of auxiliary methods; N̄ — index of average number; % — percentage)

No.	Species \ Study area	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	All areas, average	
														N̄	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	*Carabus auronitens* Fabr.	7.1	–	–	–	–	–	–	–	–	–	–	–	0.6	5.6
2	*Carabus convexus* Fabr.	–	–	–	–	–	–	–	0.8	–	–	–	–	0.1	0.9
3	*Carabus cancellatus* Ill.	–	–	–	–	–	1.8	–	–	–	–	–	–	0.2	1.9
4	*Carabus nemoralis* O. F. Mül.	3.2	0.5	0.1	–	3.7	0.3	0.2	0.9	2.6	2.0	1.0	2.7	1.4	13.1
5	*Carabus hortensis* L.	3.8	–	–	–	–	–	–	-	–	–	3.1	0.1	0.6	5.6
6	*Carabus glabratus* Payk.	0.1	–	–	–	–	–	–	–	–	–	–	–	+	0.1
7	*Cychrus caraboides* (L.)	0.2	–	–	–	–	–	–	–	–	–	–	–	+	0.1
8	*Leistus ferrugineus* (L.)	0.2	–	–	–	–	–	–	0.3	–	–	–	–	+	0.3
9	*Leistus rufescens* (Fabr.)	0.1	–	–	–	–	–	–	–	–	–	–	–	+	0.1
10	*Nebria brevicollis* (Fabr.)	0.4	0.4	0.7	×	8.5	2.7	1.5	0.1	2.3	10.3	1.6	0.5	2.4	22.4
11	*Nothiophilus biguttatus* (Fabr.)	–	–	×	–	–	–	×	–	0.1	0.4	0.1	+	0.1	0.9
12	*Nothiophilus palustris* (Duft.)	0.1	–	–	×	–	–	–	–	–	–	0.1	–	+	0.1
13	*Elaphrus aureus* Ph. Müll.	–	–	–	–	–	–	–	–	–	0.6	0.1	–	0.1	0.9
14	*Loricera caerulescens* (L.)	×	–	–	–	–	–	–	–	–	0.1	–	–	+	0.1
15	*Broscus cephalotes* (L.)	–	–	–	–	–	–	0.4	–	–	0.4	–	–	0.1	0.9
16	*Bembidion velox* (L.)	×	–	–	–	–	–	–	–	–	–	–	–	×	–
17	*Bembidion ustulatum* (L.)	–	–	–	–	–	–	–	–	–	0.1	0.5	–	0.1	0.9
18	*Epaphius secalis* (Payk.)	–	–	–	–	–	–	–	–	–	–	1.4	–	0.1	0.9
19	*Patrobus atrorufus* (Stroem)	–	–	–	–	–	–	–	–	–	–	5.8	+	0.5	4.7
20	*Amara aenea* (De Geer)	0.1	–	–	–	×	×	0.2	–	1.6	0.3	0.1	–	0.2	1.9
21	*Amara familiaris* (Duft.)	–	–	–	–	–	–	–	–	×	–	–	–	×	–
22	*Amara similata* (Gyll.)	–	–	–	0.1	0.5	–	–	–	–	–	–	–	0.1	0.9
23	*Amara bifrons* (Gyll.)	–	–	0.1	–	–	–	0.3	–	–	–	–	–	+	0.3
24	*Amara consularis* (Duft.)	–	–	–	–	–	–	–	–	0.1	–	–	–	+	0.1
25	*Amara aulica* (Panz.)	0.1	–	–	–	–	–	–	–	–	–	0.1	–	+	0.1
26	*Stomis pumicatus* (Panz.)	–	–	–	–	–	–	–	–	–	–	+	+	+	0.1
27	*Pterostichus virens* (O. F. Müll.)	–	–	–	–	–	–	–	–	–	0.1	–	–	+	0.1
28	*Pterostichus oblongopunctatus* (Fabr.)	1.4	–	–	0.3	–	–	–	–	–	–	6.2	4.5	1.0	9.3
29	*Pterostichus niger* (Schall.)	0.3	–	–	–	–	0.2	–	–	–	0.4	0.3	–	0.1	0.9
30	*Pterostichus vulgaris* (L.)	0.6	0.3	–	–	1.4	0.1	2.4	–	0.1	1.1	1.6	–	0.6	5.6
31	*Pterostichus nigrita* (Fabr.)	–	–	–	–	–	–	–	–	–	–	+	–	+	0.1
32	*Pterostichus strenuus* (Panz.)	0.1	–	–	–	–	–	–	–	–	–	0.9	0.3	0.1	0.9
33	*Calathus erratus* (C. R. Sahlb.)	–	–	1.1	–	–	–	–	–	–	0.1	–	–	0.1	0.9
34	*Calathus fuscipes* (Goeze)	–	–	0.1	–	0.4	0.1	0.4	–	0.4	0.3	–	0.1	0.2	1.9
35	*Calathus melanocephalus* (L.)	–	–	–	–	–	–	0.1	–	0.1	–	–	–	+	0.1
36	*Synuchus nivalis* (Panz.)		–	–	–	–	–	0.5	–	0.1	–	–	–	0.1	0.9
37	*Agonum viduum* (Panz.)	–	–	–	–	–	–	–	–	–	–	–	0.1	+	0.1
38	*Agonum assimile* (Payk.)	0.1	–	–	0.1	0.5	0.1	–	–	0.1	–	1.8	–	0.2	1.9
39	*Agonum obscurum* (Herbst)	–	–	–	–	–	–	–	–	–	–	+	–	+	0.1
40	*Agonum dorsale* (Pont.)	–	–	–	–	0.6	0.2	–	–	–	–	–	–	0.1	0.9
41	*Badister bipustulatus* (Fabr.)	–	–	–	–	×	×	–	0.4	–	–	+	+	+	0.3
42	*Badister kineli* Mak.	–	–	–	0.2	–	–	–	–	–	–	+	0.1	+	0.1
43	*Licinus depressus* (Payk.)	–	–	–	–	–	–	–	1.8	–	–	–	–	0.2	1.9

Tab. 5 (contd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
44	*Anisodactylus binotatus* (Fabr.)	–	–	–	–	–	–	–	–	–	0.1	–	–	+	0.1
45	*Harpalus punctatulus* (Duft.)	0.9	–	0.1	–	–	–	–	–	–	–	–	0.1	0.1	0.9
46	*Harpalus seladon* Schaub.	0.2	–	–	–	1.4	–	0.2	–	–	–	–	–	0.2	1.9
47	*Harpalus rufipes* (De Geer)	–	–	–	–	–	0.1	0.2	–	–	0.2	+	+	+	0.3
48	*Harpalus affinis* (Schrank)	–	–	0.1	–	0.5	–	–	–	–	–	–	–	0.2	1.9
49	*Harpalus latus* (L.)	–	–	–	–	–	–	–	–	0.1	1.4	0.3	–	0.2	1.9
50	*Harpalus quadripunctatus* Dej.	–	–	–	–	–	–	–	–	–	–	0.1	+	+	0.1
51	*Harpalus smaragdinus* (Duft.)	–	–	–	–	0.3	–	–	–	–	–	–	–	+	0.3
52	*Harpalus tardus*. (Panz.)	0.1	0.1	–	–	–	–	–	0.1	0.6	0.1	+	–	0.1	0.9
53	*Harpalus winkleri* Schaub.	0.6	0.6	0.1	–	0.6	–	–	0.8	–	0.4	0.1	–	0.3	2.8
54	*Bradycellus collaris* (Payk.)	–	–	–	–	–	–	–	–	–	–	×	–	×	–
	Total	19.7	1.9	2.4	0.7	18.4	5.6	6.4	5.2	8.2	18.4	25.8	8.8	10.1	

Tab. 6. Occurrence and numbers of *Carabidae* in Warsaw's allotment gardens (+ — scarce numbers; N — index of number; % — percentage)

No.	Species	N	%
1	*Carabus granulatus* L.	0.2	0.4
2	*Carabus cancellatus* Ill.	0.9	1.7
3	*Carabus nemoralis* O. F. Müll.	0.7	1.3
4	*Nebria brevicollis* (Fabr.)	6.4	12.2
5	*Nothiophilus biguttatus* (Fabr.)	+	0.1
6	*Nothiophilus palustris* (Duft.)	+	0.1
7	*Loricera caerulescens* (L.)	0.1	0.2
8	*Clivina collaris* (Herbst)	0.8	1.5
9	*Clivina fossor* (L.)	0.3	0.6
10	*Broscus cephalotes* (L.)	0.9	1.7
11	*Asaphidion flavipes* (L.)	0.3	0.6
12	*Bembidion lampros* (Herbst)	0.5	1.0
13	*Bembidion properans* (Steph.)	0.3	0.6
14	*Bembidion ustulatum* (L.)	0.7	1.3
15	*Trechus quadristriatus* (Schrank)	0.2	0.4
16	*Amara aenea* (De Geer)	0.9	1.7
17	*Amara similata* (Gyll.)	0.1	0.2
18	*Stomis pumicatus* (Panz.)	0.3	0.6
19	*Pterostichus virens* (O. F. Müll.)	0.1	0.2
20	*Pterostichus niger* (Schall.)	0.6	1.1
21	*Pterostichus vulgaris* (L.)	29.7	56.7
22	*Calathus fuscipes* (Goeze)	3.0	5.7
23	*Synuchus nivalis* (Panz.)	+	0.1
24	*Agonum dorsale* (Pont.)	0.1	0.2
25	*Chlaenius nigricornis* (Fabr.)	+	0.1
26	*Anisodactylus binotatus* (Fabr.)	2.3	4.4
27	*Harpalus rufipes* (De Geer)	2.6	5.0
28	*Harpalus affinis* (Schrank)	0.1	0.2
29	*Acupalpus teutonus* (Schrank)	+	0.1
	Total	52.3	

Tab. 7. Occurrence and numbers of *Carabidae* in Warsaw's urban greenery (symbols as in tabs 2—6); species found exclusively beyond study areas have been marked with as asterisk

No.	Species	Lawns		All town green	
		N̄	%	N̄	%
1	2	3	4	5	6
1	*Cicindela germanica* L.	+	<0.5	+	<0.5
2	*Carabus auronitens* Fabr.	+	<0.5	0.1	0.5
3	*Carabus convexus* Fabr.	–	–	+	<0.5
4	*Carabus granulatus* L.	–	–	+	<0.5
5	*Carabus cancellatus* Ill.	0.1	0.7	0.3	1.5
6	*Carabus nemoralis* O. F. Müll.	0.1	0.7	0.5	2.5
7	*Carabus hortensis* L.	–	–	0.1	0.5
8	*Carabus glabratus* Payk.	–	–	+	<0.5
9	*Cychrus caraboides* (L.)	–	–	+	<0.5
10	*Leistus ferrugineus* (L.)	+	<0.5	+	<0.5
11	*Leistus rufescens* (Fabr.)	–	–	+	<0.5
12	*Nebria brevicollis* (Fabr.)	1.2	9.3	2.5	12.3
13	*Nothiophilus aquaticus* (L.)	+	<0.5	+	<0.5
14	*Nothiophilus biguttatus* (Fabr.)	+	<0.5	+	<0.5
15	*Nothiophilus palustris* (Duft.)	0.1	0.7	+	<0.5
16	**Elaphrus riparius* (L.)	–	–	×	–
17	*Elaphrus aureus* Ph. Müll.	–	–	+	<0.5
18	*Loricera caerulescens* (L.)	+	<0.5	+	<0.5
19	*Clivina collaris* (Herbst)	–	–	0.2	1.0
20	*Clivina fossor* (L.)	+	<0.5	0.1	0.5
21	*Broscus cephalotes* (L.)	0.1	0.7	0.2	1.0
22	*Asaphidion flavipes* (L.)	0.1	0.7	0.1	0.5
23	*Bembidion velox* (L.)	–	–	×	–
24	**Bembidion striatum* (Fabr.)	–	–	×	–
25	*Bembidion lampros* (Herbst)	0.1	0.7	0.1	0.5
26	*Bembidion properans* (Steph.)	1.4	10.8	0.9	4.4
27	**Bembidion varium* (Oliv.)	–	–	×	–
28	*Bembidion ustulatum* (L.)	+	<0.5	0.2	1.0
29	*Bembidion biguttatum* (Fabr.)	×	–	×	–
30	*Bembidion guttula* (Fabr.)	+	<0.5	+	<0.5
31	*Epaphius secalis* (Payk.)	+	<0.5	+	<0.5
32	*Trechus austriacus* Dej.	+	<0.5	+	<0.5
33	*Trechus quadristriatus* (Schrank)	+	<0.5	+	<0.5
34	*Trechoblemus micros* (Herbst)	+	<0.5	+	<0.5
35	*Patrobus atrorufus* (Stroem)	–	–	0.1	0.5
36	*Panageus bipustulatus* (Fabr.)	+	<0.5	+	<0.5
37	*Amara plebeja* (Gyll.)	×	–	×	–
38	*Amara aenea* (De Geer)	0.9	7.0	0.7	3.4
39	*Amara famelica* Zimm.	+	<0.5	+	<0.5
40	*Amara familiaris* (Duft.)	+	<0.5	+	<0.5
41	*Amara similata* (Gyll.)	0.1	0.7	0.1	0.5
42	**Amara spreta* Dej.	–	–	×	–
43	*Amara bifrons* (Gyll.)	0.4	3.1	0.2	1.0
44	**Amara ingenua* (Duft.)	–	–	×	–
45	*Amara municipalis* (Duft.)	+	<0.5	+	<0.5
46	*Amara apricaria* (Payk.)	+	<0.5	+	<0.5
47	*Amara consularis* (Duft.)	+	<0.5	+	<0.5

Tab. 7 (contd).

1	2	3	4	5	6
48	*Amara aulica* (Panz.)	0.2	1.5	0.2	1.0
49	*Amara equestris* (Duft.)	+	<0.5	+	<0.5
50	*Stomis pumicatus* (Panz.)	–	–	0.1	0.5
51	*Pterostichus caerulescens* (L.)	0.1	0.7	+	<0.5
52	*Pterostichus cupreus* (L.)	+	<0.5	+	<0.5
53	*Pterostichus virens* (O. F. Müll.)	0.7	5.4	0.4	2.0
54	*Pterostichus vernalis* (Panz.)	+	<0.5	+	<0.5
55	*Pterostichus oblongopunctatus* (Fabr.)	+	<0.5	0.2	1.0
56	*Pterostichus niger* (Schall.)	0.1	0.7	0.2	1.0
57	*Pterostichus vulgaris* (L.)	2.4	18.6	7.5	36.9
58	**Pterostichus anthracinus* (Ill.)	–	–	×	–
59	*Pterostichus nigrita* (Fabr.)	+	<0.5	+	<0.5
60	*Pterostichus strenuus* (Panz.)	–	–	+	<0.5
61	*Calathus ambiguus* (Payk.)	+	<0.5	+	<0.5
62	*Calathus erratus* (C. R. Sahlb.)	0.1	0.7	0.1	0.5
63	*Calathus fuscipes* (Goeze)	2.0	15.5	1.8	8.9
64	*Calathus melanocephalus* (L.)	0.5	3.9	0.3	1.5
65	*Dolichus halensis* (Schall.)	+	<0.5	+	<0.5
66	*Synuchus nivalis* (Panz.)	0.1	0.7	0.1	0.5
67	*Agonum gracilipes* (Duft.)	+	<0.5	+	<0.5
68	*Agonum sexpunctatum* (L.)	+	<0.5	+	<0.5
69	*Agonum viduum* (Panz.)	–	–	+	<0.5
70	*Agonum assimile* (Payk.)	+	<0.5	0.1	0.5
71	*Agonum obscurum* (Herbst)	+	<0.5	+	<0.5
72	*Agonum dorsale* (Pont.)	+	<0.5	0.1	0.5
73	*Agonum fuliginosum* (Panz.)	+	<0.5	+	<0.5
74	**Agonum micans* (Nic.)	–	–	×	–
75	*Badister bipustulatus* (Fabr.)	0.1	0.7	0.1	0.5
76	*Badister kineli* Mak.	–	–	+	<0.5
77	*Badister dilatatus* Chaud.	0.1	0.5	0.1	0.5
78	**Badister peltatus* (Panz.)	–	–	×	–
79	*Licinus depressus* (Payk.)	–	–	+	<0.5
80	*Chlaenius nigricornis* (Fabr.)	+	<0.5	+	<0.5
81	**Dicheirotrichus rufithorax* (Sahlb.)	–	–	×	–
82	*Anisodactylus binotatus* (Fabr.)	0.1	0.7	0.5	2.5
83	**Anisodactylus signatus* (Panz.)	–	–	×	–
84	*Harpalus punctatulus* (Duft.)	–	–	+	<0.5
85	*Harpalus seladon* Schaub.	+	<0.5	+	<0.5
86	*Harpalus griseus* (Panz.)	0.1	0.7	0.1	0.5
87	*Harpalus rufipes* (De Geer)	1.1	8.5	1.2	5.9
88	**Harpalus froelichii* Sturm	–	–	×	–
89	*Harpalus affinis* (Schrank)	0.7	5.4	0.5	2.5
90	*Harpalus anxius* (Duft.)	+	<0.5	+	<0.5
91	*Harpalus latus* (L.)	+	<0.5	+	<0.5
92	*Harpalus progrediens* Schaub.	+	<0.5	+	<0.5
93	*Harpalus psittaceus* (Fourcr.)	+	<0.5	+	<0.5
94	*Harpalus quadripunctatus* Dej.	–	–	+	<0.5
95	*Harpalus rubripes* (Duft.)	+	<0.5	+	<0.5
96	*Harpalus servus* (Duft.)	+	<0.5	+	<0.5
97	*Harpalus smaragdinus* (Duft.)	+	<0.5	+	<0.5
98	*Harpalus tardus* (Panz.)	+	<0.5	+	<0.5

Tab. 7 (contd).

1	2	3	4	5	6
99	*Harpalus vernalis* (Fabr.)	0.1	0.7	<0.1	0.5
100	*Harpalus winkleri* Schanb.	+	<0.5	0.1	0.5
101	*Bradycellus collaris* (Payk.)	–	–	×	–
102	*Bradycellus harpalinus* (Aud.-Serv.)	+	<0.5	+	<0.5
103	*Acupalpus brunnipes* (Sturm)	+	<0.5	+	<0.5
104	*Acupalpus dorsalis* (Fabr.)	+	<0.5	+	<0.5
105	*Acupalpus exiguus* Dej.	×	–	×	–
106	*Acupalpus teutonus* (Schrank)	+	<0.5	+	<0.5
107	*Zabrus tenebrioides* (Goeze)	+	<0.5	+	<0.5
108	*Dromius laeviceps* Motsch.	+	<0.5	+	<0.5
109	*Dromius quadraticollis* A. Mor.	×	–	×	–
110	*Drominus quadrimaculatus* (L.)	×	–	×	–
111	*Metabletus foveatus* (Fourcr.)	+	<0.5	+	<0.5
112	*Metabletus truncatellus* (L.)	+	<0.5	+	<0.5
113	**Microlestes minutulus* (Goeze)	–	–	×	–
	Total	12.9		20.3	

Tab. 8. Occurrence and numbers of *Carabidae* in Warsaw's suburban habitats — Białołęka Dworska (symbols as in tabs 2—6)

No.	Species \ Study area	Meadow		Forest		Average	
		N	%	N	%	$\bar{N}$	%
1	*Carabus cancellatus* Ill.	+	0.3	–	–	+	0.1
2	*Carabus nemoralis* O. F. Müll.	+	0.4	2.1	9.8	1.1	7.3
3	*Nebria brevicollis* (Fabr.)	1.4	17.1	1.6	7.4	1.5	9.9
4	*Nothiophilus palustris* (Duft.)	×	–	0.4	1.9	0.2	1.3
5	*Clivina fossor* (L.)	–	–	×	–	×	–
6	*Broscus cephalotes* (L.)	+	0.4	–	–	+	0.2
7	*Asaphidion flavipes* (Duft.)	–	–	×	–	×	–
8	*Bembidion properans* (Steph.)	–	–	+	0.2	+	0.2
9	*Bembidion guttula* (Fabr.)	–	–	×	–	×	–
10	*Epaphius secalis* (Payk.)	0.1	1.2	0.1	0.5	0.1	0.7
11	*Trechus quadristriatus* (Schrank)	–	–	×	–	×	–
12	*Patrobus atrorufus* (Stroem)	+	0.4	–	–	+	0.2
13	*Panageus bipustulatus* (Fabr.)	–	–	+	0.2	+	0.2
14	*Amara plebeja* (Gyll.)	×	–	×	–	×	–
15	*Amara aenea* (De Geer)	0.6	7.3	0.1	0.5	0.4	2.6
16	*Amara convexior* Steph.	0.1	1.2	–	–	+	0.2
17	*Amara famelica* Zimm.	0.2	2.4	+	0.1	0.1	0.7
18	*Amara familiaris* (Duft.)	0.3	3.6	×	–	0.1	0.7
19	*Amara similata* (Gyll.)	0.1	1.2	+	0.2	0.1	0.7
20	*Amara bifrons* (Gyll.)	0.1	1.2	+	0.2	0.1	0.7
21	*Amara aulica* (Panz.)	0.1	1.2	–	–	0.1	0.7
22	*Amara equestris* (Duft.)	1.0	12.2	–	–	0.5	3.3
23	*Stomis pumicatus* (Panz.)	+	0.4	–	–	+	0.2
24	*Pterostichus caerulescens* (L.)	0.1	1.2	0.1	0.5	0.1	0.7
25	*Pterostichus cupreus* (L.)	+	0.4	0.3	1.4	0.2	1.3
26	*Pterostichus vernalis* (Panz.)	0.1	1.2	+	0.2	0.1	0.7
27	*Pterostichus oblongopunctatus* (Fabr.)	–	–	0.7	3.3	0.3	2.0
28	*Pterostichus niger* (Schall.)	–	–	0.2	0.9	0.1	0.7
29	*Pterostichus vulgaris* (L.)	0.2	2.4	4.8	22.3	2.5	16.5
30	*Calathus ambiguus* (Payk.)	+	0.4	0.1	0.5	0.1	0.7

1	2	3	4	5	6	7	8
31	*Calathus erratus* (C. R. Sahlb.)	–	–	0.1	0.5	+	0.2
32	*Calathus fuscipes* (Goeze)	1.3	15.9	0.3	1.4	0.8	5.3
33	*Calathus mollis* (Marsh.)	–	–	0.1	0.5	+	0.2
34	*Dolichus halensis* (Schall.)	+	0.3	0.3	1.4	0.1	0.7
35	*Synuchus nivalis* (Panz.)	–	–	0.1	0.5	0.1	0.7
36	*Agonum gracilipes* (Duft.)	–	–	×	–	×	–
37	*Badister bipustulatus* (Fabr.)	×	–	0.4	1.9	0.2	1.3
38	*Badister dilatatus* Chaud.	+	0.4	–	–	+	0.2
39	*Anisodactylus binotatus* (Fabr.)	–	–	+	0.2	+	0.2
40	*Anisodactylus signatus* (Panz.)	–	–	+	0.2	+	0.2
41	*Harpalus rufipes* (De Geer)	2.0	24.4	8.7	40.5	5.4	35.7
42	*Harpalus latus* (L.)	0.2	2.4	0.6	2.8	0.4	2.6
43	*Harpalus tardus* (Panz.)	–	–	+	0.2	+	0.2
44	*Bradycellus harpalinus* (Aud.-Serv.)	+	0.4	–	–	+	0.2
45	*Acupalpus dorsalis* (Fabr.)	–	–	×	–	×	–
46	*Dromius quadrimaculatus* (L.)	–	–	×	–	×	–
47	*Metabletus truncatellus* (L.)	×	–	–	–	×	–
	Total	8.2		21.5		14.9	

study areas of this type) are *Amara aenea* and *Calathus fuscipes* (C= 100%), and also *Nebria brevicollis, Amara similata, Pterostichus vulgaris, Synuchus nivalis*, and *Harpalus rufipes* (C = 87.5%). The relatively constant species are *Bembidion properans* (C = 75%), and *Nothiophilus palustris, Amara bifrons, Pterostichus niger, Calathus melanocephalus*, and *Harpalus affinis* (C = 62.5%).

It follows from the above statements that the species of the greatest numbers in park greenery are at the same time the most spread in habitats of that type.

In order to distinguish the faunas of particular types of urban greenery a fidelity scale (F) has been used [50]. Pawłowski [50] considers the species of at least 80% fidelity as characteristic of a given type of habitat. This criterion has also been applied here, however an additional condition to accept a species as characteristic was its, at least, 1% participation in the number of carabids in the whole of urban greenery (due to this, accidental species have been eliminated). Moreover, the species occurring in small numbers (below 1%) but of absolute fidelity (F = 100%) in a given type of greenery (so-called not numerous exclusive species) have also been distinguished; it has been also estimated whether they are ecologically connected with a given type of habitats.

It has been determined that there are no species characteristic of park greenery. Moreover, 3 out of 9 not numerous, exclusive species (Tab. 12) (*Panageus bipustulatus, Amara municipalis, Harpalus anxius*) occur in the least typical park only (P 1), and *Acupalpus exiguus* (a peat-bog species) is undoubtedly an accidental element in the centre of the city.

Tab. 9. Occurrence and numbers of *Carabidae* in wooded areas of rural parks — Młochów and Radziejowice (symbols as in the tabs 2—6)

No.	Species \ Locality	Młochów N	Młochów %	Radziejowice N	Radziejowice %	Average N	Average %
1	*Carabus auronitens* Fabr.	0.1	1.5	–	–	+	0.3
2	*Carabus nemoralis* O. F. Müll.	–	–	+	0.2	+	0.1
3	*Carabus hortensis* L.	0.1	1.5	0.1	0.5	0.1	0.7
4	*Nebria brevicollis* (Fabr.)	2.8	42.4	16.4	78.4	9.6	69.6
5	*Nothiophilus biguttatus* (Fabr.)	0.3	4.5	+	0.2	0.2	1.4
6	*Nothiophilus palustris* (Duft.)	–	–	0.1	0.5	+	0.3
7	*Loricera caerulescens* (L.)	0.1	1.5	0.2	1.0	0.2	1.4
8	*Clivina fossor* (L.)	–	–	0.2	1.0	0.1	0.7
9	*Asaphidion flavipes* (L.)	+	0.4	–	–	+	0.1
10	*Bembidion lampros* (Herbst)	0.1	1.5	0.2	1.0	0.2	1.4
11	*Bembidion ustulatum* (L.)	0.1	1.5	–	–	+	0.3
12	*Epaphius secalis* (Payk.)	–	–	0.9	4.3	0.5	3.6
13	*Trechoblemus micros* (Herbst)	–	–	+	0.2	+	0.1
14	*Patrobus atrorufus* (Stroem)	–	–	0.1	0.5	+	0.3
15	*Amara plebeja* (Gvll.)	×	–	0.1	0.5	+	0.3
16	*Amara aenea* (De Geer)	–	–	0.1	0.5	+	0.3
17	*Amara similata* (Gyll.)	1.0	15.1	–	–	0.5	3.6
18	*Amara fulva* (O. F. Müll.)	–	–	×	–	×	–
19	*Stomis pumicatus* (Panz.)	0.1	1.5	–	–	+	0.3
20	*Pterostichus oblongopunctatus* (Fabr.)	0.1	1.5	–	–	+	0.3
21	*Pterostichus niger* (Schall.)	0.2	3.0	0.6	2.9	0.4	2.9
22	*Pterostichus vulgaris* (L.)	0.5	7.6	1.5	7.2	1.0	7.2
23	*Calathus melanocephalus* (L.)	–	–	0.1	0.5	+	0.3
24	*Synuchus nivalis* (Panz.)	+	0.5	+	0.2	+	0.2
25	*Agonum assimile* (Payk.)	0.9	13.6	0.1	0.5	0.5	3.6
26	*Agonum dorsale* (Pont.)	+	0.4	–	–	+	0.1
27	*Badister lacertosus* Sturm	–	–	+	0.2	+	0.1
28	*Harpalus punctatulus* (Duft.)	0.1	1.5	–	–	+	0.3
29	*Harpalus rufipes* (De Geer)	+	0.5	–	–	+	0.1
	Total	6.6		20.9		13.8	

The average index of number of *Carabidae* in park greenery is 6.8 (±2.0)[1] and ranges from 3.2 (P 2) to 17.8 (P 1). Thus, two study areas similar in some respect have shown extreme results — both areas lie at the border of the city's closely built-ap areas, both are adjacent to forest areas and due to this are least affected by urbanization pressure of all the parks studied. The feature which essentially differentiates them is the condition of horticultural management; park P 1 is left nearly completely without cultivation treatments, while park P 2 is managed like a typical city-centre park. The number of the carabid community in P 1 study area considerably exceeds the numbers in the remaining parks, whereas the number of carabids in P 2 is strikingly close

[1] The confidence interval determined by the standard error of the mean at 0.95 confidence level (according to Student t-test).

Tab. 10. Occurrence and numbers of *Carabidae* in rural parks' lawns — Młochów and Radziejowice (symbols as in tabs 2—6)

No.	Species \ Locality	Młochów		Radziejowice		Average	
		N	%	N	%	N	%
1	*Carabus auronitens* Fabr.	0.1	1.2	–	–	+	0.2
2	*Carabus granulatus* L.	0.3	3.7	–	–	0.2	3.1
3	*Nebria brevicollis* (Fabr.)	2.6	32.5	2.9	58.7	2.8	43.1
4	*Nothiophilus palustris* (Duft.)	+	0.5	×	–	+	+
5	*Loricera caerulescens* (L.)	0.2	2.5	–	–	0.1	1.5
6	*Clivina collaris* (Herbst)	–	–	0.1	2.0	+	0.2
7	*Clivina fossor* (L.)	+	0.5	–	–	+	+
8	*Bembidion lampros* (Herbst)	–	–	0.1	2.0	+	0.2
9	*Bembidion quadrimaculatus* (L.)	–	–	×	–	×	–
10	*Amara aenea* (De Geer)	0.4	5.0	0.3	6.1	0.4	6.2
11	*Amara familiaris* (Duft.)	0.3	3.7	0.2	4.1	0.3	4.6
12	*Amara similata* (Gyll.)	0.3	3.7	–	–	0.2	3.1
13	*Pterostichus caerulescens* (L.)	0.1	1.2	–	–	+	0.2
14	*Pterostichus vernalis* (Panz.)	+	0.5	+	0.8	+	+
15	*Pterostichus niger* (Schall.)	0.1	1.2	–	–	+	0.2
16	*Pterostichus vulgaris* (L.)	1.0	12.5	0.5	10.1	0.8	12.3
17	*Calathus fuscipes* (Goeze)	0.3	3.7	0.4	8.1	0.4	6.2
18	*Calathus melanocephalus* (L.)	+	0.5	–	–	+	+
19	*Synuchus nivalis* (Panz.)	0.3	3.7	0.3	6.1	0.3	4.6
20	*Agonum dorsale* (Pont.)	+	0.5	–	–	+	+
21	*Harpalus rufipes* (De Geer)	1.7	21.2	0.1	2.0	0.9	13.8
22	*Harpalus affinis* (Schrank)	0.1	1.2	–	–	+	0.2
23	*Harpalus latus* (L.)	+	0.5	–	–	+	+
	Total	8.0		4.9		6.5	

to the rest of these figures (Tab. 2). The intensity of horticultural operations such as the mechanical treatment of soil, mowing, removing of mowed grass and litter, maintaining lawns' monoculture, etc., is thus more important for the number of carabids than the location of an area and the intensity of other anthropogenic influences. This thesis is supported by the relatively high number of the community in P 3 park [13.3], which despite its situation in the centre of Warsaw is far less intensively cultivated than other city-centre parks.

In order to investigate the degree of differentiation of carabid communities within a given type of geenery, quotients of species similarity have been calculated. A modified Sørensen's equation has been used for this purpose [60]; the indices of numbers of particular species were substituted for the numbers of species. Thus the assumption of the dominant and accessory species' equivalence has been avoided — this being a basic fault of Sørensen's equation [6]. The figures obtained in this way determine the quantitative-qualitative similarity of communities. Such a variant of calculating similarity markedly diminishes the influence of accidental species,

Tab. 11. Occurrence and numbers of *Carabidae* in a forest of *Tilio-Carpinetum* type in Hamernia (symbols as in tabs 2—6)

No.	Species	N	%
1	*Carabus coriaceus* L.	0.1	0.7
2	*Carabus violaceus* L.	0.6	3.9
3	*Carabus convexus* Fabr.	0.1	0.7
4	*Carabus arcensis* Herbst	2.7	17.6
5	*Carabus nemoralis* O. F. Müll.	1.1	7.2
6	*Carabus hortensis* L.	4.2	27.5
7	*Carabus glabratus* Payk.	2.3	15.0
8	*Cychrus caraboides* (L.)	0.3	2.0
9	*Nebria brevicollis* (Fabr.)	0.2	1.3
10	*Nothiophilus aquaticus* (L.)	+	0.2
11	*Nothiophilus biguttatus* (Fabr.)	×	—
12	*Nothiophilus germinyi* Fauv.	+	+
13	*Loricera caerulescens* (L.)	+	+
14	*Clivina fossor* (L.)	×	—
15	*Bembidion guttula* (Fabr.)	×	—
16	*Amara plebeja* (Gyll.)	×	—
17	*Amara aenea* (De Geer)	+	0.2
18	*Amara communis* (Panz.)	+	+
19	*Amara familiaris* (Duft.)	+	0.2
20	*Amara similata* (Gyll.)	×	—
21	*Pterostichus caerulescens* (L.)	0.1	0.7
22	*Pterostichus oblongopunctatus* (Fabr.)	1.3	8.5
23	*Pterostichus niger* (Schall.)	1.4	9.2
24	*Pterostichus vulgaris* (L.)	0.1	0.7
25	*Pterostichus nigrita* (Fabr.)	×	—
26	*Pterostichus strenuus* (Panz.)	+	+
27	*Calathus erratus* (C. R. Sahlb.)	+	+
28	*Calathus micropterus* (Duft.)	0.3	2.0
29	*Synuchus nivalis* (Panz.)	0.3	2.0
30	*Agonum assimile* (Payk.)	+	+
31	*Anisodactylus binotatus* (Fabr.)	×	—
32	*Harpalus affinis* (Schrank)	+	0.2
33	*Harpalus autumnalis* (Duft.)	×	—
34	*Harpalus latus* (L.)	+	0.2
35	*Bradycellus collaris* (Payk.)	×	—
36	*Acupalpus brunnipes* (Sturm)	×	—
37	*Dromius agilis* (Fabr.)	×	—
38	*Dromius quadrimaculatus* (L.)	×	—
39	*Metabletus foveatus* (Fourcr.)	×	—
40	*Metabletus truncatellus* (L.)	×	—
	Total	15.3	

it also eliminates errors resulting from unequal periods of investigation in the compared study areas.

The figures indicating the similarities of the *Carabidae* communities from the parks studied are contained in Table 13. The average similarity between communities from any two parks is 74%. The least similarity

Tab. 12. Characteristic species (A), and scarce, exclusive species (B) of all particular habitats of urban greenery (species occurring undoubtedly accidentally have been put into brackets; species occurring only in study areas the least typical of a given kind of habitat have been marked with an asterisk)

	Lawns		
	parks	housing estates	streets
A	—	Amara aulica	—
B	**Panagenus bipustulatus* *Bembidiom bigutatum* *Amara municipalis* **Harpalus anxius* *Acupalpus brunnipes* (*Acupalpus exiguus*) *Dromius laeviceps* *Dromius quadraticollis* *Dromius quadrimaculatus*	*Trechus austriacum* *Dolichus halensis* *Harpalus progrediens* (*Zabrus tenebrioides*)	(*Agonum fuliginosum*)

	Wooded areas	Allotments
A	*Pterostichus oblongopunctatus*	*Clivina collaris* *Broscus cephalotes* *Bembidion ustulatum* *Anisodactylus binotatus*
B	*Carabus auronitens* *Carabus convexus* *Carabus hortensis* *Carabus glabratus* *Cychrus caraboides* *Leistus rufescens* *Elaphrus aureus* *Patrobus atrorufus* *Pterostichus strenuus* *Agonum viduum* *Badister kineli* *Licinus depressius* *Harpalus punctatulus* *Harpalus quadripunctatus* *Bradycellus collaris*	*Carabus granulatus*

(29%) is between parks P 1 and P 2 (at the same time the most different on the score of the numbers of communities) despite their similar locations and the fact that the carabid communities from forest areas neighbouring on the two parks (W 12, W 1) feature relatively big similarity — 66%, one of the highest in case of urban wooded areas (Tab. 18). The difference in numbers of the communities itself is not the reason of such a low quantitative-qualitative similarity between P 1 and

P 2 study areas, as the "strictly" qualitative similarity (according to the classical Sørensen's equation) is in this case 21%, i.e. still less. The minute similarity between the faunas of both parks is another proof of the decisive role of agrotechnical treatments in the formation of *Carabidae* communities in urban greenery.

Tab. 13. Quantitative-qualitative similarities of *Carabidae* communities in particular study areas of urban greenery — park greenery

	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	Average
P 1		29	65	84	54	61	36	57	55
P 2	29		67	62	82	67	57	64	61
P 3	65	67		94	88	92	82	93	83
P 4	84	62	94		89	85	81	80	82
P 5	54	82	88	89		86	86	87	82
P 6	61	67	92	85	86		79	92	80
P 7	36	57	82	81	86	79		76	71
P 8	57	64	93	80	87	92	76		78
Average									74

As expected, the fauna of carabids in the peripheral and uncultivated park P 1 differs most in its nature from the communities in the remaining study areas. It has the smallest (55%) figures for the average similarity to the fauna of other parks (Tab. 13). The greatest similarity is featured by the communities from park P 3 (average — 83%), and also P 4 and P 5 (82% each). It was determined that the study area most typical of the fauna of *Carabidae* in Warsaw's park greenery is the park at the Cemetery-Mausoleum of Soviet Soldiers (P 5) (Tab. 2). This choice is substantiated by the smallest similarity between the carabid community from this park and P 1 (a non-typical park area), and the high, frequent also in other parks, domination of *Pterostichus vulgaris*, and the number of the community, close to the average for the whole of park greenery. Moreover, this community has no characteristic exclusive species ($F = 96\%$ within park greenery; $N > 1\%$ within urban greenery). In the least typical park P1 there were as many as 3 such species: *Amara bifrons, A. municipalis, Calathus erratus.*

HOUSING ESTATES' GREENERY

With respect to species composition the greenery of housing estates is second rich only to park greenery, but the difference is quite significant. 66% of species found in lawn greens occur here, as well as 48% of species recorded in the whole urban greenery. On the average, 18 species of carabids occur in every study area of lawn greenery, which is fewer than in the parks, however parks are usually much larger areas. The greatest number of species (26) was found in the community of a ruderal green square at Nowolipki (H 3), the smallest (9) — in that of a city-centre lawn at Piękna Street (H 8) (Tab. 3).

The dominating group in the fauna of the housing estates consists of *Pterostichus vulgaris* (21.5%), *Bembidion properans* and *Calathus fuscipes* (13.5% each), *Harpalus rufipes* (9.2%), *Nebria brevicollis* (8.5%), *Harpalus affinis* (6.2%), *Amara aenea* (5.4%), and *Pterostichus virens* (5.0%). Five of these species are main dominants in particular communities: *Bembidion properans* is the most numerous species in 4 study areas (H 5, H 6, H 8, H 10), and *Pterostichus vulgaris* is a dominant of 3 communities (H 1, H 2, H 3), *Calathus fuscipes* (H 7), *Amara aenea* (H 9), and *Pterostichus virens* (H 4) dominate in the remaining study areas.

The constant species in the housing estates are *Calathus fuscipes* (C = 100%), *Bembidion properans, Amara aenea,* and *Harpalus rufipes* (C = 90%), and also *Pterostichus vulgaris, Calathus melanocephalus,* and *Harpalus affinis* (C = 80%). The relatively constant are: *Amara bifrons* (C = 70%), *A. similata*, and *Pterostichus virens* (C = 60%). The only of the dominating species missing here is *Nebria brevicollis* which occurs in great numbers but only in some areas of the housing estates' greenery.

A characteristic species is *Amara aulica*. Moreover, in the greenery of the housing estates 5 not numerous exclusive species occur (Tab. 12), two of which must be considered accidental: *Trechus austriacus* is a synanthrope inhabiting cellars (or caves) and under normal circumstances does not occur in wild nature [13]; *Zabrus tenebrioides* is a species strictly connected with corn cultivations (granivorous), so far never recorded within the limits of Warsaw.

The number of carabids in the housing estates is several times greater than in parks, the average index is 25.8 (± 6.6). The considerable standard mean error results from the enormous differentiation in numbers in particular study areas: from 4.6 (H 7) to 68.6 (H 2). The number of the community in the Za Żelazną Bramą housing estate (H 7) corresponds to the numbers of carabids in intensively cultivated park lawns. This is undoubtedly connected with the condition of maintenance and the intensity of cultivation work in the greenery of this study area. The most numerous communities occur in the study areas with "neglected" greens — lawns with luxuriant diversified herbaceous vegetation, littered with organic wastes. The average similarity of communities in the housing estates study areas is 75% (it is not significantly different from the figure typical of parks). As in the case of the peripheral park P 1, here also the study area least similar to the rest of the study areas proved to be a peripheral housing estate H 1 (Tab. 14). The typical study area is Wierzbno (H 6) — a modern, loosely built-up housing estate with spacious green areas linked with each other. The carabid community from this housing estate (Tab. 3) shows the greatest average similarity to communities of other housing estates, the smallest similarity to the fauna of H 1 housing estate (Tab. 14), and in number close to the average for the whole of the housing estates' greenery. (Tab. 3). The Wierzbno community has no characteristic species.

Tab. 14. Quantitative-qualitative similarities of *Carabidae* communities in particular study areas of urban greenery — housing estates greenery

	H 1	H 2	H 3	H 4	H 5	H 6	H 7	H 8	H 9	H 10	Average
H 1		87	80	76	51	70	73	38	56	57	65
H 2	87		68	62	82	92	60	28	56	85	69
H 3	80	68		95	68	87	73	49	68	81	74
H 4	76	62	95		75	92	80	74	89	88	81
H 5	51	82	68	75		94	81	80	75	84	77
H 6	70	92	87	92	94		91	74	76	96	86
H 7	73	60	73	80	81	91		78	67	75	75
H 8	38	28	49	74	80	74	78		89	96	67
H 9	56	56	68	89	75	76	67	89		92	74
H 10	57	85	81	88	84	96	75	96	92		84
Average											75

Figures similar to the above-mentioned have been shown by the M.D.M. estate, extremely differing in appearance: a small backyard lawn, isolated from other parts of the greenery. The high similarity of this community of *Carabidae* to communities in the other study areas results perhaps from the characteristic habitat conditions, which are the quintessence of the human pressure (an uncovered rubbish heap, the excess of feed for pigeons, intensive treading, numerous dogs and cats). The degree of similarity of the fauna of *Carabidae* of the H 10 housing estate to the fauna of the typical H 6 housing estate is the highest (96%) among the figures obtained for all compared pairs of the study areas (Tab. 14). This degree of similarity is matched only by the communities from H 10 and H 8 — study areas situated close to one another and of analogus habitat conditions. Anyhow, the correlation between local conditions, especially the type of vegetation and greenery landscaping, and the nature of carabid communities is common. There is, for instance, an extremely high similarity (95%) between the faunas of H 3 and H 4 housing estates — areas with ruderal vegetation, and also from H 5, and H 6 housing estates (94%) — related on the score of the vegetation structure. On the other hand, however, despite the great differentiation of the greenery of housing estates, a tendency towards the unification of fauna can be noticed, expressing itself in an extremely high (higher even than in parks) average similarity of carabid communities.

STREET GREENERY

Fewer species of carabids occur in street greens than in any other type of urban greenery. The species recorded here constitute 57% of the carabid fauna of lawn greenery and 42% of the fauna of the whole urban greenery. The mean number of species in a community (14) is also the smallest here. Most species (27) are to be found at Żwirki i Wigury Avenue (St 3) — an area of 3 strips of greenery, situated between the Cemetery--Mausoleum of Soviet Soldiers (P 5) and the Rakowiec housing estate (H 4). The smallest number of species (6) has been recorded in Ujazdowskie Avenue (St 5), where the road-side lawn is very thin, devastated by salt and fumes. The great number of species in the St 3 study area stems from the streaklike arrangement of lawns and their location between two different complexes of greenery: the P 5 park and the greenery of the H 4 housing estate. In the respective strips of the area in question there occur (counting from the park) 19, 17, and 13 species of *Carabidae*.

The group of dominants in street greens consists of 9 species (more than in other types of greenery): *Calathus fuscipes* (21.7%), *Amara aenea* and *Harpalus rufipes* (11.7% each), *Pterostichus virens* (10.0%), *Bembidion properans*, *Pterostichus vulgaris*, and *Harpalus affinis* (8.3% each) and also *Nebria brevicollis* and *Harpalus vernalis* (5.0% each). As many as 6 different species are main dominants in the communities of the respective study areas: *Amara aenea* (St 6, St 8, St 9), *Calathus fuscipes* (St 1, St 5), *Pterostichus virens* (St 3, St 7), *P. vulgaris* (St 2), *Harpalus rufipes* (St 10), and *H. affinis* (St 4).

There are, however, few species of high constancy of occurence. The constant species are only *Harpalus rufipes* and *H. affinis* (C = 100%), and *Amara aenea* and *Calathus fuscipes* (C = 90%); relatively constant: *Bembidion properans* (C = 70%), and also *Amara bifrons* and *Pterostichus virens* (C = 60%). Thus, the fauna of street lawns is very diversified.

There are no characteristic species in street greenery, and *Agonum fuliginosum* (a coastal species), one of only two exclusive forms (Tab. 12), is undoubtedly an accidental element.

Communities in the street greenery are the least numerous — their numbers are on the average 6.0 (± 1.4). This figure is not statistically different from the average for park greenery. It is probably connected with the way street greens are cultivated, which is similar to that of park greens, and suggests that traffic pollution has little influence on the total number of carabids. The greatest number of carabids (16.5) were recorded on the lawn at Woronicza Street (St 1). This result is considerably different from the remaining ones. The St 1 green square is very wide, and partly shaded by trees and shrubs. Administratively it belongs to the Wierzbno housing estate (H 6), and like the housing estate lawns it is perfectly maintained (not in the sense of the intensity of cultivation but the actual condition of greenery). The great number of the local carabid community, incomparable with other areas of the street greenery, is probably due to the superiority of the human pressure over the influence of the traffic factors.

The smallest number of carabids 1.0 was found, however, in St 5 study area. In this lawn, due to its shape (very narrow) and closeness to the street, the stratocoenosis of soil and herb layer (herbaceous vegetation disappears almost completely in the middle of the vegetation season) does not actually develop. In this situation the carabids which occur there do not form a community, in the exact meaning of the word, but they remain a collection of single individuals, probably migrating from the nearby Ujazdowski Park (P 7).

The similarity between the communities from different study areas of the street greenery is 66% on the average (Tab. 15), so it is visibly smaller than in the parks and the housing estates. This supports a previous statement that the street greenery communities are more diversified among themselves than those of the parks or the housing estates. The dual carriageway partition lawn at Niepodległości Avenue (St. 8) (Tab. 4) is most representative; its average similarity to other greens is 77%. The carabid community inhabiting this study area is, at the same time, the least similar to the St 5 study area community (Tab. 15).

The fauna of carabids at Niepodległości Avenue has no characteristic species, just like at the Cemetery-Mausoleum of Soviet Soldiers and Wierzbno, study areas typical of park and housing estates' greenery.

Tab. 15. Quantitative-qualitative similarities of *Carabidae* communities in particular study areas of urban greenery — street greenery

	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	Average
St 1		92	95	46	58	67	92	79	60	71	73
St 2	92		88	65	54	52	85	63	59	57	68
St 3	95	88		70	36	62	94	86	55	73	73
St 4	46	65	70		46	51	48	87	67	92	64
St 5	58	54	36	46		28	25	51	58	54	46
St 6	67	52	62	51	28		88	72	52	63	59
St 7	92	85	94	48	25	88		89	35	60	68
St 8	79	63	86	87	51	72	89		75	94	77
St 9	60	59	55	67	58	52	35	75		69	59
St 10	71	57	73	92	54	63	60	94	69		70
Average											66

The greatest similarity occurs between the communities of St 1 and St 2 study areas (95%), St 3 and St 7 (94%), St 8 and St 10 (94%). In the first 2 cases the greens are large, and neighbour on big complexes of greenery, and in the third, small and isolated (although one is circular — St 8, the other long and narrow — St 10).

The fauna of street lawns shows great similarity to the fauna of the neighbouring vast areas of greens: parks, housing estates, allotments. This situation may well be illustrated by the relations between carabid communities in a sequence of plots lying along one line: P 5 (park), St 3 I (a lawn between a park and a carriage-way), St 3 II (a dual carriage-way partition lawn), St 3 III (a lawn between a carriage-way and a housing estate), H 4 (a housing estate). The closer a given plot is situated to a large area of greenery (a park or a housing estate), the more is its fauna similar to the fauna of that area (Fig. 6). It is alike with other greens. The similarity between the communities of street greens lying near parks, housing estates, or allotments and the communities of these areas is 77% on the average, and without taking into account the St 5 study area, where it can barely be referred to as a community, as much as 86%. In both cases it is more than the average similarity of fauna within street communities, and even within parks or housing estates themselves. This supports the thesis on the existence of an extensive exchange of fauna between the areas of urban greenery separated by barriers such as a pavement or even a street (e.g. the similarity between the communities from the dual carriage-way partition lawn at Marszałkowska Street — St 7 and Saski Garden — P 8), study areas separated by a busy carriage-way and tram tracks, amounts to 91%).

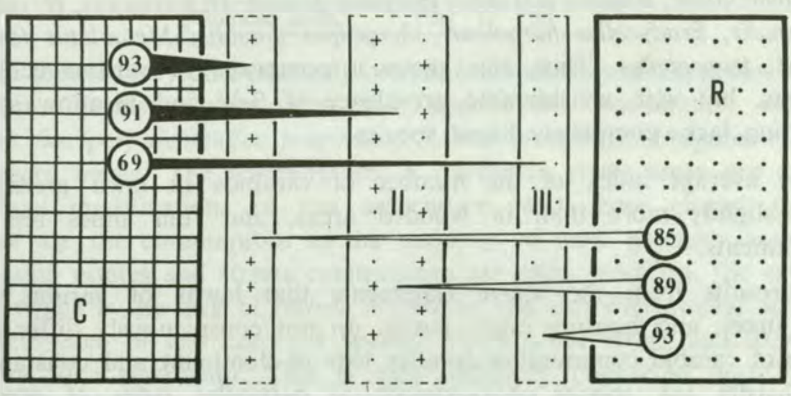


Fig. 6. The influence of a big greenery complex on the carabid fauna of street greens. C — P 5 park; R — H 4 housing estate; I, II, III — the consecutive plots of the St 3 study area; the figures denote the values of qualitative-quantitative similarity of the communities

LAWN GREENERY IN GENERAL

Lawns in the parks, the housing estates and the streets of Warsaw are together inhabited by 73% of the species of *Carabidae* recorded in the whole of urban greenery (Tab. 7). Altogether the following species dominate here: *Pterostichus vulgaris* (18.6%), *Calathus fuscipes* (15.5%), *Bembidion properans* (10.8%), *Nebria brevicollis* (9.3%), *Harpalus rufipes* (8.5%), *Amara aenea* (7.0%), *Pterostichus virens* and *Harpalus affinis* (5.4% each). Subdominants are *Calathus melanocephalus* (3.9%), *Amara bifrons* (3.1%), and *Amara aulica* (1.5%).

Constant species in lawn greenery (regardless of its type) are *Calathus fuscipes* (C = 96%), *Amara aenea*, and *Harpalus fuscipes* (C = 93%), *Harpalus affinis* (C = 82%), and *Bembidion properans* (C = 79%). Relatively constant: *Pterostichus vulgaris* (C = 71%), *Amara bifrons* and *Calathus melanocephalus* (C = 64%), *Nebria brevicollis* (C = 61%), and *Pterostichus virens* (C = 54%).

The insignificant number of species characteristic of each type of lawn greenery, in comparison to the specificity of fauna in other types of urban greenery (wooded areas and allotments) (Tab. 12) allows us to determine species characteristic of lawns as one category of the habitat. These species are *Bembidion properans*, *Amara bifrons*, *A. aulica*, *Pterostichus virens*, and *Calathus melanocephalus*, species of open areas, field or ubiquitous; xerophilous or mesohygrophilous. Not numerous exclusive species in lawns (species occurring in at least two types of greenery and not occurring in wooded areas and allotments have been included here are *Cicindela germanica*, *Nothiophilus aquaticus*, *Bembidion guttula*, *Trechoblemus micros*, *Amara plebeja*, *A. apricaria*, *A. equestris*, *Pterostichus caerulescens*, *P. cupreus*, *P. vernalis*, *Calathus ambiguus*, *Agonum gracilipes*, *A. sexpunctatum*, *Badister dilatatus*, *Harpalus griseus*, *H. psittaceus*, *H. rubripes*, *H. vernalis*, *Bradycellus harpalinus*, *Acupalpus dorsalis*, *Metabletus foveatus*, and *M. truncatellus*. Thus, this group is composed of various ecological elements, but with considerable prevalence of field and meadow species; the group lacks completely forest species.

The average index of the number of carabids in lawn greenery is 12.9 — slightly more than in wooded areas, and four times less than in allotments.

It results from the above statements that lawns of various types: park, street, and housing estate lawns, do not conspicuously differ in the nature of carabid communities (similar lists of dominant and constant species, hardly any species characteristic of particular types of greenery). This situation is corroborated by the great similarity of the faunas of park, street, and housing estates' greenery. On the average this similarity is 96%, whereas the average similarity index of the three kinds of lawn greenery to the fauna of wooded areas equals 75% (Tab. 16).

Tab. 16. Quantitative-qualitative similarity of the fauna of *Carabidae* from various habitats of urban greenery

		Lawns			Wooded areas
		street	housing estates	park	
Lawns	park		98	94	83
	housing estates	98		96	76
	street	94	96		66
Wooded areas		83	76	66	

The faunas of particular types of lawn greenery are very similar to one another also with respect to Kulczyński's index. The subject of the analysis is in this case a set of species common to the compared habitats [71]. Thus calculated average similarity of the fauna of park, street, and housing estates' greenery is 85%, and the average similarity between the fauna of lawn habitats and the fauna of wooded areas — 71% (Tab. 17).

Tab. 17. Similarity of constancy of the fauna of *Carabidae* from various habitats of urban greenery

		Lawns			Wooded areas
		street	housing estates	park	
Lawns	park		84	84	71
	housing estates	84		88	71
	street	84	88		70
Wooded areas		71	71	70	

Then there is only one, relatively constant, association of *Carabidae* which occurs in Warsaw's lawns. Its main species are *Pterostichus vulgaris*, *Calathus fuscipes*, *Bembidion properans*, *Nebria brevicollis*, *Harpalus rufipes*, and *Amara aenea*. The communities in particular study areas are at the very most modifications of this association, and those closest to the standard are the communities in the majority of park greenery areas. In the housing estates and streets communities are often modified, the extreme sign of which is the lack of *Nebria brevicollis* and (or) *Pterostichus vulgaris*. The occurrence of less constant species, *Pterostichus virens* and *Harpalus affinis*, is also significant. This is only indirectly connected with localization and the utilization of a green area (park, street, housing estate). Habitat conditions are of decisive importance here, especially the degree of moisture (or rather aridity) in soil.

The species *Nebria brevicollis* and *Pterostichus vulgaris* are more (*N. brevicollis*) or less (*P. vulgaris*) hygrophilous. They do not have opposing thermic requirements either: *N. brevicollis* is a thermophilous species, *P. vulgaris* is eurythermophilous. It seems that the main factor restricting their occurrence in towns is excessive aridity, characteristic of street lawns and many housing estate lawns. *N. brevicollis* does not occur, or occurs in small numbers ($N < 1\%$), in the lawns of only two studied parks, and it does not occur in as many as 7 study areas in the housing estates and 6 in streets. *P. vulgaris*, more tolerant, does not occur in 1 park, 4 housing estates, and 5 street greens. In all areas where there is no *P. vulgaris*, *N. brevicollis* does not occur either. Apart from the street greens where the aridity of soil is almost a rule, these are usually areas of large lawns, open to a considerable extent (e.g. H 3, H 4) or areas situated in the city centre within built-up areas and busy thoroughfares (P 8, H 10).

The influence of humidity (dependent on shading) exceeds the influence of chemical pollution, at least some of it. For instance, in an open housing estate green (H 6 I) where the lead content in soil is 43 ppm. [12], *N. brevicollis* does not occur at all, while at a nearby street, which is shaded, green St 1 where the lead content is 131 ppm., the number of this species is 1.7, and the participation in the community 10.3%. It is alike with *P. vulgaris*. It almost does not occur at all in an arid and large dual carriage-way partition lawn St 7 (120 ppm. Pb), whereas it is a dominant (25.7%) in the community at a shaded lawn St 3 I (161 ppm. Pb).

N. brevicollis finds the lawns at the P 1 park too arid, despite the direct neighbourhood of Bielański Forest (W 12) where this species is very numerous.

Nebria brevicollis and *Pterostichus vulgaris*. which leave certain areas because of unfavourable living conditions, are usually replaced by 2 xerophilous field species: *Pterostichus virens* and *Harpalus affinis*. These species show great resistance to the environment pollution, especially *H. affinis*, numerous in a dual carriage-way partition lawn St 8, where the lead content in soil amounts to 210 ppm.

The studied habitats of urban lawn greenery, arranged in a series of increasing anthropogenic influences compose a gradient: parks — housing estates — streets. This order is imposed by the amounts of general urbanization influence, and also by the sum of the main components of the pressure (Tab. 1). Together with the growth of urbanization influences the internal differentiation of the fauna of carabids also increases (the variety of communities within park greenery is far smaller than within street greenery). It seems that where the pressure (which is a combination of various factors of different intensity) is stronger, there the specificity of local habitat conditions is greater and, consequently, the reflection of that state in the local fauna is more visible.

WOODED AREAS

Carabids found in the wooded areas of Warsaw constitute 48% of the species composition of *Carabidae* in the whole of urban greenery. On the average 13 species occur in every study area (in lawns: 19). The differentiation of the communities' composition is immense: from 5 (W 2) to 27 (W 11) species (Tab. 5).

The dominating species in wooded areas are *Nebria brevicollis* (22.4%), *Carabus nemoralis* (13.1%), *Pterostichus oblongopunctatus* (9.3%), and *Carabus auronitens, C. hortensis*, and *Pterostichus vulgaris* (5.6% each). Only two among those species (*N. brevicollis* and *P. vulgaris*) are also dominants in lawn greenery. The main dominants in the communities of particular study areas are 8 different species, i.e. almost every area has its own dominant. This clearly reflects the great variety of habitat conditions in the wooded areas of urban greenery. Only 2 species dominate in 3 study areas at the time: *Nebria brevicollis* (W 5, W 6, W 10) and *Pterostichus oblongopunctatus* (W 4, W 11, W 12). The dominance of the remaining species is not repeated elsewhere (the remaining species dominate in one habitat each: *Carabus auronitens* — W 1, *C. nemoralis* — W 9, *Licinus depressus* — W 8, *Calathus erratus* — W 3, *Pterostichus vulgaris* — W 7, *Harpalus winkleri* — W 2).

Wooded areas are more similar to lawn greenery on the score of the constancy of the occurrence of particular species than with respect to dominance. The constant species are *Nebria brevicollis* (C = 100%), and *Carabus nemoralis* (C = 91.5%); the relatively constant: *Pterostichus vulgaris* and *Harpalus winkleri* (C = 66.5%), and also *Amara aenea, Calathus fuscipes*, and *Agonum assimile* (C = 58,5%). Thus, missing from the group of dominating species are *Carabus auronitens, C. hortensis*, and *Pterostichus oblongopunctatus*, which are abundant only locally, mostly in peripheral areas (Tab. 5).

The species characteristic of wooded areas is *Pterostichus oblongopunctatus*. There are, moreover, as many as 15 not numerous exclusive species (Tab. 12). This fact makes a clear distinction between urban wooded areas and the greenery of the lawn type.

The index of the number of carabid communities in the wooded areas is 10.1 on the average (± 2.4) (in lawns: 12.9) and ranges from 0.7 to 25.8 (!). The smallest number occurs at W 4 — a study plot within a park and undergoing especially intensive horticultural and maintenance operations. This place is nearly completely devoid of litter (systematically raked away) and herbaceous vegatation; hence the survival of an original forest community of *Carabidae* is not possible there, and neither is the formation of a community characteristic of lawns, composed of species of open areas. Carabids are most abundant in the W 11 study area, a lime-oak-hornbeam stand, relatively little transformed and barely accessible to people.

The communities of particular study areas differ considerably between themselves, more than those in the parks, housing estates, or even streets. The average similarity of the communities in wooded study areas is only 46%. This figure is essentially different ($P < 0.01$) from analogus figures for lawn greenery study areas.

The carabid community least similar to the remaining ones is that of the W 4 study area (average similarity — 10%); it is the one quantitatively and qualitatively most degraded. The most typical ones are the communities of W 10 (average similarity — 64%) and W 5 (63%) (Tab. 18). Of these the Sejm (W 5) has been determined as the area with a community most representative of wooded areas (Tab. 5), and not Kaskada (W 10), where the high dominance of *Nebria brevicollis* unduly raises the similarity to other study areas, while *Elaphrus aureus* which occupies a high position in the community does not occur anywhere else.

Tab. 18. Quantitative-qualitative similarities of *Carabidae* communities in particular study areas of urban greenery — wooded areas

	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	Average
W 1		31	28	9	56	32	34	27	42	52	62	66	40
W 2	31		56	0	79	57	64	49	68	78	23	45	50
W 3	28	56		0	71	50	39	36	58	73	14	41	42
W 4	9	0	0		6	3	0	0	2	0	32	54	10
W 5	56	79	71	6		78	81	62	75	78	48	61	63
W 6	32	57	50	3	78		67	37	64	74	31	45	49
W 7	34	64	39	0	81	67		23	86	80	27	37	49
W 8	27	49	36	0	62	37	23		49	62	17	39	36
W 9	42	68	58	2	75	64	86	49		89	41	51	57
W 10	52	78	73	0	78	74	80	62	89		53	63	64
W 11	62	23	14	32	48	31	27	17	41	53		79	39
W 12	66	45	41	54	61	45	37	39	51	63	79		53
Average													46

Communities of *Carabidae* in the urban wooded areas are relatively least unified, and their fauna is also quite clearly different from the fauna of the park, street, and housing estate greenery (Tabs 16, 17).

ALLOTMENT GARDENS

29 carabid species have been found in the studied allotment (Tab. 6), i.e. about 26% of the species composition of carabids in the whole of the city greenery. While on the average ca 30% of the species recorded in all study areas of a given type of greenery together occurred in every study area in the types of greenery discussed so far, the comparable

number of species in allotments can amount even to 90. The following species dominate in the allotment community: *Pterostichus vulgaris* (56.7%), *Nebria brevicollis* (12.2%), *Calathus fuscipes* (5.7%), and *Anisodactylus binotatus* (5. 0%). There is an extremely wide disproportion between the participation of the most abundant species in the community and the participation of the remaining ones. Such a situation is typical of strongly anthropogenic habitats [48].

Allotments are a very specific urban habitat. As many as 4 characteristic species occur there: *Clivina collaris, Broscus cephalotes, Bembidion ustulatum*, and *Anisodactylus binotatus*. Moreover, *Carabus granulatus* is a not numerous exclusive species (Tab. 12). The composition of the group of characteristic species responds to the conditions in allotments: the listed species (except for *B. cephalotes*) are definitely hygrophilous.

The number of the community in question is very high (52.3), several times exceeding the numbers of *Carabidae* in most other urban areas. The reason for this is probably the group cover in allotments, particularly favourable for carabids. Compost heaps, loosely lying pavement slabs, boxes, boards, etc., create optimum conditions for the hiding and reproduction of these beetles.

URBAN GREENERY IN GENERAL

The dominants among 113 species of *Carabidae* recorded in the urban greenery of Warsaw (Tab. 7) are *Pterostichus vulgaris* (36.9%), *Nebria brevicollis* (12.3%), *Calathus fuscipes* (8.9%), and *Harpalus rufipes* (5.9%). The subdominating species are *Bembidion properans* (4.4%), *Amara aenea* (3.4%), *Carabus nemoralis* (2.5%), *Anisodactylus binotatus* (2.5%), *Harpalus affinis* (2.5%), *Pterostichus virens* (2.0%), *Carabus cancellatus* (1.5%), *Calathus melanocephalus* (1.5%), and also *Clivina collaris, Broscus cephalotes, Bembidion ustulatum, Amara bifrons, A. aulica, Pterostichus oblongopunctatus*, and *P. niger* (1.0% each). A comparison of the above list with analogous lists of the particular types of the urban greenery leads to the conclusion that it is determined to a great extent by the relatively high numbers of many species in allotments (dominance has been determined assuming that each type of greenery has an equal share in the overall area of urban greenery).

The constant species in the whole of the urban greenery are *Calathus fuscipes* (C = 85%), *Amara aenea* (C = 83%), and *Harpalus rufipes* (C = 78%). The relatively constant species are *Nebria brevicollis* (C = 73%), *Pterostichus vulgaris* (C = 71%), *Harpalus affinis* (C = 63%), and also *Carabus nemoralis* and *Bembidion properans* (C = 56%).

There is a certain relation between the number of dominating species and the constancy of their occurrence, in the whole of the urban greenery, as well as in the lawn type greenery alone. In both cases the most abundant species, *Pterostichus vulgaris* and *Nebria brevicollis*, show smaller constancy of occurrence, while the less abundant, *Calathus fuscipes* and *Harpalus rufipes*, are the most constant. Hence the conclusion that *C. fuscipes* and *H. rufipes* are on the average better adapted to various conditions of the urban environment, while *P. vulgaris* and *N. brevicollis* prefer more strictly defined urban habitats, where, on the other hand, they may reach an immense quantitative superiority over other species. Wooded areas, allotments, and shaded lawns are the places of mass occurrence of these species.

Among the *Carabidae* of urban greenery a leading role is played by the species of open areas, especially field-oriented, mesohygrophilous or xerophilous species, adapted to poor sandy and clay soils. Forest species, characteristic of humic soil, are not infrequent, however their occurrence is usually restricted to wooded places, and even single isolated stands.

INDICES OF STRUCTURE AND THE EVALUATION OF COMMUNITIES

The structure of faunistic communities is characterized by such parameters as number (abundance), number of species, and quantitative relations between the species of particular dominance classes. Shannon's index ($\bar{H}$) is commonly used for the estimation of the degree of species diversity in communities, whereas Pielou's index of species equitability ($\bar{J}$) determines their dominance structure [73].

The numbers of carabid communities in various types of Warsaw's greenery and the numbers of species which compose these communities have already been discussed. The percentage participation of dominating species and the number of accessory species (participation smaller than 1%) have also been recognized as important elements of the structure of communities. The high participation of one species testifies to the strong influence of a determined habitat factor or a group of homogenous physico-chemical factors which have a selective role within a community. Small in numbers, accessory species, although they do not play an important role in the functioning of associations, decide to a large extent on their homeostatic abilities.

The smallest disproportion between the participation of the dominant and the participation of the remaining species is characteristic of the communities in the greenery of the housing estates. The dominating species there constitutes, on the average, 31.8% of the total number (in particular study areas from 21.8% to 49.3%). The worst situation in this respect is in the allotments — 56.7%, and in the urban wooded areas — 40.5% (24.0—56.0%) (Tab. 19).

In the allotments, however, the greatest number of accessory species occurs. The 16 species occurring there constitute 55% of the species composition of the community. The fewest accessory species occur in the communities of the wooded areas, on the average 29% of the composition (Tab. 19).

The highest indices of diversity ($\bar{H}$), averaging 2.05 (1.71—2.58) are featured by park greenery communities. The index reaches its lowest values in the wooded areas, on the average 1.71 (1.41—2.31) (Tab. 19). However, after excluding study areas with small numbers of *Carabidae* ($N < 3.0$), where organized communities practically do not exist, the habitat with the lowest $\bar{H}$ index are the allotments.

The greatest evenness with which the individuals are distributed among all species in a community, in other words, the most proper dominance structure, is a feature of the communities in the housing estates' greenery. The average $\bar{J}$ index there is 0.71 (0.56—0.86). Although this figure is higher in the street and wooded areas greenery than in the study areas of the housing estates, it nonetheless decreases after the exclusion of those areas whose communities, due to their numbers may be considered as an accidental assemblage of individuals (the $\bar{J}$ index is then respectively: 0.69 and 0.70). The definitely lowest $\bar{J}$ index (0.52) is featured by the community in the allotments (Tab. 19). The immense participation of the dominant played a decisive role here, despite the great number of accessory species.

The analysis of the data contained in Table 19 enables evaluation of carabid communities occurring in various habitats of the urban greenery on the score of their proper structure. Such an arrangement would take up the following form: the communities of the housing estates' greenery — park greenery — street greenery — wooded areas — allotments. Thus, the first positions are occupied by the lawn greenery communities. These habitats, despite considerable anthropogenization, retain certain stability, or rather, they are maintained stable artificially. Due to this, stable communities of fauna may form there. Such possibilities are far more restricted in the wooded areas and allotments. In the allotments, the reason for this is continuous cultivation and crop-rotation, while in the wooded areas, owing to the density of trees, the conditions are similar to forest conditions, hence typical urban species of open areas find adaption there difficult. On the other hand, typical forest species cannot survive everywhere, mostly because of the lack of proper ground: litter and natural herb layer. Hence the degradation of the structure of carabid communities in these habitats.

The above arrangement is based on the values of structure parameters average for all the study areas of a given type of greenery. However, in particular types of greenery these values are very different. All the areas studied have therefore been arranged according to the growing values of the $\bar{H}$ and $\bar{J}$ indices, the best measurable and, at the same time, the most synthetic parameters of the communities' structure. Special attention has been paid to those areas whose indices exceed (in plus and in minus) the boundaries of confidence interval determined by the standard mean error (Figs. 7, 8).

Tab. 19. Structure of *Carabidae* communities in various habitats of urban greenery: N — index of number; %D — proportion of a dominant; S — total number of species; S_a — number of accessory species (numbers of species found with auxiliary methods have been given in brackets); $\bar{H}$ — index of general diversity; $\bar{J}$ — index of equitability equitability

Habitat	Study area	N	%D	S	S_a	$\bar{H}$	$\bar{J}$
Park lawns	P 1	17.8	28.6	25	15	2.07	0.64
	P 2	3.3	36.4	15(+2)	–(+2)	2.06	0.76
	P 3	13.3	36.8	21	12	2.05	0.67
	P 4	3.5	25.7	29(+1)	15(+1)	2.58	0.71
	P 5	6.6	53.0	27(+5)	17(+5)	1.83	0.56
	P 6	3.3	24.2	15(+4)	–(+4)	2.31	0.85
	P 7	3.5	45.7	12	–	1.77	0.71
	P 8	3.4	53.0	19(+2)	11(+2)	1.71	0.58
	Average	6.8	37.9	20(+2)	9(+2)	2.05	0.69
Lawns of housing estates	H 1	23.2	26.3	19	8	2.09	0.71
	H 2	68.6	37.3	23	13	1.76	0.56
	H 3	49.6	32.5	26	15	2.19	0.67
	H 4	14.8	22.3	22(+1)	11(+1)	2.31	0.75
	H 5	15.7	31.2	11	4	1.91	0.80
	H 6	22.1	34.8	20(+1)	13(+1)	1.85	0.62
	H 7	4.6	21.8	10	–	1.99	0.86
	H 8	7.1	49.3	9	–	1.66	0.75
	H 9	11.5	20.0	23(+1)	12(+1)	2.40	0.76
	H 10	40.8	40.7	13	6	1.61	0.63
	Average	25.8	31.8	18	8	1.98	0.71
Street lawns	St 1	16.5	46.1	16(+1)	5(+1)	1.88	0.68
	St 2	8.3	31.3	16	10	1.68	0.60
	St 3	6.6	18.2	25(+2)	13(+2)	2.39	0.74
	St 4	2.5	36.4	10(+1)	4(+1)	1.47	0.64
	St 5	1.0	30.0	6	–	1.70	0.95
	St 6	8.2	37.8	12(+3)	–(+3)	1.83	0.74
	St 7	4.7	48.9	20	11	1.72	0.58
	St 8	6.6	27.3	8	–	1.74	0.84
	St 9	1.4	35.7	8	–	1.71	0.82
	St 10	4.0	32.5	13	4	1.69	0.68
	Average	6.0	34.4	13(+1)	5(+1)	1.78	0.73
Wooded areas	W 1	19.7	36.0	22(+2)	8(+2)	2.02	0.67
	W 2	1.9	31.6	5	1	1.49	0.93
	W 3	2.4	45.8	9(+1)	–(+1)	1.51	0.73
	W 4	0.7	42.9	6(+2)	–(+2)	1.28	0.92
	W 5	18.4	46.2	13(+2)	–(+2)	1.74	0.73
	W 6	5.6	48.2	12(+3)	–(+3)	1.40	0.64
	W 7	6.4	37.5	12(+1)	–(+1)	1.90	0.79
	W 8	5.2	34.6	8	–	1.76	0.85
	W 9	8.2	31.7	13(+1)	–(+1)	1.75	0.71
	W 10	18.4	56.0	18	6	1.95	0.67
	W 11	25.8	24.0	27(+1)	13(+1)	2.31	0.71
	W 12	8.8	51.1	16	6	1.41	0.51
	Average	10.1	40.5	13(+1)	3(+1)	1.71	0.74
Allotments		52.3	56.7	29	16	1.76	0.52

Indices of species diversity ($\bar{H}$) exceeding the boundary of the confidence interval of the mean for all the study areas (1.86 ± 0.1) are shown by communities in 5 areas of the park greenery (62.5% of the studied areas of this type), 5 housing estates areas (50%), 2 wooded areas (17%), and 1 street green (10%). The reverse arrangement occurs in the case of study areas whose $\bar{H}$ index value does not reach the lower boundary of the confidence interval. In this group there are as many as 7 street greens (70%), 7 wooded areas (58%), 2 housing estates (20%), and only 1 park (12,5%). This order remains unchanged even when the areas with communities of small numbers are excluded (Fig. 7).

A similar situation takes place in the case of the distribution of the equitability index ($\bar{J}$) values. The communities of 5 housing estate areas (50% of study areas), 3 parks (37,5%), 4 wooded areas (33%), and 3 street greens (30%) have values higher than the confidence interval of the mean (0.71 ± 0.063). The values of $\bar{J}$ lower than the confidence interval belong to the communities in the allotments, and also 4 parks (50%), 4 housing estates (40%), 4 wooded areas (33%), and 3 street greens (30%). Some changes in this arrangement are introduced by the possible exclusion of communities of extremely small numbers (Fig. 8).

It may be assumed that the communities from the study areas which appear on both lists, i.e. of $\bar{H}$ and $\bar{J}$ values higher than the range of the confidence interval, feature the most proper structure. 3 areas of the park greenery (37.5% of the studied areas): P 2, P 4, and P 6, as well as 3 housing estates' areas (30%): H 4, H 7, and H 9 belong to such areas of the most diversified communities and, at the same time, of the most proper dominance structure. There are no areas representing street greenery, wooded areas, or allotments in this group. The above data support ealier conclusions on the relatively proper structure of the communities from the park and housing estates' greenery.

The areas of the worst community structure have been determined in the same way. Among them are 3 street greens (30%): St 2, St 4, and St 7; 3 wooded areas (25%): W 4, W 6, and W 12; 1 park (12.5%): P 8; and 1 housing estate area (10%): H 10.

The unfavourable structure of the Bielański Forest (W 12) carabid community may be surprising, as the area is situated within a sizeable forest complex and, at least formally, a nature reserve. However, the part of the forest where the catches were carried out had been intensely penetrated by people (school excursions, mushroom pickers), and, moreover, the clearing of the shrubs layer and new dense plantings had been carried out. The community from the nearby W 11 area, free of that kind of anthropogenic influences, has one of the most proper structures (Figs. 7, 8).

The example below testifies to the fact of how important the condition of vegetation in the town is for the proper formation of fauna. Areas

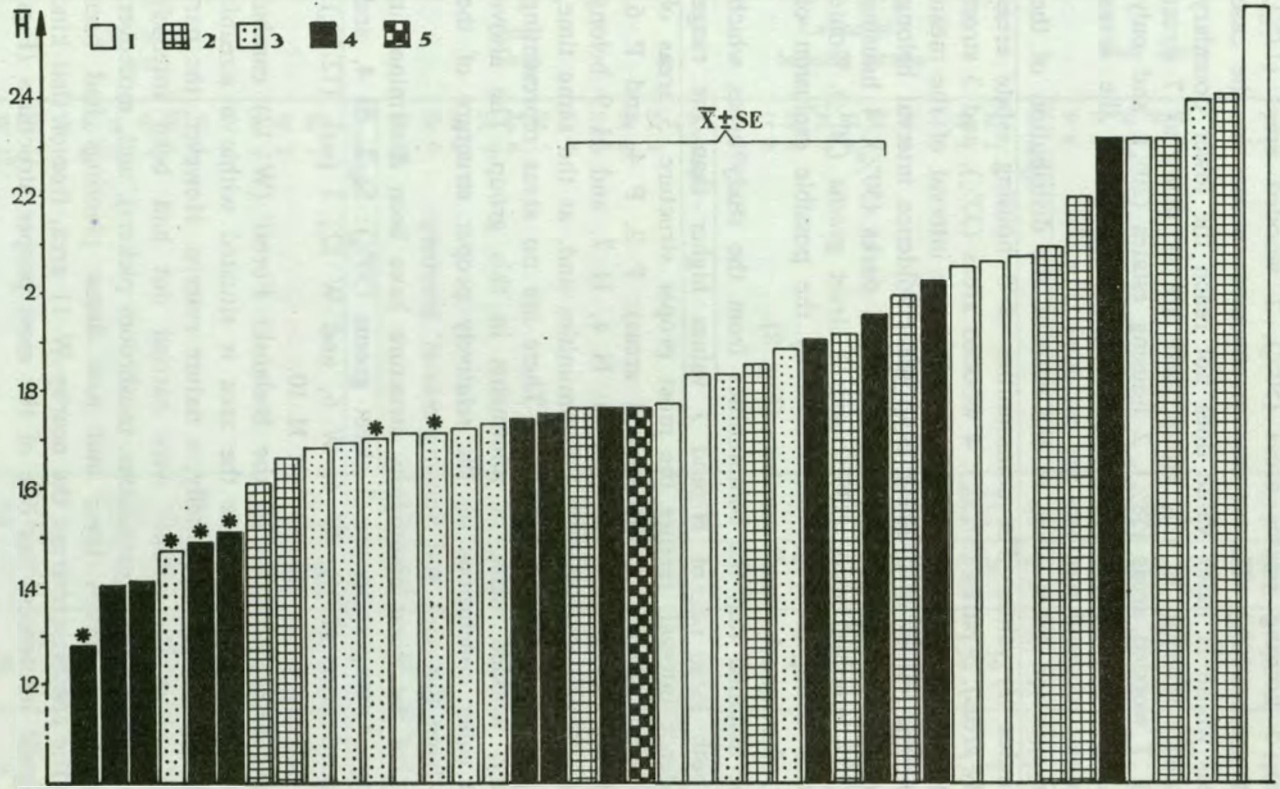


Fig. 7. The variability of the index of species diversity (H̄) of carabid communities in urban greenery. 1 — park greenery; 2 — housing estates' greenery; 3 — street greenery; 4 — wooded areas; 5 — allotments (* — communities of very low numbers; X̄ ± SE — the confidence interval set by range of the standard mean error)

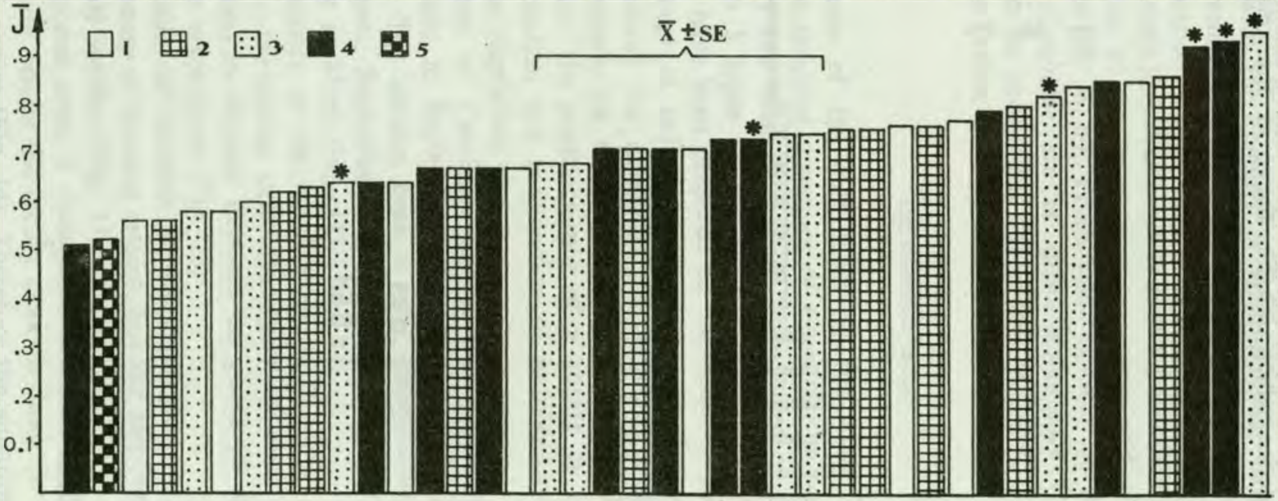
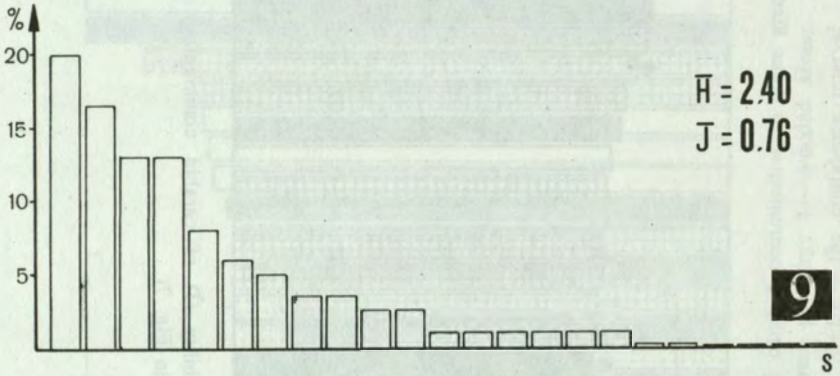


Fig. 8. The variability of the index of species equitability (J̄) of carabid communities in urban greenery (symbols as in Fig. 7)

H 9 and H 10 belong to the same type of greenery — backyard greens among the city-centre's built-up areas situated close to one another. They do, however, entriely differ in the condition of vegetation, and the communities of *Carabidae* which inhabit them, in the quality of their structure (Figs 9, 10).



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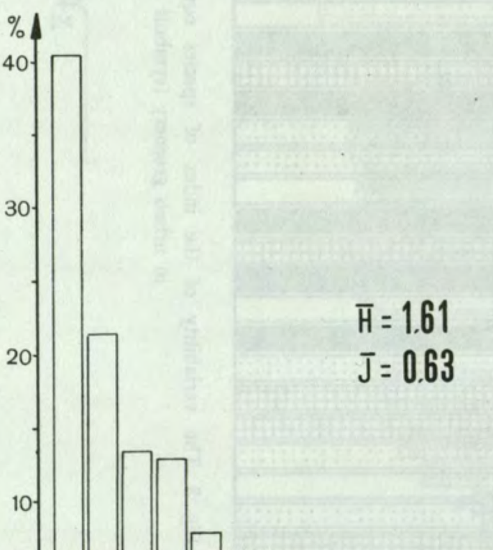

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Fig. 9 and 10. The proper domination structure of the carabid community from the H 9 study area (Fig. 9) and the unfavourable structure of the H 100 community (Fig. 10). S — species; % — proportion of particular species

PHENOLOGY AND SEASONAL DYNAMICS

The seasonal dynamics of *Carabidae* is connected with their reproductive and metamorphosis cycles. The reproductive cycle, regulated hormonally, is connected with the changes of environmental factors, mainly climatic. Hence the correlation between the phenological type and the distribution of species in various environments — both in the scale of climatic zones, and local conditions [65]. A commonly known phenomenon is the predominance of spring species in the fauna of open areas, and autumn species in the fauna of forests [26, 38, 64]. Proportions between the participation of spring and autumn *Carabidae* are of great importance for the role of their communities in an ecosystem, since each of these groups has a different function in the matter and energy cycling [27, 28].

THE SEASONAL CYCLE

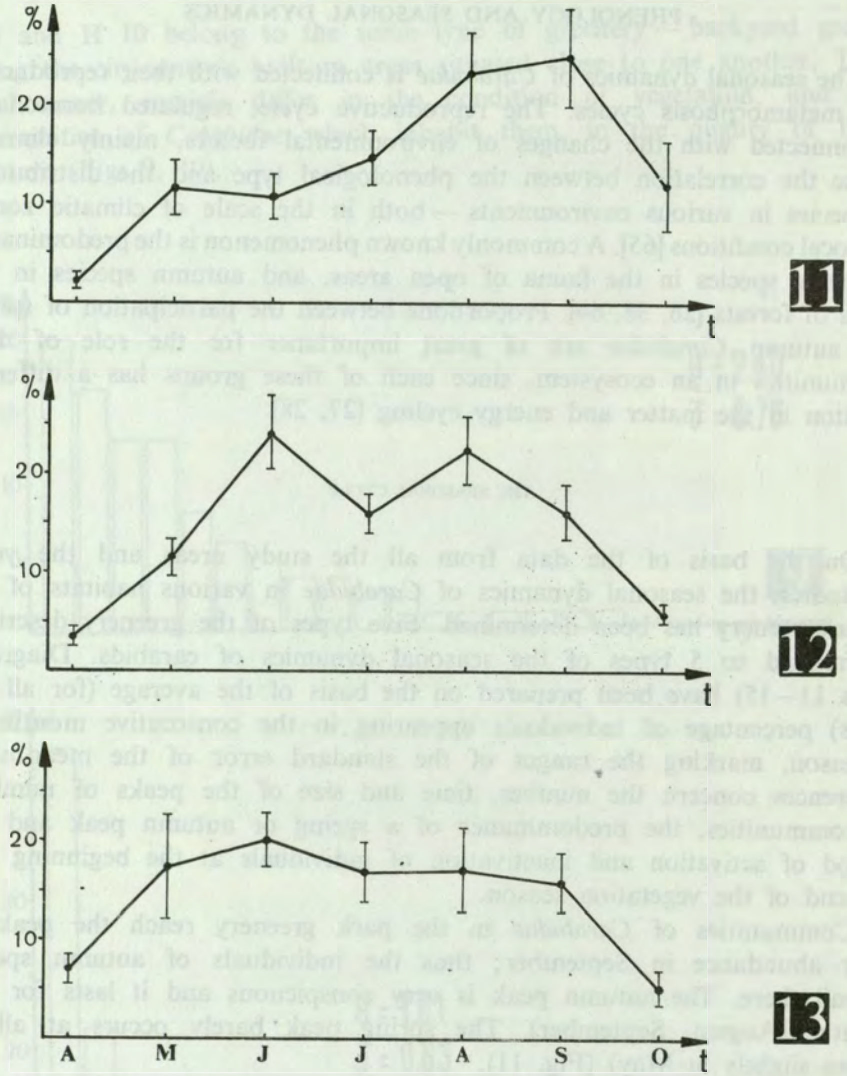
On the basis of the data from all the study areas and the years of studies, the seasonal dynamics of *Carabidae* in various habitats of the urban greenery has been determined. Five types of the greenery described are related to 5 types of the seasonal dynamics of carabids. Diagrams (Figs 11—15) have been prepared on the basis of the average (for all the areas) percentage of individuals appearing in the consecutive months of a season, marking the ranges of the standard error of the mean. The differences concern the number, time and size of the peaks of numbers of communities, the predominance of a spring or autumn peak and the period of activation and inactivation of individuals at the beginning and the end of the vegetation season.

Communities of *Carabidae* in the park greenery reach the peak of their abundance in September; thus the individuals of autumn species prevail there. The autumn peak is very conspicuous and it lasts for two months (August, September). The spring peak barely occurs at all (it shows slightly in May) (Fig. 11).

In the greenery of the housing estates 2 peaks almost equal in value are observed: the spring peak (stronger) in June, and the autumn one (slightly weaker) in August. Between the peaks (in July) a visible decrease of abundance takes place (Fig. 12).

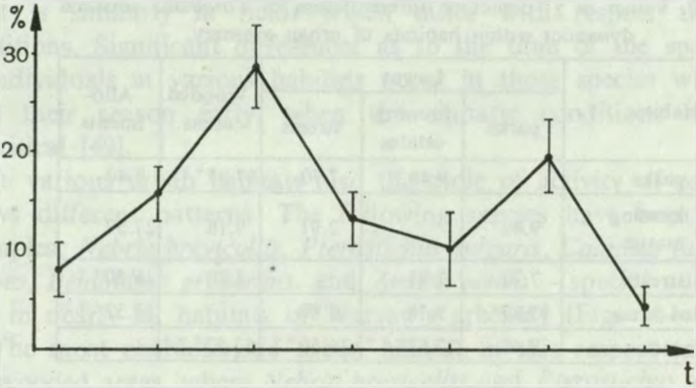
The dynamics of carabids in the street greenery is generally the same as in the greenery of housing estates, but the amplitude of seasonal changes is considerably smaller (Fig. 13).

In the wooded areas 2 clearly visible peaks of numbers take place, of which the main one is the spring peak in June. In September the weaker autumn peak occurs (Fig. 14). Therefore the situation in the urban wooded areas is completely different from the situation in natural forests where usually autumn species are dominants.



Figs 11—13. The seasonal dynamics of carabids from various types of urban greenery: park greenery (Fig. 11); housing estates' greenery (Fig. 12); street greenery (Fig. 13). t — time in months — from April to October; % — percentage of individuals caught

An entirely different type of dynamics is featured by the communities of *Carabidae* in the allotments. Only one peak of abundance occurs there but it is much stronger than anywhere else. That is the autumn peak, in August (Fig. 15). Although these data come from only one study area it may be considered that this type of dynamics is characteristic of allotment communities in general. As for their utilization, the allotments resemble root crops areas, where the essential part of carabid communities consists of autumn species [51—53].



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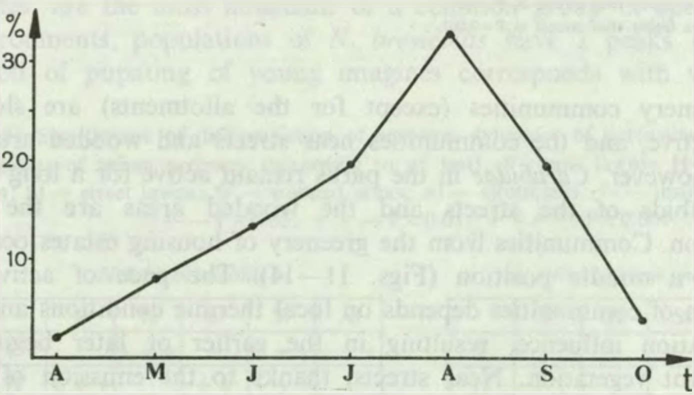

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Figs 14 and 15. The seasonal dynamics of carabids from various types of urban greenery: wooded areas (Fig. 14); allotments (Fig. 15) (symbols as in Figs 11—13)

In order to show the significance of the seasonal dynamics of *Carabidae* in the studied types of urban greenery, the χ^2 test has been applied (the operations have been carried out on the values of the indices of numbers). It has shown high significance of this differentiation: $P<0.001$ ($\chi^2=81.79$; the critical value at the level of significance 0.05 is 26.30). Because of this result, the dynamics of *Carabidae* from every type of urban greenery has been compared by means of the system "each with all others". Significant differences have been found in 5 cases among 10 combinations. In other 3 cases the values of χ^2 obtained are very close to the critical value. The greatest differences ($P<0.001$) occur between the wooded areas and the allotments as well as between the allotments and the greenery of the housing estates (Tab. 20).

Meaningful differences among the types of greenery occur in the duration of the appearance of active individuals at the beginning and the end of a season. This can be measured by percentage of individuals caught in the first and last month of the study season, i.e. in April and October.

Tab. 20. Values of χ^2 depicting differentiation of *Carabidae* seasonal dynamics within habitats of urban greenery

Habitat		Lawns			Wooded areas	Allo-tments
		parks	housing estates	streets		
Lawns	parks		9.48^{+}	7.70	17.87^{++}	8.40
	housing estates	9.48^{+}		2.91	9.18	27.57^{+++}
	streets	7.70	2.91		2.80	16.50^{++}
Wooded areas		17.87^{++}	9.18	2.80		53.52^{+++}
Allotments		8.40	27.57^{+++}	16.50^{++}	53.52^{+++}	

$^{+}$ value higher than critical at $P=0.05$;
$^{++}$ value higher than critical at $P=0.01$;
$^{+++}$ value higher than critical at $P=0.001$.

The park greenery communities (except for the allotments) are slowest in becoming active, and the communities near streets and wooded areas — the quickest. However, *Carabidae* in the parks remain active for a long time, while the carabids of the streets and the wooded areas are the first to end the season. Communities from the greenery of housing estates occupy, in both cases, a middle position (Figs. 11—14). The pace of activation and inactivation of communities depends on local thermic conditions and the direct urbanization influence, resulting in the earlier or later beginning and end of plant vegetation. Near streets, thanks to the emission of heat by houses and vehicles, the temperature is much higher than over lawns and inside parks [3]. In wooded areas it is usually slightly cooler than in the open areas of the town, though the thermal stability in these areas is greater (smaller temperature differences during a 24-hour cycle). Moreover, it seems of decisive importance here that at the beginning of the vegetation season (in April) the temperature in the evening (and probably at night) is higher in the urban wooded areas than in the neighbouring open areas [3].

The greenery of streets and urban wooded areas in turn ends its vegetation period relatively quickly. A direct reason behind the earlier withering of herbaceous vegetation at roadside lawns is the drying up of soil, and its contamination with toxic substances. Also the trees in towns have a shifted and shortened vegetation period [10], and the herb layer is very poor in urban wooded areas.

Allotments are a specific habitat. The activity of *Carabidae* is the latest to begin and the earliest to end there (Fig. 15). This is connected with the artificially regulated vegetation cycle of the plants grown in allotments. After the winter the ground is actually deprived of herbaceous vegetation which would start spontaneous growing, like for instance in lawns. This is due to the autumn gathering of crops which leaves the soil bare.

It is similarly in fields which differ with respect to microclimatic conditions. Significant differences as to the time of the spring appearance of individuals in various habitats occur in those species which, as a rule, start their season early, when the climatic conditions are still similar to critical [49].

In various urban habitats also the cycle of activity of particular species shows different patterns. The following species have been studied as the examples: *Nebria brevicollis*, *Pterostichus vulgaris*, *Calathus fuscipes*, *Harpalus rufipes*, *Bembidion properans*, and *Amara aenea* — species numerously occurring in nearly all habitats of Warsaw's greenery (Figs 16—21, Tab. 21).

The most characteristic urban habitat in this respect turned out to be the wooded areas, where *Nebria brevicollis* and *Pterostichus vulgaris*, autumn species, are the most abundant of a common group of species. In natural environments, populations of *N. brevicollis* have 2 peaks of activity. The period of pupating of young imagines corresponds with the spring peak

Tab. 21 Significance of differentiation of seasonal dynamics of particular *Carabidae* species in habitats of urban greenery (according to χ^2 test); P – park lawns; H – lawns of housing estates; St — street lawns; W — wooded areas; Al — allotments; — — insignificant difference; + — $P<0.05$; + + — $P<0.01$; + + + — $P<0.001$

Nebria brevicollis

	P	H	St	W	Al
P		+ + +	–	+ + +	+ + +
H	+ + +		+ +	+ + +	+
St	–	+ +		+ + +	–
W	+ + +	+ + +	+ + +		+ + +
Al	+ + +	+	–	+ + +	

Pterostichus vulgaris

	P	H	St	W	Al
P		–	–	+ +	–
H	–		–	+ + +	–
St	–	–		+ +	–
W	+ +	+ + +	+ +		+ + +
Al	–	–	–	+ + +	

Calathus fuscipes

	P	H	St	Al
P		+	+ +	+ + +
H	+		–	+ + +
St	+ +	–		+ +
Al	+ + +	+ + +	+ +	

Harpalus rufipes

	P	H	St	Al
P		–	+ +	–
H	–		+ +	–
St	+ +	+ +		+ + +
Al	–	–	+ + +	

Bembidion properans

	P	H	St	Al
P		+ + +	+ + +	+ + +
H	+ + +		+	+ + +
St	+ + +	+		+ + +
Al	+ + +	+ + +	+ + +	

Amara aenea

	P	H	St	Al
P		+ +	–	+ + +
H	+ +		+ + +	+ + +
St	–	+ + +		+ + +
Al	+ + +	+ + +	+ + +	

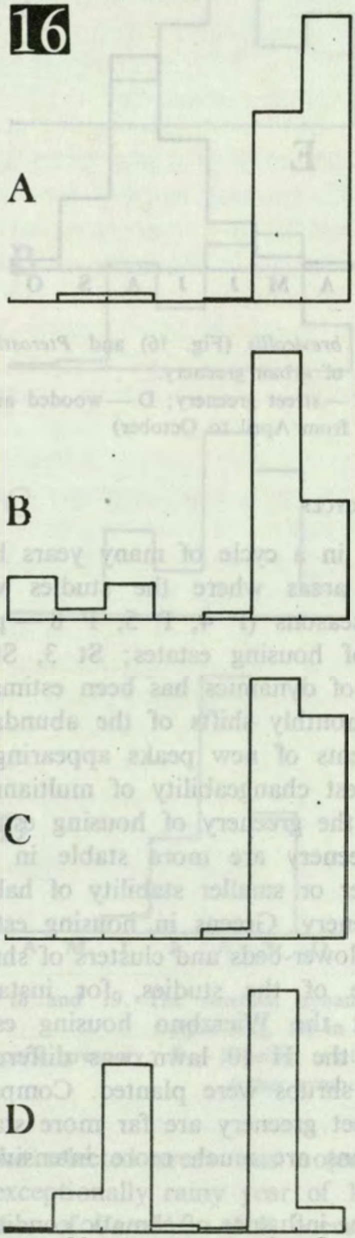
(weaker than the autumn one), then there is ca 2-months period of estivation. The main peak of activity, connected with a period of reproduction, is in September and October [25, 31, 72]. In the town this type of seasonal dynamics occurs in the wooded areas only, i.e. in habitats most suitable for *N. brevicollis* (Fig. 16D). In the remaining habitats of urban greenery the basic autumn peak is unaffected but the spring peak is markedly declining (Fig. 16A—C, E). In street greenery the individuals of this species do not appear at all in the spring. Thus, it may be believed that the proper place for the life and development of the urban population of *N. brevicollis* are wooded areas, and in the lawn greenery this species is an immigrant element, coming from urban and suburban forests. *N. brevicollis* shows a tendency to migrate from its usual habitats into open areas, where it can even reproduce [72]. In these untypical places, however, the death-rate of larvae is greater [25]. This explains the small numbers of young imagines in open urban areas during spring.

Pterostichus vulgaris is a field species. Its lawn (park, housing estates, and street) and allotment populations have seasonal dynamics typical of its phenology. There is one clearly noticeable autumn peak, which follows a gradual increase in numbers corresponding with the pupating of young individuals (Fig. 17A—C). In wooded areas the pattern of dynamics is reversed: the autumn peak shifts from September to June (Fig. 17D). Thus, on the score of seasonal dynamics, *P. vulgaris* becomes actually a spring species. It requires additional autecological studies to explain if this change is accompanied by a shift in the breeding cycle. It is known, however, that the annual rhythm of some species may be modified by habitat conditions [2]. Migrations from other habitats must be rather ruled out. *P. vulgaris* shows a tendency to change its living habitats [59], although, unlike *N. brevicollis*, it does not fly, and "pedestrian" (ground) migrations cannot be quite successful in the town.

Apart from wooded areas, allotments are another type of habitat considerably differing from the rest. Both the autumn (*Nebria brevicollis, Calathus fuscipes*, *Harpalus rufipes*), and the spring species (*Bembidion properans*, *Amara aenea*) there have, when compared with other habitats, a shorter period of activity (Figs 16—21).

On this score, the greenery of the housing estates is the least typical habitat (Figs 16—21).

Of all the species studied the most changeable seasonal dynamics was featured by *Bembidion properans* (Fig. 20). This species has the greatest average value of χ^2 for all compared pairs of habitats (Tab. 21). The dynamics of this species, however, does not exceed anywhere the limits imposed by the phenological type (the spring peak). The greatest stability of dynamics is the feature of, surprisingly, *Pterostichus vulgaris* (Fig. 17, Tab. 21). The behaviour of this species in wooded areas is exceptional.


16
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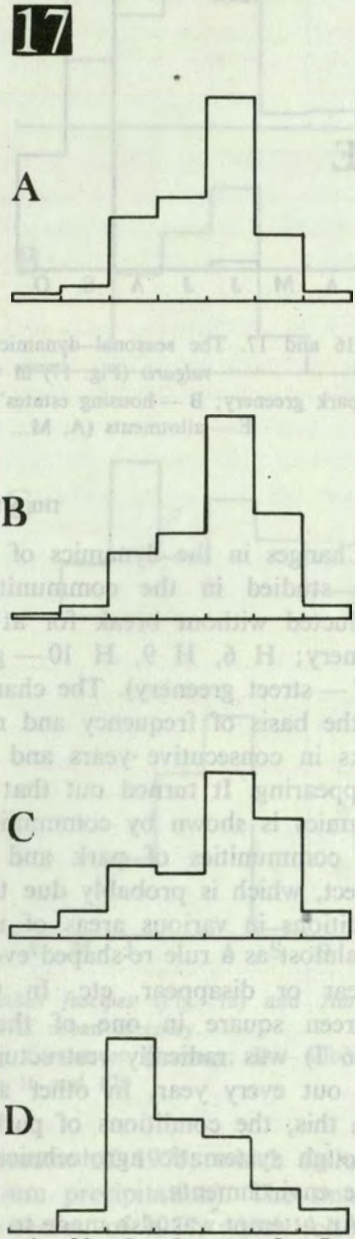
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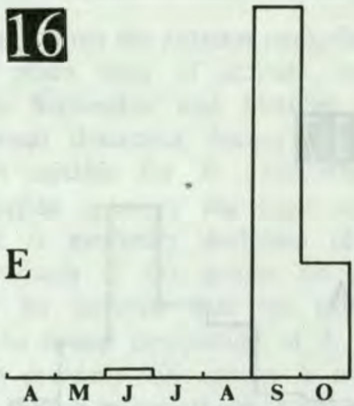
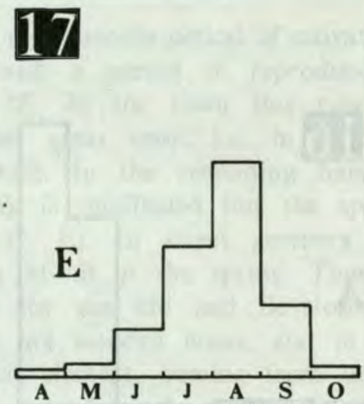


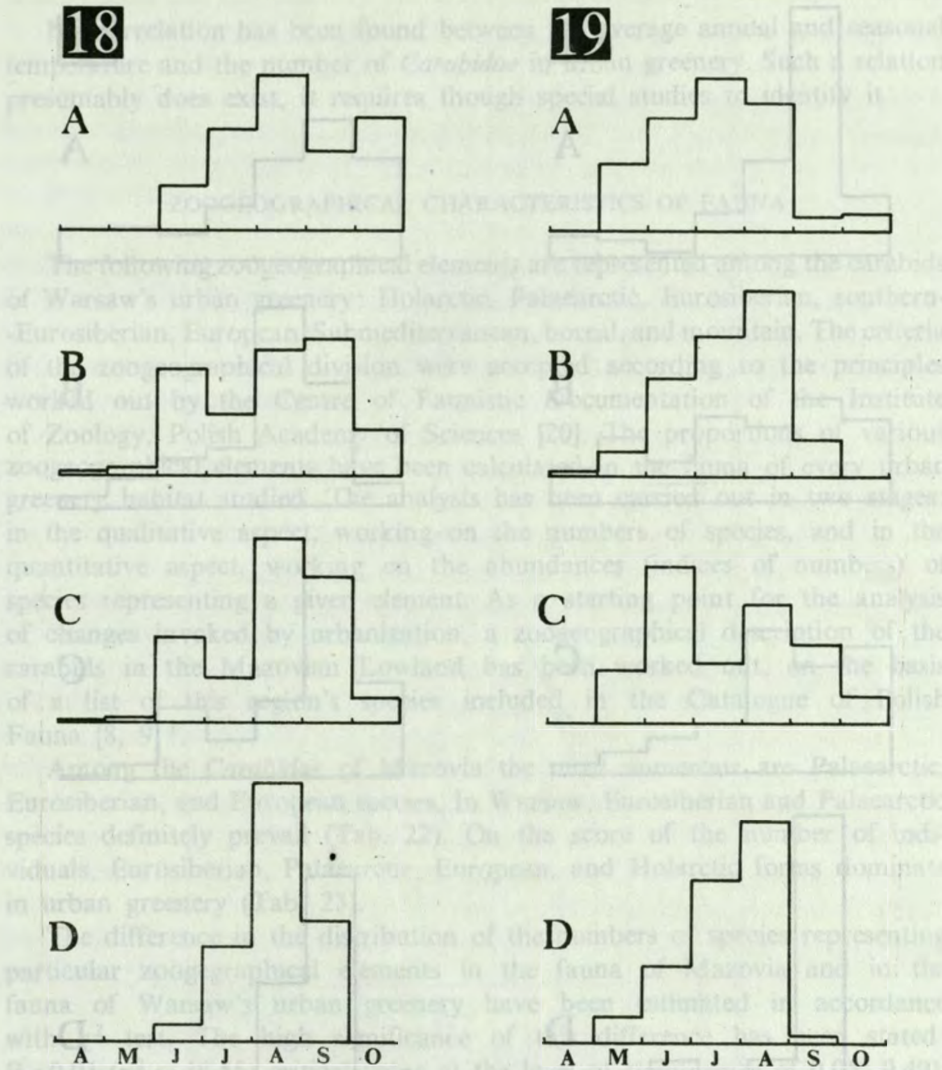


Figs 16 and 17. The seasonal dynamics of *Nebria brevicollis* (Fig. 16) and *Pterostichus vulgaris* (Fig. 17) in various types of urban greenery.
A — park greenery; B — housing estates' greenery; C — street greenery; D — wooded areas; E — allotments (A, M... O — months from April to October)

THE MULTIANNUAL CYCLE

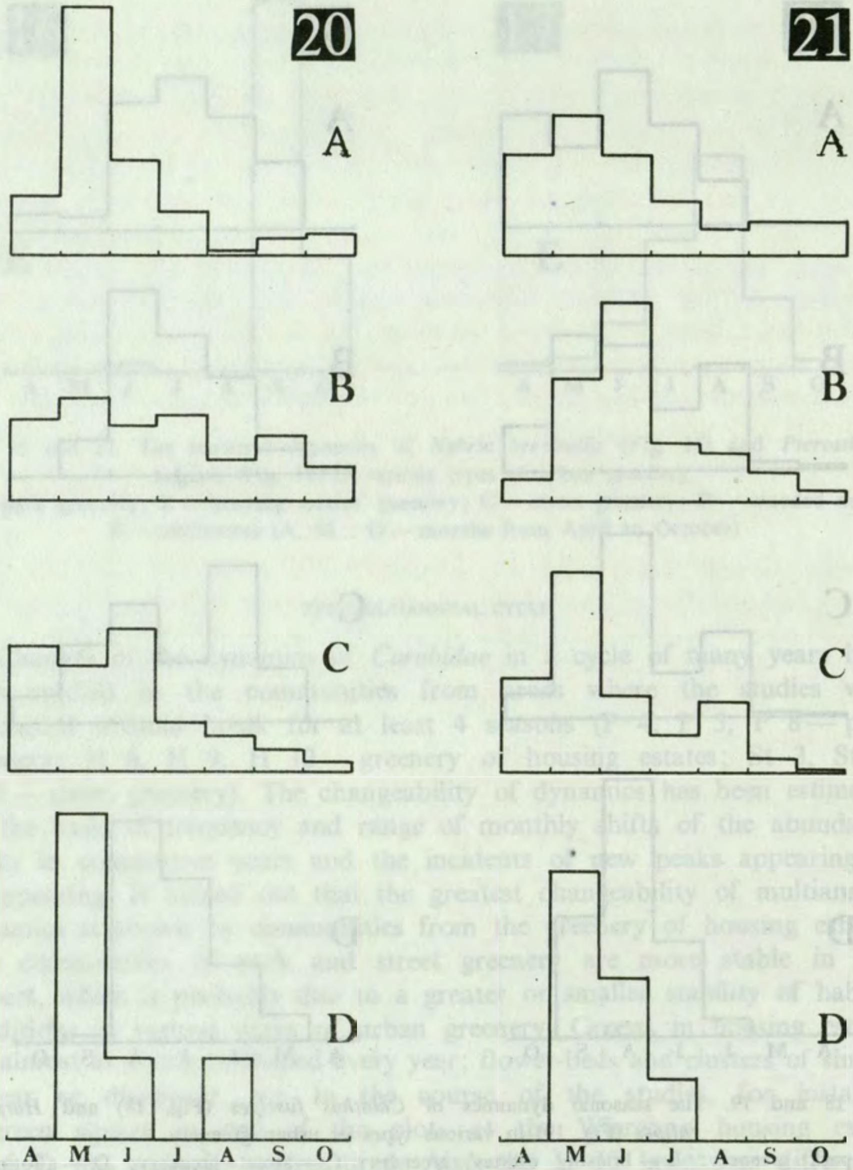
Changes in the dynamics of *Carabidae* in a cycle of many years have been studied in the communities from areas where the studies were conducted without break for at least 4 seasons (P 4, P 5, P 8 — park greenery; H 6, H 9, H 10 — greenery of housing estates; St 3, St 4, St 7 — street greenery). The changeability of dynamics has been estimated on the basis of frequency and range of monthly shifts of the abundance peaks in consecutive years and the incidents of new peaks appearing or disappearing. It turned out that the greatest changeability of multiannual dynamics is shown by communities from the greenery of housing estates. The communities of park and street greenery are more stable in this respect, which is probably due to a greater or smaller stability of habitat conditions in various areas of urban greenery. Greens in housing estates are almost as a rule re-shaped every year; flower-beds and clusters of shrubs appear or disappear, etc. In the course of the studies, for instance, a green square in one of the plots at the Wierzbno housing estate (H 6 I) was radically restructured. Also the H 10 lawn was differently laid out every year. In other areas new shrubs were planted. Compared with this, the conditions of park and street greenery are far more stable, although systematic agrotechnical operations are much more intensive in these environments.

An attempt was also made to estimate the influence of climatic conditions upon the annual oscillation of the carabids' number. It has been found that there is a correlation between these oscillations and the quantity of rainfall in consecutive years, and that there occurs an annual shift of these cycles in relation to each other. The highest abundance of carabids (10.8)



Figs 18 and 19. The seasonal dynamics of *Calathus fuscipes* (Fig. 18) and *Harpalus rufipes* (Fig. 19) in various types of urban greenery.
A — park greenery; B — housing estates' greenery; C — street greenery; D — allotments (other symbols as in Figs 16 and 17)

in the selected areas was noted in the season of 1975, which followed an exceptionally rainy year of 1974 (691 mm precipitation). The smallest number of *Carabidae* (9.4) occurred in the season of 1977, which followed a dry year of 1976 (precipitation: 349 mm). The delay of one year between the time of the factor's occurrence and its supposed result suggests that moisture conditions are of importance for the development of eggs or the survival of larvae (especially earlier phases). Jørum [32]



Figs 20 and 21. The seasonal dynamics of *Bembidion properans* (Fig. 20) and *Amara aenea* (Fig. 21) in various types of urban greenery (symbols as in Figs 16 and 17)

has given the same interpretation of the influence of moisture on the development of *Carabidae* (as exemplified by *Nebria brevicollis*). Though a considerable part of the Warsaw's carabids are xerophilous, it can still be noticed that the drying up of soil, characteristic of a city, is a restricting factor for them.

No correlation has been found between the average annual and seasonal temperature and the number of *Carabidae* in urban greenery. Such a relation presumably does exist, it requires though special studies to identify it.

ZOOGEOGRAPHICAL CHARACTERISTICS OF FAUNA

The following zoogeographical elements are represented among the carabids of Warsaw's urban greenery: Holarctic, Palaearctic, Eurosiberian, southern-Eurosiberian, European, Submediterranean, boreal, and mountain. The criteria of the zoogeographical division were accepted according to the principles worked out by the Centre of Faunistic Documentation of the Institute of Zoology, Polish Academy of Sciences [20]. The proportions of various zoogeographical elements have been calculated in the fauna of every urban greenery habitat studied. The analysis has been carried out in two stages: in the qualitative aspect, working on the numbers of species, and in the quantitative aspect, working on the abundances (indices of numbers) of species representing a given element. As a starting point for the analysis of changes invoked by urbanization, a zoogeographical description of the carabids in the Mazovian Lowland has been worked out, on the basis of a list of this region's species included in the Catalogue of Polish Fauna [8, 9] [1].

Among the *Carabidae* of Mazovia the most numerous are Palaearctic, Eurosiberian, and European species. In Warsaw, Eurosiberian and Palaearctic species definitely prevail (Tab. 22). On the score of the number of individuals, Eurosiberian, Palaearctic, European, and Holarctic forms dominate in urban greenery (Tab. 23).

The difference in the distribution of the numbers of species representing particular zoogegraphical elements in the fauna of Mazovia and in the fauna of Warsaw's urban greenery have been estimated in accordance with χ^2 test. The high significance of this difference has been stated: $P<0.01$ ($\chi^2 = 16.55$; critical value at the level of significance of 0.05: 9.49). The selective influence of the urbanization pressure accounts for the fact that out of the group of Mazovian species mostly the species of wide ranges survive in the town: Holarctic, Palaearctic, and Eurosiberian. Species with more restricted ranges, beginning with European, are to a much greater extent eliminated from the town's fauna. While the total participation of the species with wide ranges in the carabid fauna of Mazovia is 65%, it becomes 83% in the fauna of the urban greenery, i.e. it grows 1.3 times (Tab. 22).

[1] In one of the previous works in this field [18] a similar analysis has been included. The operations carried out there concern, however, the number of species exclusively. The division of the habilats of urban greenery is much less precise. The theoretical foundations of the worke are also different.

Tab. 22. Proportions of particular zoogeographical elements in fauna of *Carabidae* in the Mazovian Lowland and in various habitats of urban greenery (qualitative aspect: S — number of species; % — percentage)

Zoogeographical element	Mazovian lowland		Lawns								Wooded areas		Allotments		All town green	
			parks		housing estates		streets		All lawns							
	S	%	S	%	S	%	S	%	S	%	S	%	S	%	S	%
Holarctic	19	6.2	6	9.5	8	14.5	9	19.0	10	12.0	6	11.0	6	20.5	11	9.5
Palaearctic	97	30.0	25	39.0	18	32.5	18	38.5	30	36.5	18	33.5	10	34.5	36	32.0
Eurosiberian	93	29.0	23	36.0	24	43.5	17	36.0	30	36.5	21	39.0	10	34.5	47	41.5
European	74	23.0	6	9.5	4	7.5	2	4.5	8	9.5	8	14.5	2	7.0	14	12.5
Southern-Eurosiberian	18	5.5	1	1.5	1	2.0	—	—	2	2.5	—	—	—	—	2	1.5
Submediterranean	5	1.5	1	1.5	—	—	1	2.0	1	1.0	—	—	1	3.5	1	1.0
Subatlantic	2	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Subpontic	1	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Boreal	9	2.5	1	1.5	—	—	—	—	1	1.0	—	—	—	—	1	1.0
Mountain	5	1.5	1	1.5	—	—	—	—	1	1.0	1	2.0	—	—	1	1.0

In the carabid fauna of particular types of the urban greenery the proportions of these elements are usually still higher. This depends on the degree of urbanization of an area. In the fauna of street greenery, which is under greatest pressure, Holarctic, Palaearctic, and Eurosiberian elements comprise in total 93.5% of the carabid species; in the greenery of the housing estates — 90.5%, and in the park greenery only 84.5% (and still less in the wooded areas). The participation of species with small ranges decreases proportionally to the increase of elements widely distributed in the world. The tendency to change the total proportions of species with large and small ranges is visible within different urban habitats (Tab. 22). There are no important deviations (χ^2; $P>0.5$) in the distribution of particular analysed elements.

As for the distribution of the numbers of individuals representing particular zoogeographical elements, the group of habitats in the urban greenery is highly non-homogenous: $P<0.001$ ($\chi^2=250.98$; critical value: 21.03). This difference is caused by an incomparably high proportion of European species in the wooded areas and Eurosiberian species in the allotments (Tab. 23) as compared with other environments. Within the lawns themselves the difference is insignificant (χ^2; $P>0.1$), although there is a tendency towards an increase of the proportion of forms with wide ranges in the gradient of: parks — housing estates — streets. In the fauna of these habitats the proportions of elements with wide ranges (represented by individuals) are respectively: 84%, 90.5%, 95% (Tab. 23) and are almost identical with the proportion of species (Tab. 22).

The reason for the prevalence of elements with wide ranges in the town seems clear. Species of large range, distributed in several biomes, hence inhabiting various habitats, must feature a sufficient biotic potential. Thus they have the means to colonize new environments and adapt to changing conditions [18].

ECOLOGICAL CHARACTERISTICS OF FAUNA

As in the case of zoogeographical issues, the proportions of various ecological elements among the *Carabidae* in various studied environments have also been analysed. Eight categories of features were taken into account and on this basis the species occurring in the Mazovian Lowland were classified. The following criteria have been chosen: range of ecological amplitude, habitat preferences, quality of soil and moisture requirements, type of food specialization, phenological type, size of the body, ability to fly.

Ecological amplitude. The following species have been distinguished: eurytopic — capable of living both in open and wooded areas; polytopic — occurring in many similar biotopes within a specific type of environment (e.g. in various wooded or various open environments); oligotopic — occurring

Tab. 23. Proportions of particular zoogeographical elements in the fauna of *Carabidae* from various habitats of urban greenery (quantitative aspect: N — index of number; % — percentage; + — scarce number of participation)

Zoogeographical element	Lawns: parks N	Lawns: parks %	Lawns: housing estates N	Lawns: housing estates %	Lawns: streets N	Lawns: streets %	Lawns: All lawns N	Lawns: All lawns %	Wooded areas N	Wooded areas %	Allotments N	Allotments %	All town green N	All town green %
Holarctic	1.6	23.5	5.6	21.5	1.9	31.5	3.0	23.5	0.5	4.5	4.5	8.5	2.8	14.0
Palaearctic	2.2	32.5	9.3	36.0	2.1	35.0	4.5	35.0	1.9	18.0	7.3	14.0	4.6	22.5
Eurosiberian	1.9	28.0	8.5	33.0	1.7	28.5	4.0	31.5	2.9	27.5	33.4	64.0	9.7	48.0
European	1.1	16.0	2.4	9.5	0.3	5.0	1.3	10.0	4.8	44.5	7.1	13.5	3.1	15.0
Others	+	+	+	+	+	+	+	+	0.6	5.5	+	+	0.1	0.5

in various biotopes, but dependent on a specific habitat condition; stenotopic — characteristic of specific type of biotopes only.

Habitat preferences. The following types of species have been distinguished: ubiquitous — which may occur both in wooded and open areas (= eurytopic on the score of amplitude); forest species — occurring in wooded areas; species of open areas — meadow and heath etc. forms, visiting arable lands to a small extent; water-bank species — connected with water reservoirs; swamp and peat species; synanthropic — connected with the interiors of human dwellings.

Moisture requirements. The following types of species have been distinguished: hygrophilous, mesohygrophilous, and xerophilous.

Soil requirements. A general division into species of fertile and poor types of soils has been applied.

Types of food specialization. Types distinguished: zoophagous — predatory in both stages of development; pantophagous — as a rule predatory as larvae, and omni- or herbivorous as adults.

Phenological type. Spring species (breeding in spring, metamorphosis is summer), and autumn species (breeding in autumn, metamorphosis with winter break) have been distinguished.

Size of the body. Forms distinguished: big (over 20 mm long), medium (10—20 mm), and small (below 10 mm).

Ability to fly. Forms distinguished: macropterous, dimorphic, and brachypterous.

The divisions applied have been mostly based on very general criteria. Thanks to this, however, they could embrace the majority of species. This, in turn, made it possible to establish reliable trends in the restructuring of fauna. Proportions of particular elements have been calculated with reference to the number of species (and individuals) determined with respect to every criterion, i.e. every time referring to the number as 100%. Differences in the fauna of particular environments have been estimated according to χ^2 test, using for this purpose numbers of species and the indices of numbers.

SPECIES COMPOSITION

The fauna of *Carabidae* in the urban greenery of Warsaw is exceptional in terms of the fauna of the whole Mazovian Lowland on the score of the proportions of elements (groups of species) of specific ecological amplitude ($P<0.01$) and the proportions of elements connected with a specific type of habitat ($P<0.001$). In all the remaining aspects differences between Mazovia and Warsaw's fauna are irrelevant (Tabs 24, 26).

In the fauna of the urban greenery the proportions of species with the greatest ecological amplitude, eurytopic and polytopic, are greater (by a total of 1.4 times) as compared with the fauna of the whole Mazovia. Accordingly, there are less oligotopic and stenotopic species (Tab. 24).

Tab. 24. Proportions of particular ecological elements in the fauna of *Carabidae* in the Mazovian Lowland and in various habitats of urban greenery (qualitative aspect: S — number of species; % — percentage)

Ecological element	Mazovian lowland		Lawns								Wooded areas		Allotments		All town green	
			parks		housing estates		streets		All lawns							
	S	%	S	%	S	%	S	%	S	%	S	%	S	%	S	%
Eurotopic	22	8.0	7	12.0	7	14.0	6	13.5	9	12.0	8	15.5	4	15.5	10	10.0
Polytopic	116	43.5	41	71.0	36	72.0	33	75.0	51	68.0	38	73.0	20	77.0	64	64.0
Oligotopic	101	37.5	5	8.5	5	10.0	5	11.5	8	10.5	4	7.5	2	7.5	18	18.0
Stenotopic	30	11.0	5	8.5	2	4.0	—	—	7	9.5	2	4.0	—	—	8	8.0
Ubiquitous	22	7.5	7	11.5	8	15.0	6	13.5	9	11.5	8	15.5	4	14.5	10	9.5
Forest	57	19.0	12	20.0	5	9.5	5	11.5	14	17.5	17	32.5	6	21.5	24	22.0
Open areas	86	29.0	18	29.5	16	30.0	11	25.0	24	30.0	10	19.0	6	21.5	32	29.5
Field	28	9.5	15	24.5	18	34.0	15	34.0	21	26.5	12	23.0	9	32.0	22	20.5
Coastal	95	32.0	8	13.0	5	9.5	7	16.0	10	12.5	5	10.0	3	10.5	18	16.5
Marshy	7	2.0	1	1.5	—	—	—	—	1	1.0	—	—	—	—	1	1.0
Synanthropic	3	1.0	—	—	1	2.0	—	—	1	1.0	—	—	—	—	1	1.0
Hygrophilous	140	52.0	17	30.0	10	20.0	15	33.0	25	34.0	15	29.5	9	32.0	42	41.5
Mesohygrophilous	55	20.5	20	35.0	21	41.0	17	38.0	26	35.0	23	45.0	12	43.0	32	31.5
Xerophilous	4	27.5	20	35.0	20	39.0	13	29.0	23	31.0	13	25.5	7	25.0	27	27.0
Fertile soils	27	15.0	6	16.0	6	16.5	5	18.5	7	15.0	11	34.5	5	26.5	12	19.0
Poor soils	151	85.0	31	84.0	30	83.5	22	81.5	40	85.0	21	65.5	14	73.5	52	81.0
Zoophagous	195	68.5	37	59.5	31	59.5	25	59.5	45	58.5	36	68.0	21	78.0	67	76.5
Pantophagous	90	31.5	25	40.5	21	40.5	17	40.5	32	41.5	17	32.0	6	22.0	32	32.5
Spring	188	76.5	40	64.5	28	54.0	30	70.0	49	63.0	29	54.5	20	69.0	71	71.0
Autumn	58	23.5	22	35.5	24	46.0	13	30.0	29	37.0	24	45.5	9	31.0	29	29.0
Large	22	7.0	3	4.5	4	7.5	3	6.5	5	6.0	6	11.0	4	14.0	8	7.0
Medium	62	19.0	16	25.0	16	29.0	13	27.5	20	24.0	18	33.5	9	31.0	27	24.0
Small	239	74.0	45	70.5	35	63.5	31	66.0	58	70.0	30	55.5	16	55.0	78	69.0
Macropterous	150	69.5	36	68.0	31	64.5	24	57.0	46	67.5	24	51.0	14	54.0	54	63.0
Dimorphic	35	16.5	10	19.0	10	21.0	13	31.0	14	20.5	10	21.5	7	27.0	17	19.5
Brachypterous	30	14.0	7	[illegible]	7	14.5	5	11.9	8	12.0	13	27.5	5	19.0	15	17.5

Still more important differences between the Mazovian and urban fauna concern the proportions of species connected with specific habitat preferences. These are not the effect of a decrease in the proportion of forest species in the town, as there are even 3% more of them here. First of all, there is an increased proportion of typical field species (over twice) and to the same extent decreased proportion of water-bank species (Tab. 24).

There is no significant difference in any of the analysed aspects in the habitats of urban greenery themselves (Tab. 26).

NUMBERS OF INDIVIDUALS

Lack of quantitative data, representative of the whole Mazovian Lowland, makes it impossible to show ecological specificity of the fauna of urban greenery in this aspect. At the same time, the differences of the relative numbers of particular elements in the fauna of various urban habitats are very big: they considerably exceed the differences in species' proportions. Within the whole group of urban habitats the differences are highly significant ($P < 0.001$) in every aspect. In most cases significant differences occur also within lawn habitats themselves (Tab. 26).

As far as the ecological amplitude of carabids is concerned, important differences can be reduced to the varying proportions of eurytopic and polytopic forms. Oligotopic and stenotopic species are sparsely represented everywhere. Wooded areas and allotments differ from lawns in the greater proportion of polytopic forms and less abundant occurrence of eurytopes. In wooded areas, the polytopic element consists mainly of forest carabids, while in allotments of field carabids (Tab. 25).

Within lawn greenery the differentiation is smaller, although still significant ($P < 0.05$), thanks to the proportion of eurytopes in park fauna, distinctly higher than anywhere else. The environment in urban parks is usually more "mosaic-like" than in housing estates and streets. Dense clusters of shrubs and trees are situated among open lawns. This varied landscape is probably the reason behind the great proportion of the eurytopic element. Oligotopes, almost non-occurrent in the street and housing estates' greenery are also quite numerous in the parks (Tab. 25). This group consists mostly of hygrophilous water-bank species. Ponds can be found in a number of the studied parks.

The next problem is the differentiation of proportions among the elements connected with a specific type of habitat. Field species are most numerously represented in the urban fauna. Individuals of these species constitute nearly half of all carabids in Warsaw's greenery. Lawn greenery can be distinguished against the background of the whole urban greenery by the numerous occurrence of ubiquists, although field forms also significantly prevail there (Tab. 25).

Tab. 25. Proportions of particular ecological elements in the fauna of *Carabidae* from various habitats of urban greenery (quantitative aspect: N — index of number; % — percentage; + — scarce number or participation)

Ecological element	Lawns								Wooded areas		Allotments		All town green	
	parks		housing estates		streets		All lawns							
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Eurotopic	2.1	31.5	4.5	17.5	1.4	24.0	2.7	21.0	0.7	7.0	4.0	8.0	2.5	12.5
Polytopic	4.4	65.5	21.3	82.5	4.4	76.0	10.0	78.0	8.7	90.0	46.7	91.5	17.1	86.5
Oligotopic	0.2	3.0	+	+	+	+	0.1	1.0	0.1	1.0	0.3	0.5	0.1	0.5
Stenotopic	+	+	+	+	–	–	+	+	0.2	2.0	–	–	0.1	0.5
Ubiquitous	2.1	31.5	4.5	17.5	1.4	24.0	2.7	21.0	0.7	7.0	4.0	8.0	2.5	11.5
Forest	1.3	19.5	2.5	9.5	0.4	6.5	1.4	11.0	7.0	68.0	8.0	15.5	3.8	18.0
Open areas	0.4	6.0	4.7	18.5	0.9	15.5	2.0	15.5	8.5	8.5	3.6	7.0	3.6	17.0
Field	2.8	41.5	14.0	54.5	3.1	52.5	6.6	51.5	1.5	14.5	35.4	69.0	11.3	53.0
Coastal	0.1	1.5	+	+	0.1	1.5	0.1	1.0	0.2	2.0	0.4	0.5	0.1	0.5
Others	–	–	+	+	–	–	+	+	–	–	–	–	+	+
Hygrophilous	0.2	3.0	0.2	1.0	0.1	1.5	0.2	1.5	0.9	9.0	4.8	9.0	1.2	6.0
Mesohygrophilous	5.0	73.5	19.7	77.0	3.4	59.0	9.4	73.5	7.8	79.0	45.1	86.5	16.2	81.0
Xerophilous	1.6	23.5	5.7	22.0	2.3	39.5	3.2	25.0	1.2	12.0	2.3	4.5	2.6	13.0
Fertile soils	1.4	32.5	2.6	17.0	0.3	7.5	1.4	18.0	5.1	69.0	7.9	52.5	3.5	38.0
Poor soils	2.9	67.5	12.7	83.0	3.6	92.5	6.4	82.0	2.3	31.0	7.2	47.5	5.7	62.0
Zoophagous	5.0	73.5	17.0	66.5	2.9	50.0	8.3	65.5	8.7	81.5	46.1	92.5	15.9	80.5
Pantophagous	1.8	26.5	8.5	33.5	2.9	50.0	4.4	34.5	2.0	18.5	3.8	7.5	3.8	19.5
Spring	1.4	20.5	7.8	30.5	2.3	39.0	3.8	29.5	4.7	44.5	8.8	17.0	5.0	24.5
Autumn	5.4	79.5	17.9	69.5	3.6	61.0	9.0	70.5	5.9	55.5	43.5	83.0	15.3	75.5
Large	0.1	1.5	0.5	2.0	+	+	0.2	1.5	2.9	27.5	2.7	5.0	1.2	6.0
Medium	4.1	60.5	18.0	69.5	4.0	66.5	8.7	68.0	5.1	48.0	44.8	86.0	15.2	75.0
Small	2.6	38.0	7.3	28.5	2.0	33.5	3.9	30.5	2.6	24.5	4.8	9.0	3.9	19.0
Macropterous	3.0	45.5	10.3	42.0	2.4	46.0	5.2	43.5	4.9	49.0	14.1	27.5	6.9	35.5
Dimorphic	2.3	35.0	10.1	41.5	1.2	23.0	4.5	37.5	1.2	12.0	31.3	61.5	9.2	47.5
Brachypterous	1.3	19.5	4.0	16.5	1.6	31.0	2.3	19.0	3.9	39.0	5.7	11.0	3.3	17.0

Tab. 26. Significance of ecological differences between the fauna of carabids from Warsaw's urban greenery and the fauna of the Mazovian Lowland, and differentiation within urban habitats (according to χ^2 test). Left side of each column contains an appraisal on the basis of the number of species, right side — on the basis of indices of number: – — insignificant difference; + — $P \leq 0.05$; ++ — $P < 0.01$; +++ — $P < 0.001$; ? — no data

Criterion of classification \ Compared habitats	Mazovia — town green		Types of town green		Types of lawns	
Ecological amplitude	++	?	–	+++	–	+
Habitat requirements	+++	?	–	+++	–	++
Moisture requirements	–	?	–	+++	–	+
Soil requirements	–	?	–	+++	–	+
Trophic group	–	?	–	+++	–	+
Phenology	–	?	–	+++	–	–
Body size	–	?	–	+++	–	–
Ability to fly	–	?	–	+++	–	–

The proportion of ubiquists in the fauna of lawns is ca 3 times higher than in the wooded areas and the allotments. Other basic differences between the particular types of greenery are the 6 times higher proportion of forest forms and 3.6 times lower proportion of field forms in the fauna of wooded areas as compared to the lawn greenery, as well as the 4.4 times higher proportion of forest forms and 4.8 times lower proportion of field forms in the fauna of the wooded areas as compared to the allotments (Tab. 25).

Within lawn greens themselves, which differ very considerably on the above score ($P < 0.001$), the thing that attracts attention is the extremely high proportion of ubiquists in the parks. In park lawns there is a significant proportion of forest carabids (2 times more than in the housing estates and 3 times more than in the streets). There are visibly fewer representatives of the species of open areas than anywhere else (Tab. 25). The increased occurrence of ubiquists in the park greenery has already been explained earlier — according to the adopted classification they are also eurytopes. The mosaic character of park areas is also a reason for a high proportion of forest carabids in the fauna of those lawns. Forest *Carabidae*, owing to their characteristic tendency to migration [35], visit lawns in the nearby wooded areas.

Among the *Carabidae* of urban greenery most of the species occurring are hygrophilous (Tab. 24). However, these hygrophilous species feature very low total abundance (Tab. 25). This convincingly testifies to the existence of the urbanization influence which restricts their occurrence. The majority of hygrophilous carabids occur in wooded areas and allotments. The proportion of xerophilous forms in these habitats, especially in the regularly watered allotments, is relatively small. Mesohygrophilous carabids constitute the bulk of the fauna. In the fauna of lawn greenery the hygrophilous element is represented by a very small number. There too, mesohygrophilous carabids are the most numerous, but xerophilous carabids are also abundant. The fauna of the street greens has an extremely high proportion of the xerophilous element (Tab. 25), and hence the differentiation within urban lawn habitats reaches the limit of significance ($P = 0.05$).

Poor, mainly clay and sandy soils dominate in Mazovian Lowland. This is reflected by the state of fauna, in which species connected with soils of that type prevail. *Carabidae* of poor soils dominate also in Warsaw, mainly because of the number of species (Tab. 24) and their abundance (Tab. 25). Proportions of the elements of poor and fertile soils are very different in particular types of urban greenery. In wooded areas and allotments carabids of fertile soils prevail. Their high proportions in the fauna of these habitats are respectively 4 and 3 times higher than in the fauna of lawn greenery, where the element of poor soils dominates decisively (Tab. 25).

The types of lawn greenery form a clear gradient: parks — housing estates — streets, determined by the increasing value of the relation between the proportion of carabids of poor soils and the proportion of forms connected with fertile soils. The proportion of the latter is 4.3 times lower in the fauna of street greenery than in the park fauna (Tab. 25). The difference is important enough to make the differentiation within the habitats in question significant ($P < 0.05$).

With respect to food specialization, zoophagans prevail among *Carabidae* of urban greenery. This results, first of all, from the nature of the family as such. Nonetheless, the differentiation of the quantitative relation of zoophagans to pantophagists in the fauna of particular habitats is very high. This differentiation is in concord with a general regularity: there are more pantophagists and fewer zoophagans in open areas than in forests [72]. In Warsaw the highest proportion of zoophagans is shown in the fauna of allotments and wooded areas. (Tab. 25). Forest *Carabidae*, which as a rule are zoophagans, dominate in wooded areas. Although field forms, most of which are pantophagists, have a majority in allotments, it is *Pterostichus vulgaris*, a predatory field species, which decisively dominates there.

The proportion of pantophagists in lawn greenery is much higher and it grows in a gradient: parks — housing estates — streets. In street greenery the abundance of zoophagans and pantophagists becomes equal (Tab. 25). The differentiation within lawns is significant ($P<0.05$).

The problem of the participations of carabids of different phenological types in urban fauna is quite complicated. Ca 3/4 of the species composition of *Carabidae* in Warsaw (and in the whole of Mazovia) consists of spring species (Tab. 24). Most of the spring species are field, xero- and thermophilous species, i.e. those which are clearly preferred by the urbanization pressure. Thus one could expect also the quantitative prevalence of spring forms over autumn forms, at least in lawn greenery and in allotments. Still, it is just the opposite. More than 3/4 of carabids in urban greenery are individuals of autumn species (Tab. 25). Therefore, in the town, those field species whose breeding period is in autumn gain in numbers. What is even stranger, the greatest proportion of spring species is in wooded areas. The key to the problem seems to be the differences in the composition of carabid faunas in variously utilized areas. Spring forms prevail in those fields where in the middle of the vegetation season (in summer) agrotechnical operations are not applied (cereal cultivations). Autumn *Carabidae* are characteristic of root crop cultivations [29, 33]. Hence, it may be assumed that summer agrotechnical operations eliminate spring carabids from fields by destroying their larvae. Autumn *Carabidae* survice this period as adults — probably more resistant to mechanical injuries and having the possibility to escape from the endangered areas.

The situation in Warsaw is similar to that of root crop cultivations. To a large extent the species composition of carabids in such cultivations [51, 53] are even similar to that of the urban greenery. Such a state of fauna has probably been shaped as a result of horticultural operations carried out in the urban greenery (turning over the soil, mechanical mowing, raking away the litter; some importance must be also attached to the use of herbicides in the spring-summer period, i.e. in the period of reproduction of spring species).

Agrotechnical operations are most intensively carried out in allotments. There, the proportion of spring carabids is the lowest. In lawn greenery, far less intensively cultivated in comparison to allotments, the proportion of spring forms is 1.7 times higher; in wooded areas, where human interference is the smallest, 2.6 times higher than in allotments (Tab. 25).

Another issue that attracts attention is a relatively high proportion of spring carabids in urban wooded areas, i.e. a state opposite to that in natural forests. It seems that the time-table of horticultural and cleaning-up operations is responsible also for this phenomenon. The basic operation carried out in wooded areas is raking the litter. These operations are usually carried out twice a year: early in the spring and late in autumn, i.e. in those periods, when spring *Carabidae* occur in the form of adults, and autumn *Carabidae* either still as chrysalides or already as the larvae, the phases during which owing to their passiveness they can be more easily removed with the litter.

Within the lawn greenery itself, the differentiation of fauna on the score in question is not significant ($P>0.1$). It is notable, however, that the fewest of spring carabids are to be found in parks, where lawns are cultivated most intensively (Tab. 25).

The differentiation of the fauna of urban habitats, estimated on the score of the proportion of individuals of different size, consists in the incommensurably high proportion of big *Carabidae* in wooded areas as compared with other habitats. This results from the numerous occurrence of forest species of the *Carabus* L. genus. Another reason of highly significant differentiation is a relatively small proportion of small *Carabidae* in the fauna of allotments (Tab. 25).

The differentiation within lawn greenery is insignificant ($P>0.1$). The proportion of big forms is low everywhere there and carabids of medium size dominate (Tab. 25).

According to Topp [70], the urban fauna of *Carabidae*, characterized on the basis of data from a small park in Kiel, differs from non-urban fauna by a visibly greater proportion of species represented by macropterous individuals, while their abundance (number) is definitely higher than the numbers of brachypterous and dimorphic forms. However, as it has already been shown previously (Tabs 24, 26), the fauna of Warsaw's greenery does not differ in this respect from the fauna of Mazovia. Macropterous forms do not show a clearcut prevalence in numbers over the remaining groups in Warsaw either (Tab. 25). On the other hand, the differences between urban study areas are considerable. This is due to a relatively high proportion of dimorphic forms in allotments (high dominance of *Pterostichus vulgaris*) and a significant proportion of brachypterous forms in wooded areas (species of the *Carabus* L. genus) (Tab. 25). There is, however, no significant differentiation within urban lawn greens ($P>0.05$). Particular study areas differ considerably between themselves. This is caused to a great extent by the high proportions of dominating species characteristic of given urban communities, the nature of which influences the whole community.

INFLUENCE OF SETTLEMENT PRESSURE ON *CARABIDAE*

Carabids, thanks to their sensitivity to the changes of habitat conditions, occupy an important place on the list of bioindicators [22] and are frequently the object of studies on the ecological effects of various transformations of environment. The influence of such anthropogenic factors as industrial emissions or forest and agricultural management on *Carabidae* have already become relatively well known. Little known, however, are the effects of the total restructuring of environment aimed at adapting the environment to human technological and aesthetic requirements (this issue has already been touched upon in an earlier paper [16], being an introductory report in its nature).

The object of the analysis in this paper are changes caused by settlement pressure in the communities of *Carabidae* from areas variously transformed and utilized. Communities from a relatively unaffected habitat of *Tilio-Carpinetum* forest have been considered as a starting point. The studied anthropogenized habitats include 2 rural parks (Młochów, Radziejowice), Warsaw's suburban quarter (Białołęka Dworska) and the urban greenery of Warsaw. The selected study areas, representing various habitats, undergo different forms of anthropogenic pressure prevailing in them. They form 4 respective sequences of transformations of the lime-oak-hornbeam forest habitat: a sequence of wooded areas, a sequence of park greenery, a sequence of the greenery of housing estates, and a sequence of the greenery of roads. The sequence of anthropogenized wooded areas originates directly from *Tilio-Carpinetum* forest. The three sequences of grassy (lawn) communities should actually have been derived from natural wet meadows (the *Arrhenatherion* alliance), however such a community has not been investigated. The comparison, of necessity, of these sequences with a lime-oak-hornbeam forest, is justified inasmuch as *Tilio-Carpinetum* association is a potential association for all (open and wooded) study areas. It cannot be excluded either that the anthropogenized open areas in question had not been originally covered with a forest.

Final points for all the sequences are areas characteristic of the main types of Warsaw's urban greenery, representing urban wooded areas (W 5), park greenery (P 5), housing estates' greenery (H 6), and street greenery (St 8). Four degrees of settlement pressure have been adopted, corresponding to the following groups of environments: 1) rural, non-managed (a grown-wild manor park in Młochów); 2) rural managed (a tended palace park in Radziejowice); 3) suburban (Białołęka Dworska — a peripheral quarter of Warsaw); 4) Warsaw's urban greenery.

In this diagram (Fig. 22) a full sequence of areas-stages is represented by wooded areas exclusively. The remaining sequences are incomplete. In the sequence of park lawns a suburban area is missing, there no rural areas in the housing estates' greenery, and the greenery of roads is represented by an urban area only. However, the arrangement of the studied areas enables the approximative generalization of results (at least 2 study areas belong to each degree of pressure).

In the case of the communities from both rural parks, despite a different degree of their anthropogenization, a number of points for the analysis have been based on the values of parameters average for 2 communities.

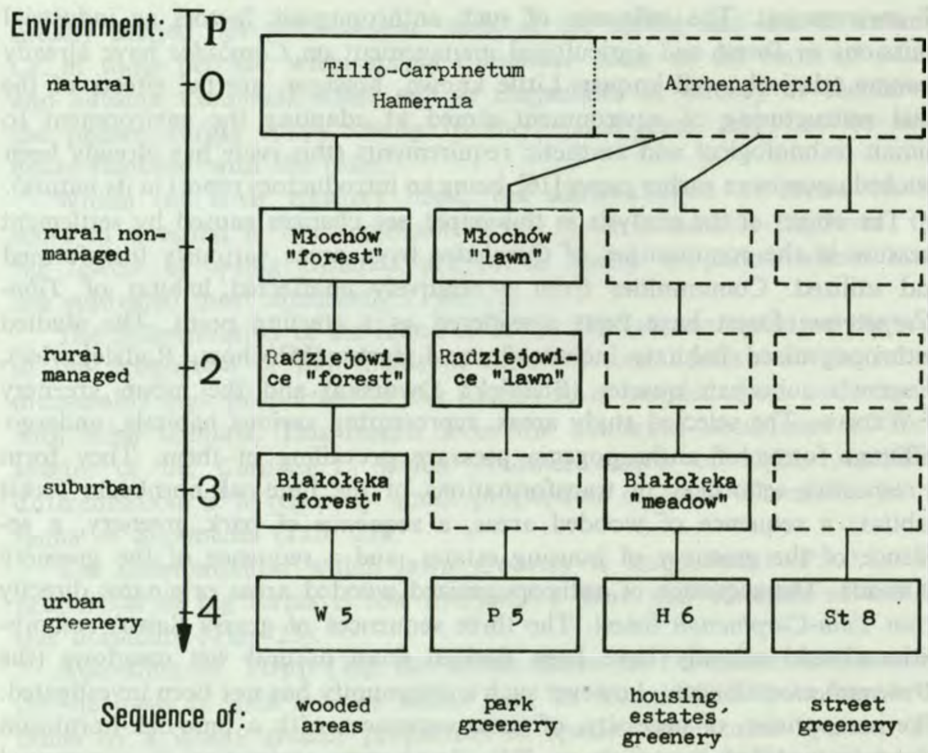


Fig. 22. The schematic arrangement of the environments and studied areas with respect to the degree of anthropogenization (P — degree of intensity of settlement pressure)

The influence of the basic factor, i.e. the horticultural cultivation of an area or its lack, was often concealed by the influence of side factors such as treading down or the accessability of the area for farm animals.

The analysis encompasses the species' richness, abundance (number) and structure of communities, proportions of various ecological elements in the fauna and seasonal dynamics of carabids.

CHANGES IN SPECIES COMPOSITION AND ABUNDANCE

The decrease in the number of animal species in the environment in the course of its anthropogenization is a common phenomenon. Generally speaking, the decreases takes place also in the case of settlement influence; the average number of carabid species in the communities of urban greenery is 1.5 times lower than the number of species in a control environment (according to data from pitfall traps). The observed dependence is not simple, however. Sometimes the increase in pressure is accompanied by an increase in the number of species. After the initial average drop (1.5 times less) in the number of species in rural parks there is a marked increase in suburban areas (there are even slightly more species there than in the forest in Hamernia). Then, the number of species decreases again (ca 1.5 times too) in urban habitats. Obviously these are average values — communities in particular study plots differ considerably among themselves. The carabid community in the P 5 study area (park greenery) has even one species more than in Hamernia, while at St 8 (street greenery) there are 3 times fewer species (Fig. 23).

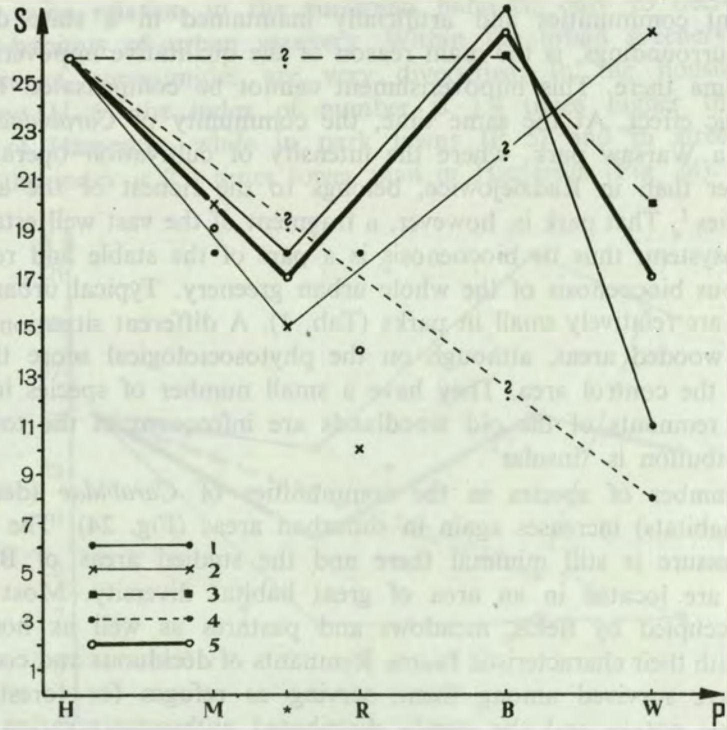


Fig. 23. The influence of settlement pressure on the number of species in carabid communities from various habitat sequences.

1 — wooded areas, 2 — park greenery; 3 — housing estates' greenery; 4 — street greenery (P — intensity of pressure; H — Hamernia; M — Młochów; R — Radziejowice; * — rural parks on average; B — Białołęka Dworska; W — urban greenery of Warsaw; S — number of species; ? — no data available)

A detailed description and interpretation of changes in particular environment sequences would be extremely complicated, as these sequences do not form homogenous systems with one ecological factor changing. The number of species and other parameters of communities depend not only on the form and intensity of anthropogenic pressure; a whole complex of factors, as well as surroundings of a given study area play an important role here.

The transformation of an original forest habitat into a rural park means, first of all, a complete restructuring of the plant cover (in lawns) or, at least, a radical limiting of forest area and thinning of trees (in the case of park woodlands area). These changes are maintained by more or les intensive horticultural operations. Moreover, the rural parks in question have an insular character lying within an area of a completely different nature — the non-managed (uncultivated) park in Młochów among vast arable lands, the managed (cultivated) park in Radziejowice, amongst meadows and forests.

It is possible that this isolation of small park areas, encircled by other plant communities and artificially maintained in a state different from its surroundings, is the main reason of the qualitative impoverishment of the fauna there. This impoverishment cannot be compensated even by an ecotonic effect. At the same time, the community of *Carabidae* in the lawns of a Warsaw park, where the intensity of cultivation operations is still greater than in Radziejowice, belongs to the richest of the analysed communities [1]. That park is, however, a fragment of the vast well established urban ecosystem, thus its biocoenosis is a part of the stable and relatively homogenous biocoenosis of the whole urban greenery. Typical urbanization influences are relatively small in parks (Tab, 1). A different situation occurs in urban wooded areas, although on the phytosociological score they are closest to the control area. They have a small number of species in them. However, remnants of the old woodlands are infrequent in the town and their distribution is "insular".

The number of species in the communities of *Carabidae* (decreasing in rural habitats) increases again in suburban areas (Fig. 24). The urbanization pressure is still minimal there and the studied areas of Białołęka Dworska are located in an area of great habitat diversity. Most of the area is occupied by fields, meadows and pastures as well as homestead gardens with their characteristic fauna. Remnants of deciduous and coniferous forests have survived among them, serving as refuges for forest fauna. The mosaic nature and the evenly distributed anthropogenization of the whole area probably eliminate the barriers which restrict the exchange of fauna. In this situation the ecotonic effect comes into full power.

The easiness of migration enriches particular communities, and, at the same time, unifies the fauna in phytosociologically different habitats. This is corroborated by the fact that although in each study area in Białołęka Dworska more species occur than in the control environment, the total number of species in all habitats of this suburban quarter (in deciduous and coniferous forests as well as meadows) is smaller than the total number of species in homologous natural environments [19].

Changing from suburban habitats to the urban greenery there is once again the decrease of the average number of species in the communities

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[1] Some divergences between the data presented here and the data given in the previous paper [16] result from the introductory nature of the latter (a shorter period of studies), as well as a slightly different approach to the problem.

(Fig. 23). This is undoubtedly caused by the strong influence of typical urbanization factors.

The general tendency to change the abundance of communities together with the increasing degree of the anthropogenization of habitats is identical with the tendency of changing the number of species: the average number of communities from every study area first decreases in the rural habitats (1.5 times in relation to the state in Hamernia), then increases in the same relation in the suburban habitats, only to decrease again in the habitats of urban greenery. Within the urban greenery itself the numbers of communities are very diversified. In the housing estates' greenery (H 6) the index of number is 1.4 times higher than in the forest of Hamernia, while in park lawns (P 5) and in street greenery (St 8) the index is 2.3 times lower than in Hamernia (Fig. 24).

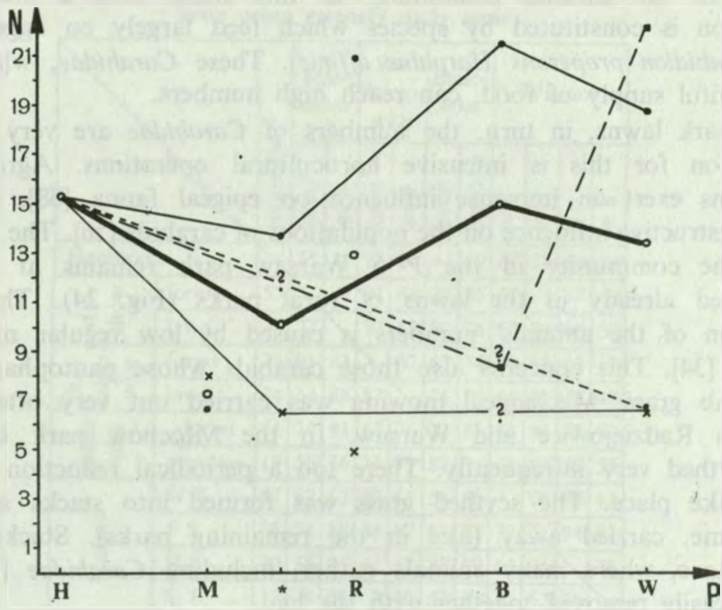


Fig. 24. The influence of settlement pressure on the numbers of carabid communities from various habitat sequences.
N — number; other symbols as in Fig. 23

Anthropogenic pressure usually causes the increases in the numbers of *Carabidae* in wooded areas (a number lower than in Hamernia occurs only in Młochów — Fig. 24, where the wooded part of the park is especially intensively penetrated by hens). A high index of the number of carabids in anthropogenized wooded areas does not automatically mean that the active pressure there influences the increase in numbers of the local fauna. This result should rather be ascribed to the influence of the pressure on the fauna of the surrounding open areas (lawns, fields), this influence being more unfavourable than in wooded areas. Wooded areas, on the other hand, may consitute a permanent or temporary hiding place for the emigrating fauna. Among the *Carabidae* of anthropogenized wooded areas many elements are characteristic of open areas (Tab. 31, Fig. 36). Without them the abundance of communities in the sequence of wooded areas would show a rather decreasing tendency.

High numbers of the *Carabidae* community in urban housing estates' greenery (H 6) must be attributed, however, to direct anthropogenic influence (Fig. 24). The pollution of lawns with excrements of domestic animals and food refuse is the reason of the increased number of saprophagous invertebrates, especially the larvae of *Diptera*. In Warsaw, the density of the distribution of *Diptera* larvae in the soil is 50 individuals/1 sq. m. on the average. In Wierzbno (H 6) the density exceeds 100 individuals/1 sq. m. In the carabid community in this study area a considerable proportion is constituted by species which feed largely on eggs of flies (e.g. *Bembidion properans Harpalus affinis*). These *Carabidae*, when given the plentiful supply of food, can reach high numbers.

On park lawns, in turn, the numbers of *Carabidae* are very low and the reason for this is intensive horticultural operations. Agrotechnical operations exert an immense influence on epigeal fauna [68], and thus also a destructive influence on the populations of carabids [56]. The abundance of the community in the P 5 Warsaw park remains at the level established already in the lawns of rural parks (Fig. 24). The radical restriction of the animals' numbers is caused by low regular mechanical mowing [34]. This concerns also those carabids whose pantophagous species climb grass. Mechanical mowing was carried out very often in the parks in Radziejowice and Warsaw. In the Młochów park the lawns were scythed very infrequently. There too a periodical reduction of fauna could take place. The scythed grass was formed into stacks and, after some time, carried away (like in the remaining parks). Stacks of hay are a place, where many animals gather, including *Carabidae* [5], which can be easily removed together with the hay.

It is obvious that such radical changes of habitats must consequently result in the qualitative restructuring of fauna. Carabids occurring in lime-oak-hornbeam forest in Hamernia belong to 11 genera (according to the data from pitfall traps; together 18 genera have been found) (Tab. 11). Most numerously represented is the *Carabus* L. genus — 7 species. Further places belong to the *Pterostichus* Bon. and *Amara* Bon. genera (respectively 5 and 3 species). Settlement pressure does not usually cause a decrease in the number of genera of which a community is composed, and by no means are these changes proportional to a decrease in the number of species. On the contrary, the number of genera often increases in anthropogenized habitats. For instance, there are 15 genera in the wooded park in Radziejowice, and 12 genera in the greenery of Wierzbno

(H 6) housing estate. In the park near the Cemetery-Mausoleum of Soviet Soldiers (P 5) the number of genera is still higher (17), but there are also more species than in the forest in Hamernia. An increase of the number of genera is linked tò the influx to anthropogenic habitats of numerous and various forms connected with open areas, non-occurrent in compact tree stands.

The dominant role of the *Carabus* L. genus (in the analysed urban areas only *C. nemoralis* remains from 7 species in the forest in Hamernia) is gradually being taken over in anthropogenized habitats by the following genera: *Amara* Bon., *Pterostichus* Bon., *Harpalus* Latr., and *Calathus* Bon. Many new genera appear too, represented by singular species (Tabs 2—5, 8—10).

Tab. 27. Quantitative-qualitative similarities of *Carabidae* communities from non-urban, suburban, and selected Warsaw's urban greenery study areas

		Hamernia	Młochów		Radziejowice		Białołęka		Warsaw			
			forest	lawn	forest	lawn	forest	meadow	W 5	P 5	H 6	St 8
Hamernia			55	31	73	24	41	19	47	38	30	13
Młochów	forest	55		77	91	64	74	55	67	71	38	9
	lawn	31	77		83	88	81	76	62	88	65	50
Radziejowice	forest	73	91	83		87	67	74	82	88	62	7
	lawn	24	64	88	87		76	79	61	87	57	40
Białołęka	forest	41	74	81	67	76		87	58	91	88	52
	meadow	19	55	76	74	79	87		66	82	59	53
Warsaw	W 5	47	67	62	82	61	58	66		79	65	11
	P 5	38	71	88	88	87	91	82	79		94	52
	H 6	30	38	65	62	57	88	59	65	94		76
	St 8	13	9	50	7	40	52	53	11	52	76	

The growing intensity of settlement pressure is reflected in the system of similarities of carabid communities from study areas with different degrees of anthropogenization. In the case of particular communities their values of similarity oscillate considerably (Tab. 27), but the average value for adequately arranged groups of study areas show a definite tendency: the greater difference in the degree of anthropogenization of habitats, the smaller the similarity of their fauna. Thus the average similarity of communities in areas which differ by one degree of the pressure (Hamernia—Młochów, Młochów—Radziejowice, Radziejowice—Białołęka, Białołęka—Warsaw) is 64%; by 2 degrees (Hamernia—Radziejowice, Radziejowice—Warsaw, Młochów—Białołęka—68% (an exceptional, but non-significant statistical deviation from the leading tendency); by 3 degrees (Hamernia—

Białołęka, Młochów—Warsaw)—54%; by 4 degrees (Hamernia—Warsaw) —32%. It can thus be seen that a consipicuous difference shows at a 3-degree interval (this refers to the transition from natural environment to suburban environments, or from uncultivated rural areas to urban greenery). At a 4-degree interval (the natural environment — urban greenery) the difference in fauna is already very large.

CHANGES IN INDICES OF STRUCTURE; EVALUATION OF COMMUNITIES

Changes in numbers and species composition result in the transformation of the structure of carabid communities in the environments under the influence of settlement pressure. All the community structure parameters, which have already been discussed in the chapter dealing with Warsaw's communities, have been analyzed here as well. They include the proportion of the dominant, the number of accessory species, as well as the indices of diversity and equitability.

Similarly to the changes of the number of species and abundance, the changes of the parameters of carabid communities' structure, average for all environment sequences, do not show any direct dependence on the intensity of anthropogenic pressure. However, the tendencies of these changes are usually convergent (Figs 23, 24, Tab. 28). It is especially visible in the case of such values as proportion of individuals of the dominant species and the index of general diversity ($\bar{H}$).

Individuals of the dominant species in a natural *Tilio-Carpinetum* forest (Hamernia) constitute 27.5% of the total number of the community. Analogus values for all anthropogenized habitats (average for the study areas of a given degree of presure) are higher. Thus settlement pressure increases the disproportion between the abundance of the dominant and the abundance of the remaining species in a community. This is a common effect of anthropogenization. The size of this disproportion changes together with the increase of the pressure. In communities from the non--managed rural park the average proportion of the dominant is 1.4 times higher than in natural environment. In the communities from the cultivated (managed) rural park the difference is already as high as 2.5 times. In suburban habitats, however, there is a serious decrease in the disproportion: the participation of the dominant there is only 1.2 times higher than in the forest in Hamernia. Another growth of disproportion occurs in the habitats of urban greenery — the difference amounts to 1.5 times (Tab. 28). Hence also in this aspect suburban habitats show a deviation from the general tendencies of the fauna's restructuring.

An identical regularity appears also in the changes of the communities' diversity. The general tendency is the decrease of the $\bar{H}$ index value alongside the increase of the pressure. This has already been stated by Müller et al. [44]. In suburban habitats the value of $\bar{H}$ comes back to the level characteristic of natural environment. The number and proportion of accessory species in suburban communities are also relatively very high — higher than in the rural parks and urban greenery. Only the changes of the index of equitability ($\bar{J}$) do not show this tendency (Tab. 28).

The worst structure in many respects is featured by the communities from the managed rural park (Tab. 28). Hence three questions come to mind: why do the communities in Białołęka have a relatively proper structure?; why do the communities in Radziejowice have such a bad structure?; why is the situation in Warsaw's urban greenery not the worst one? It seems that the reasons for this are, apart from local anthropogenic factors, the conditions of the areas in which the studied plots are situated: the "mosaic" nature of the suburban area, the insular situation of the rural park in an area of a completely different character, and the location of urban study areas within a homogenous and stable landscape. Thus, these are the same conditions which probably determine a similar system of parameters of the communities already described: the number of species and their abundance (numbers).

The proper structure of Białołęka's communities, contrary to the structure of the communities in Radziejowice, may also be to some extent the result of their different reaction to various forms of anthropogenic pressure. On the whole, the intensity of settlement pressure in Białołęka is greater than in Radziejowice, on the other hand, the agrotechnical operations

Tab. 28. Structure of *Carabidae* communities in areas anthropogenized in a different way and to a different extent: P — degree of settlement pressure; %D — proportion of individuals of a dominant in the number of community; %(N)ac. — proportion (and number) of accessory species in community's species composition; $\bar{H}$ — index of general diversity; $\bar{J}$ — index of equitability

P	Habitat	Study area	%D	%(N)ac.	$\bar{H}$	$\bar{J}$
0	Natural	Hamernia	27.5	58 (15)	2.20	0.68
1	Rural non-managed	Młochów-forest	42.4	17 (3)	1.98	0.69
		Młochów-lawn	32.5	30 (6)	2.19	0.73
		average	37.5	24 (5)	2.09	0.71
2	Rural managed	Radziejowice-forest	78.4	67 (12)	0.99	0.34
		Radziejowice-lawn	58.7	10 (1)	1.50	0.65
		average	68.5	39 (7)	1.25	0.50
3	Suburban	Białołęka-forest	40.5	61 (17)	1.98	0.60
		Białołęka-meadow	24.4	38 (10)	2.41	0.74
		average	32.5	50 (14)	2.20	0.67
4	Urban greenery	W 5	46.2	– (–)	1.74	0.73
		P 5	53.0	59 (16)	1.83	0.56
		H 6	34.8	65 (13)	1.85	0.62
		St 8	27.3	– (–)	1.74	0.84
		average	40.5	31 (7)	1.79	0.69

themselves, to which *Carabidae* are very sensitive, are much less intensive in the studied areas of Białołęka.

A problem to be explained yet is the question of the proper dominance structure (J index) of Warsaw's community from a dual carriage-way partition green (St 8). It might be thought that an area of such intensity of traffic pressure should have its fauna degenerated in every respect. This community is indeed very poor (8 species) and of relatively low diversity ($\bar{H} = 1.74$), but the dominating species constitutes there only 27.3% of the total number, and the index of equitability ($\bar{J} = 0.84$) is much higher than in the forest in Hamernia (Tab. 28). The reasons for this are to be found in the species composition of the community (Tab. 4). Seven out of 8 species which occur there belong to the group of dominants in Warsaw's street greenery. They are, therefore, the species of more or less equal degree of adaptation to the given habitat conditions. All the remaining species have been eliminated from the community by traffic pressure. A fact to be taken account of is the lack of accessory species (Tab. 28, Fig. 35). The abundance of this community is very low, equal to the abundance of carabids in lawns of the urban parks. The dual carriage-way partition community is, however, 3.5 times poorer than the park one. This suggests that the restriction of the numbers of carabids in the street greenery is mainly caused by horticultural operations, whereas the withdrawal of accessory species has occurred due to the chemical contamination of the environment.

The lack of some links in the sequences of particular study areas unfortunately makes it impossible to show exactly in which sequence of environments the settlement pressure is most influential and in which it has the least influence on the structure of carabid communities. The available data allow us only to form certain expectations as to the different influence of pressures on the structure of communities in wooded areas, park lawns, and, with the greatest risk of an approximation, in the sequence of the housing estates' greenery (the sequence of the greenery of roads cannot be taken into consideration). The most favourable structure features are shown (on the average) by communities of the housing estates' sequence. The second place is taken by communities from park lawns, the third by those from the wooded areas. This order is shown nearly without exception by all values taken into consideration (Tab. 29).

The ordering of the types of habitats obtained here is identical with the ordering of types of the urban greenery of Warsaw, arranged according to the worsening structure of their communities (chapter "Indices of structure and the evaluation of communities"). If, then, the analysed data reflect the real state it means that settlement pressure has the greatest impact on the structure of carabid communities in wooded areas, not only in the conditions of extremely advanced urbanization (within closely built-up areas) but also in loosely built-up non-urban areas. This suggests

Tab. 29. Structure of *Carabidae* communities in habitat sequences anthropogenized in a different way (the average values for the groups of study areas; symbols as in tab. 28)

Habitat sequence	%D	%(N)ac.	H̄	J̄
Wooded areas	52	36 (8)	1.67	0.59
Park lawns	48	33 (8)	1.84	0.65
Housing estates' greenery	30	52 (12)	2.13	0.68

that the forest association of carabids has much smaller abilities to adapt to anthropogenized habitats than the *Carabidae* of open areas.

The dominance structure of *Carabidae* communities from the studied areas has been presented in a graphic form (Figs 25—35), the positions occupied by species of different habitat requirements have been marked by means of the general division into forest species, species of open areas (including field species), and ubiquitous species.

In the community from the lime-oak-hornbeam forest in Hamernia 9 first places are occupied by typical forest species. The species of open areas belong to the accessory species group (Fig. 25). In particular sequences of anthropogenized habitats a gradual diminution of the significance of forest species can be observed, which are ousted by the species characteristic of open areas. The significance of ubiquists is growing. This process is

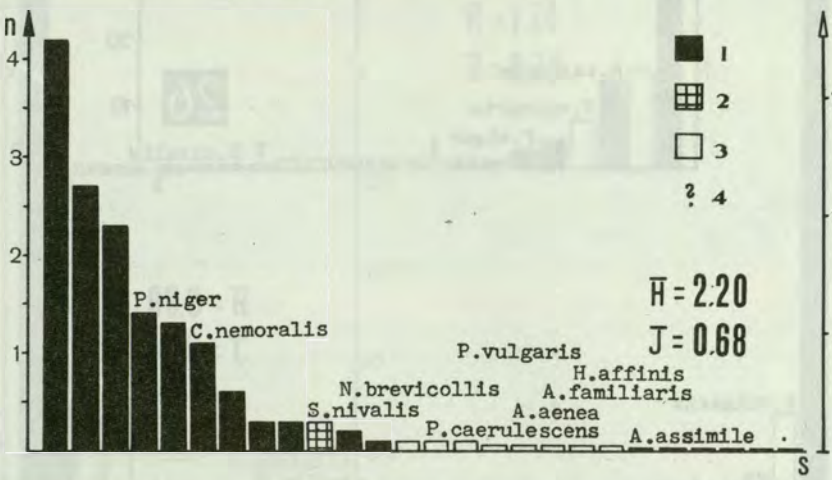
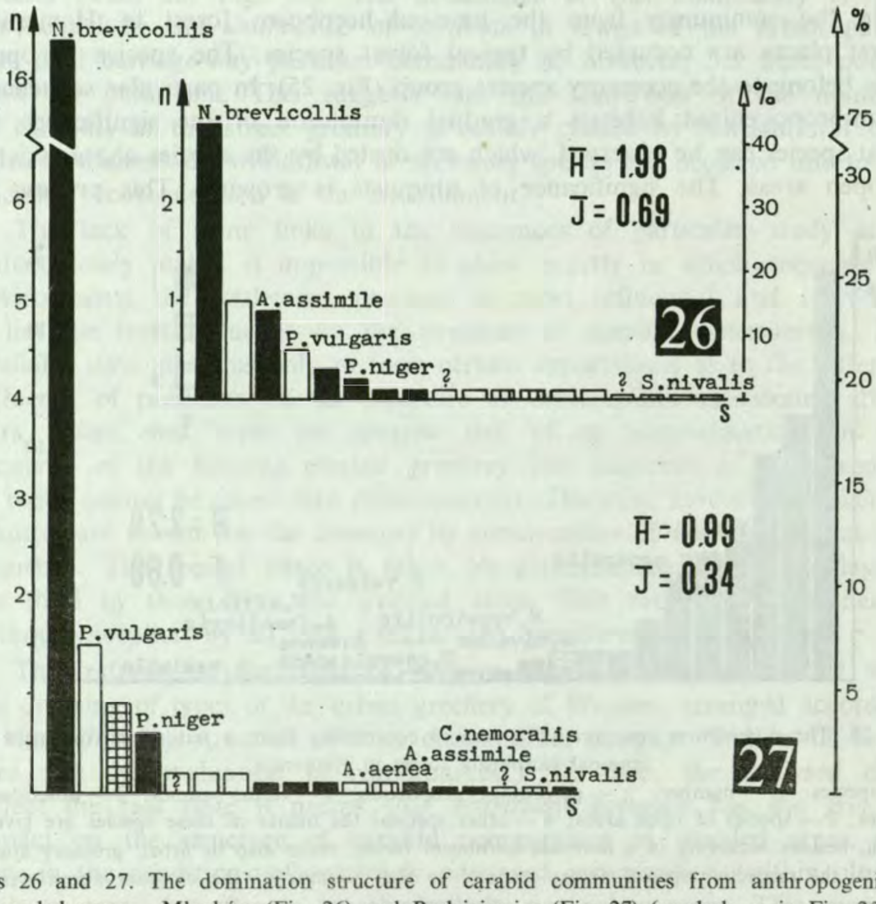


Fig. 25. The domination structure of a carabid community from a natural environment — lime-oak-hornbeam forest in Hamernia.

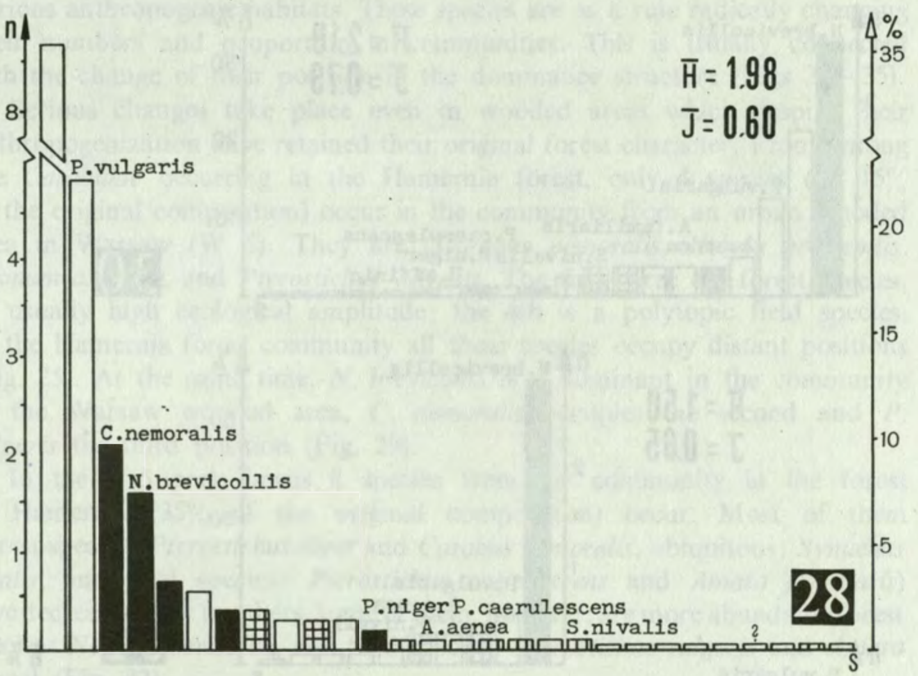
S — species; N — number; % — percentage proportion; 1 — forest species; 2 — ubiquitous species; 3 — species of open areas; 4 — other species; the names of these species are given, which, besides occurring in a lime-oak-hornbeam forest, occur also in urban greenery study areas — the respective species names respond to the columns of the diagram above which they open advancing most slowly in the sequence of wooded areas, but there too the proportion of the species from open areas is on a marked increase, and in the forest in Białołęka 2 such species even dominate a community (Figs 26—29). This is the result of the location of the studied areas of lime-oak-hornbeam forest among large arable fields. *Carabidae* of open areas do not, however, show great tendencies towards migration [35] but thus localized and so small a woodland area makes penetration inevitable. Wooded areas next to fields may also serve as a place of wintering for many field carabids [32].

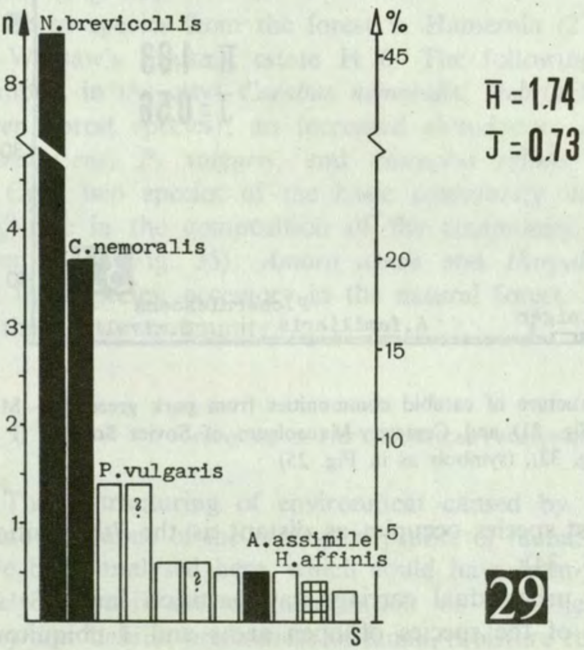
The significance of species characteristic of open areas, as well as of ubiquitous species, is usually higher in communities from park lawns than in communities from wooded areas. In the rural parks the position of dominants in lawn communities is still occupied by a forest species. It is replaced by a field species only in a Warsaw park (Figs 30—32).

In the housing estates' greenery the species of open areas and ubiquists already visibly dominate, especially in the H 6 housing estate, where

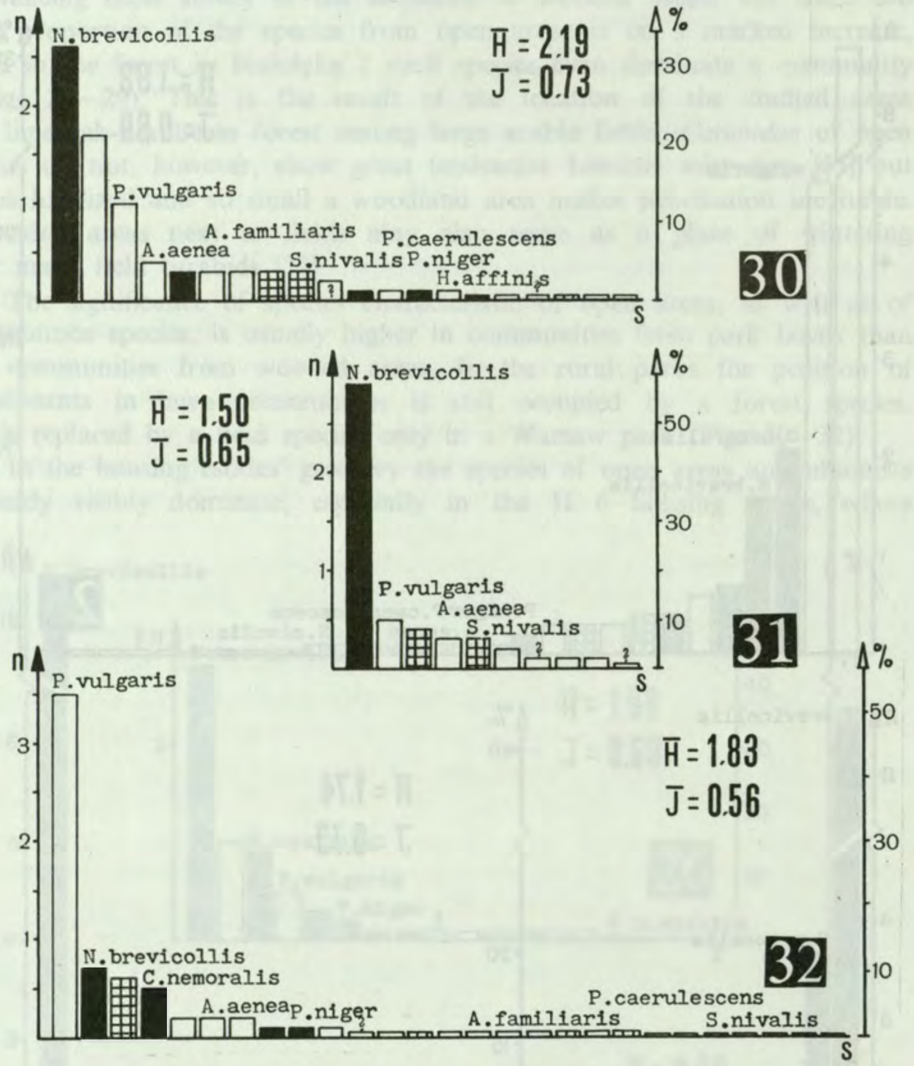


Figs 26 and 27. The domination structure of carabid communities from anthropogenized wooded areas — Młochów (Fig. 26) and Radziejowice (Fig. 27) (symbols as in Fig. 25)





Figs 28 and 29. The domination structure of carabid communities from anthropogenized wooded areas — Białołęka Dworska (Fig. 28) and the Sejm (W 5) (Fig. 29) (symbols as in Fig. 25)



Figs 30—32. The domination structure of carabid communities from park greenery — Młochów (Fig. 30), Radziejowice (Fig. 31) and Cemetery-Mausoleum of Soviet Soldiers (P 5) (Fig. 32), (symbols as in Fig. 25)

the most numerous of forest species occupies as distant as the 7th position in the community (Figs 33, 34).

The community in the urban dual carriage-way partition lawn (St 8) consists already exclusively of the species of open areas and 1 ubiquitous species (Fig. 35).

Although the changes in the species composition of *Carabidae* taking place in the course of anthropogenization are very serious, relatively many species occurring in the natural forest are to be found also in various anthropogenic habitats. These species are as a rule radically changing their numbers and proportion in communities. This is usually connected with the change of their position in the dominance structure (Figs 25—35).

Serious changes take place even in wooded areas which despite their anthropogenization have retained their original forest character. From among the *Carabidae* occurring in the Hamernia forest, only 4 species (ca 15% of the original composition) occur in the community from an urban wooded area in Warsaw (W 5). They are: *Carabus nemoralis, Nebria brevicollis, Agonum assimile*, and *Pterostichus vulgaris*. The first three are forest species, of usually high ecological amplitude; the 4th is a polytopic field species. In the Hamernia forest community all these species occupy distant positions (Fig. 25). At the same time, *N. brevicollis* is a dominant in the community of the Warsaw wooded area, *C. nemoralis* occupies the second and *P. vulgaris* the third position (Fig. 29).

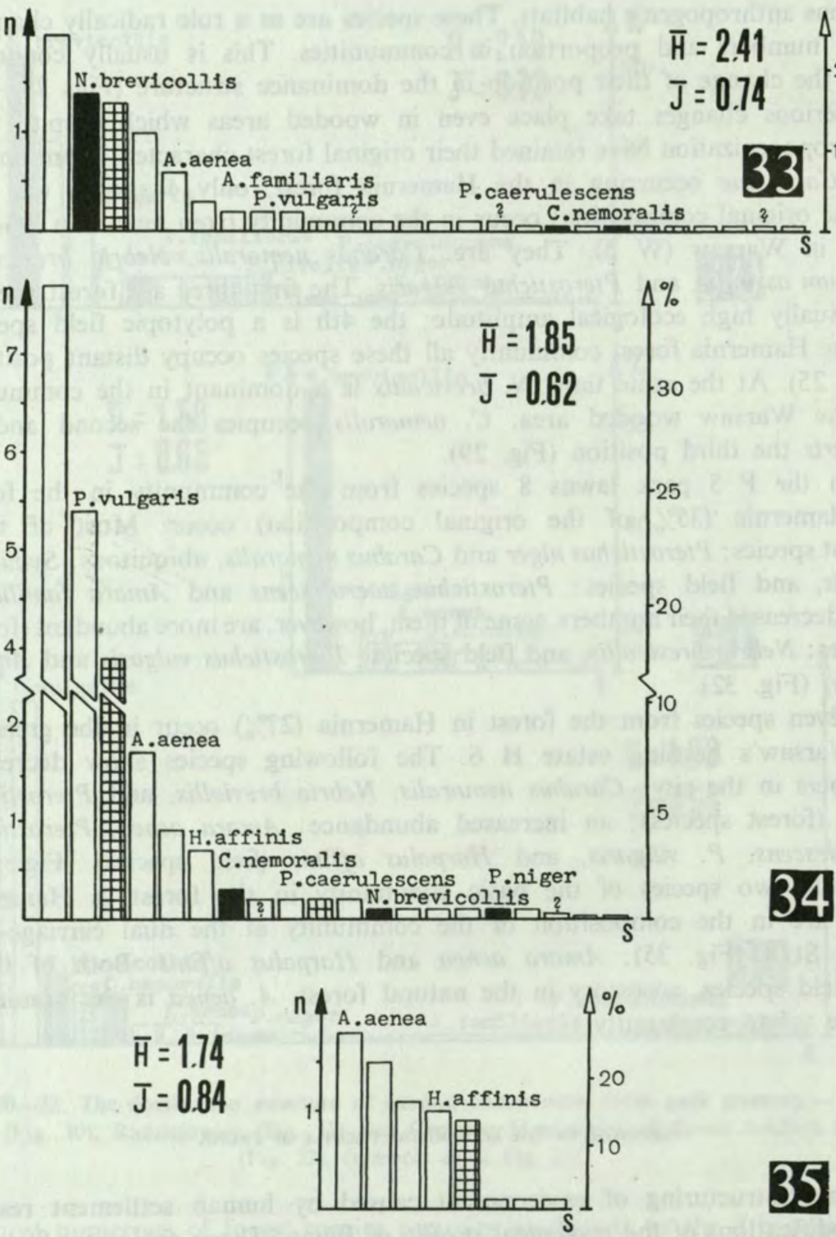
In the P 5 park lawns 8 species from the community in the forest in Hamernia (35% of the original composition) occur. Most of them (forest species: *Pterostichus niger* and *Carabus nemoralis*, ubiquitous: *Synuchus nivalis*, and field species: *Pterostichus caerulescens* and *Amara familiaris*) have decreased their numbers, some of them, however, are more abundant (forest species: *Nebria brevicollis*, and field species: *Pterostichus vulgaris* and *Amara aenea*) (Fig. 32).

Seven species from the forest in Hamernia (27%) occur in the greenery of Warsaw's housing estate H 6. The following species show decreased numbers in the city: *Carabus nemoralis, Nebria breviollis*, and *Pterostichus niger* (forest species); an increased abundance: *Amara aenea, Pterostichus caerulescens, P. vulgaris*, and *Harpalus affinis* (field species) (Fig. 34).

Only two species of the basic community in the forest in Hamernia (8%) are in the composition of the community at the dual carriage-way green St 8 (Fig. 35): *Amara aenea* and *Harpalus affinis*. Both of them are field species, accessory in the natural forest. *A. aenea* is the dominant in the urban community.

CHANGES OF THE ECOLOGICAL PROFILE OF FAUNA

The restructuring of environment caused by human settlement results in modifications of the ecological profile of fauna. Those ecological features have been analysed here, which could have been reliably estimated quantitatively through the characterization of a sufficient number of species. They are: habitat preferences of fauna, moisture requirements, food specialization, phenology, and the proportion of forms with different body size. A more general division than before has been applied in the description of the problem of habitat requirements of fauna. Similarly to the analysis of dominance structure, 3 groups of species have been distinguished:



Figs 33—35. The domination structure of carabid communities from housing estates' greenery — Białołęka Dworska (Fig. 33) and Wierzbno (H 6) (Fig. 34), and from street greenery — Niepodległości Avenue (St 8) (Fig. 35) (symbols as in Fig. 25)

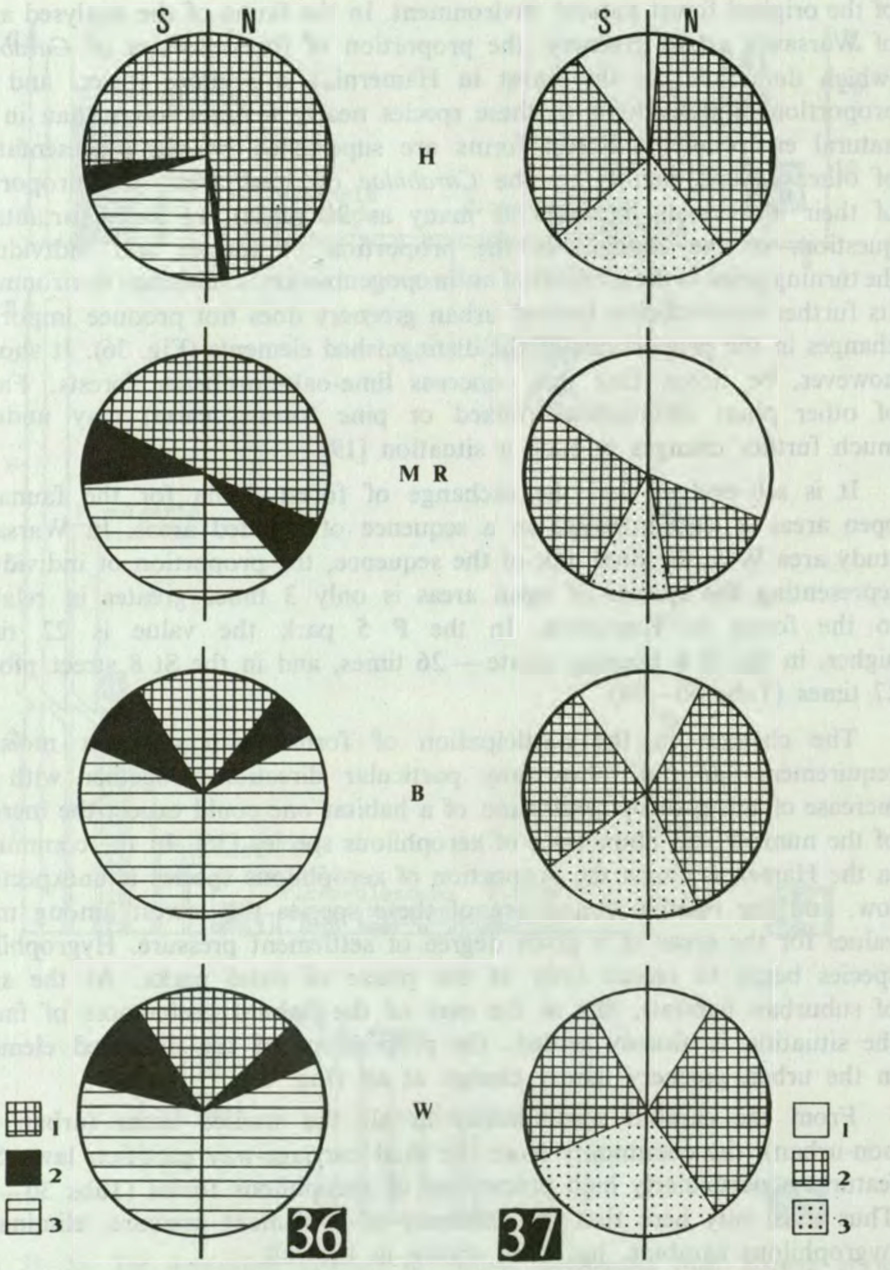
forest species, species of open areas, and ubiquitous species. It was shown before that field carabids (i.e. of open areas) and ubiquitous ones show a prevalence over forest carabids in urbanized environments. This tendency occurs, gradually increasing, in the course of the whole process of restructuring of the original forest natural environment. In the fauna of the analysed areas of Warsaw's urban greenery, the proportion of forest species of *Carabidae* (which dominated in the forest in Hamernia) is 3 times lower, and the proportion of individuals of these species nearly 4 times lower than in the natural environment. Forest forms are superseded by the representatives of other groups, mainly by the *Carabidae* of open areas (the proportion of their individuals increases as many as 21 times). In both variants in question, of the changes in the proportion of species and individuals, the turning point in the gradient of anthropogenization is suburban environment. Its further restructuring toward urban greenery does not produce important changes in the proportions of the distinguished elements (Fig. 36). It should, however, be noted that this concerns lime-oak-hornbeam forests. Fauna of other plant associations (mixed or pine forests, carrs) may undergo much further changes in such a situation [19].

It is self-evident that the exchange of forest fauna for the fauna of open areas is least intensive in a sequence of wooded areas. In Warsaw's study area W 5, the final link of the sequence, the proportion of individuals representing the species of open areas is only 3 times greater in relation to the forest in Hamernia. In the P 5 park the value is 22 times higher, in the H 6 housing estate — 26 times, and in the St 8 street plot — 27 times (Tabs 30—34).

The changes in the participation of forms with different moisture requirements do not follow any particular direction. Together with the increase of the anthropogenization of a habitat one could expect the increase of the number and abundance of xerophilous species [36]. In the community in the Hamernia forest the proportion of xerophilous species is unexpectedly low, and the relative abundance of these species the lowest among mean values for the areas of a given degree of settlement pressure. Hygrophilous species begin to recede only at the phase of rural parks. At the stage of suburban habitats, like in the case of the habitat preferences of fauna, the situation is already settled: the proportions of the discussed elements in the urban greenery hardly change at all (Fig. 37).

From the carabid communities in all the studied areas (urban and non-urban), the community from the dual carriage-way partition lawn St 8 features a particularly high proportion of xerophilous forms (Tabs 30—34). Thus it is only here that the influence of settlement pressure, eliminating hygrophilous carabids, has been shown in the full.

The changes of proportions between zoophagans and panthophagists are quite clearly correlated with the increase of settlement pressure. Pantophagous *Carabidae*, almost absent in the forest in Hamernia, gradually increase their proportion in the fauna of more and more anthropogenized habitats. This relation, simple in the case of the proportion of species of every group, is slightly disturbed when considering their relative abundance.



Figs 36—37. The changes of the proportions of particular ecological elements in the carabid fauna under the influence of settlement pressure — habitat preferences (Fig. 36). 1 — forest forms; 2 — ubiquitous forms; 3 — forms of open areas; moisture requirements (Fig. 37): 1 — hygrophilous forms; 2 — mesohygrophilous forms; 3 — xerophilous forms (S — proportions of species; N — proportions of individuals; H — Hamernia; MR — rural parks on the average; B — Białołęka Dworska; W — urban greenery of Warsaw)

Tab. 30. Proportions of particular ecological elements in the *Carabidae* community of natural habitat — *Tilio-Carpinetum* forest in Hamernia (S — number of species; $\%_S$ — proportions of species; N — index of number; $\%_N$ — proportion of individuals)

Ecological element	S	$\%_S$	N	$\%_N$
Forest	13	52	14.5	95
Open areas	10	40	0.5	3
Ubiquitous	2	8	0.3	2
Hygrophilous	5	20	0.5	3
Mesohygrophilous	13	52	11.5	76
Xerophilous	7	28	3.2	21
Zoophagous	21	81	15.2	99
Pantophagous	5	19	0.1	1
Spring	13	50	5.8	38
Autumn	13	50	9.5	62
Large	5	19	8.3	54
Medium	10	39	6.2	41
Small	11	42	0.8	5

Namely, in Białołęka there are more pantophagists than in the urban greenery of Warsaw (Fig. 38). This is a result of a higher proportion of individuals representing typical field species in the whole of the open areas species in Białołęka than in the urban greenery. Almost all field *Carabidae* are pantophagous. For more or less the same reason there are more pantophagists in the park in Młochów (due to its inter-field situation) than in the park in Radziejowice (Tabs 31, 32). The general tendency of the replacement of zoophagans by pantophagists along the increase of settlement pressure is secondary — it results from the increasing proportion of field forms.

The proportion of panthophagous species in the fauna of the urban greenery is nearly 2.5 times higher than in the forest in Hamernia, and their relative abundance (number) is 20 times higher (in Białołęka respectively: 2.1 times and 51 times) (Fig. 38). The St 8 lawn community exhibits the greatest proportion of pantophagous individuals (Tabs 31—34).

Differences in the proportion of species of different phenological types in the fauna of habitats with a different degree of anthropogenization are insignificant. The difference between the extreme areas of the gradient — the forest in Hamernia and Warsaw's greenery — is of the order of a few percent. The proportion of spring species is greater in urban greenery by 3%, and of individuals of these species by 6.5% (Fig. 39). This concerns the mean values of proportions, whereas particular study areas representing a given level of anthropogenization often differ substantially (Tabs 30—34). Thus local conditions undoubtedly influence the proportions of spring and

Tab. 31. Proportions of particular ecological elements in the *Carabidae* communities of the sequence of anthropogenized wooded areas — rural, suburban and urban habitats (symbols as in tab. 30)

Ecological element \ Study area	Młochów-forest				Radziejowice-forest				Białołęka-forest				Warsaw-W 5			
	S	$\%_S$	N	$\%_N$	S	$\%_S$	N	$\%_N$	S	$\%_S$	N	$\%_N$	S	$\%_S$	N	$\%_N$
Forest	7	44	4.5	69	9	53	17.5	84	6	22	5.0	23	3	33	12.7	78
Open areas	6	37	1.8	28	5	29	2.2	11	15	56	15.2	71	5	56	3.3	20
Ubiquitous	3	19	0.2	3	3	18	1.0	5	6	22	1.3	6	1	11	0.4	2
Hygrophilous	6	40	4.0	65	6	33	17.0	81.5	4	16	1.7	8	3	27	10.4	56
Mesohygrophilous	7	47	2.0	33	10	56	3.8	18	13	52	18.8	89	5	46	6.6	36
Xerophilous	2	13	0.1	2	2	11	0.1	0.5	8	32	0.6	3	3	27	1.4	8
Zoophagous	15	83	5.5	83	17	89	20.7	99	17	68	11.2	53	6	55	15.1	82
Pantophagous	3	17	1.1	17	2	11	0.2	1	8	32	9.9	47	5	45	3.3	18
Spring	10	56	2.7	41	10	56	1.1	5	14	52	4.5	21	7	64	7.8	42
Autumn	8	44	3.9	59	8	44	19.8	95	13	48	17.0	79	4	36	10.6	58
Large	2	11	0.2	3	2	11	0.1	0.5	1	4	2.1	10	1	9	3.7	20
Medium	7	39	4.7	71	4	21	18.6	89	12	43	17.7	82	6	55	11.6	63
Small	9	50	1.7	26	13	68	2.2	10.5	15	53	1.7	8	4	36	3.1	17

Tab. 32. Proportions of particular ecological elements in the *Carabidae* communities of the sequence of park lawns — rural and urban habitats (symbols as in tab. 30)

Ecological element \ Study area	Młochów-lawn				Radziejowice-lawn				Warsaw-P 5			
	S	%S	N	%N	S	%S	N	%N	S	%S	N	%N
Forest	5	28	3.1	40	1	12.5	2.9	60	5	22	1.4	22
Open areas	10	56	4.0	51	5	62.5	0.7	15	5	22	4.4	67
Ubiquitous	3	16	0.7	9	2	25	1.2	25	13	56	0.7	11
Hygrophilous	4	22	3.1	40	3	30	3.0	61	6	24	0.9	14
Mesohygrophilous	10	56	3.9	50	5	50	1.3	27	12	48	5.3	80
Xerophilous	4	22	0.8	10	2	20	0.6	12	7	28	0.4	6
Zoophagous	14	70	5.2	65	7	70	4.3	88	16	64	6.0	92
Pantophagous	6	30	2.8	35	3	30	0.6	12	9	36	0.5	8
Spring	11	55	1.8	22.5	5	50	0.7	14	15	56	1.3	20
Autumn	9	45	6.2	77.5	5	50	4.2	86	12	44	5.3	80
Large	2	10	0.4	5	—	—	—	—	2	7	0.5	8
Medium	8	40	5.9	74	4	40	3.9	80	11	41	5.3	80
Small	10	50	1.7	21	6	60	1.0	20	14	52	0.8	12

autumn forms in communities, and a clear tendency of changes in the gradient of anthropogenization does not show probably for the same reasons for which it is inconspicuous within various types of the urban greenery (chapter "Ecological characteristics of fauna"). This opinion is supported by the data from rural habitats: in the intensively cultivated park in Radziejowice the proportion of spring *Carabidae* is far lower than in the neglected park in Młochów (despite generally higher anthropogenization of the Radziejowice's park).

The most vulnerable to settlement pressure from among carabids of various body sizes are big forms. Individuals of these species constitute a majority of the community in Hamernia, and the proportion of the species itself is considerable. This situation is radically different already in the least anthropogenized habitats, i.e. in rural parks. There, as well as in the habitats of stronger pressure (suburban and urban), the mean proportion of big carabids is insignificant. On the average, there are 2.5 times fewer "big" species in all anthropogenized habitats than in the forest in Hamernia, and over 10 times fewer individuals of these species (Fig. 40).

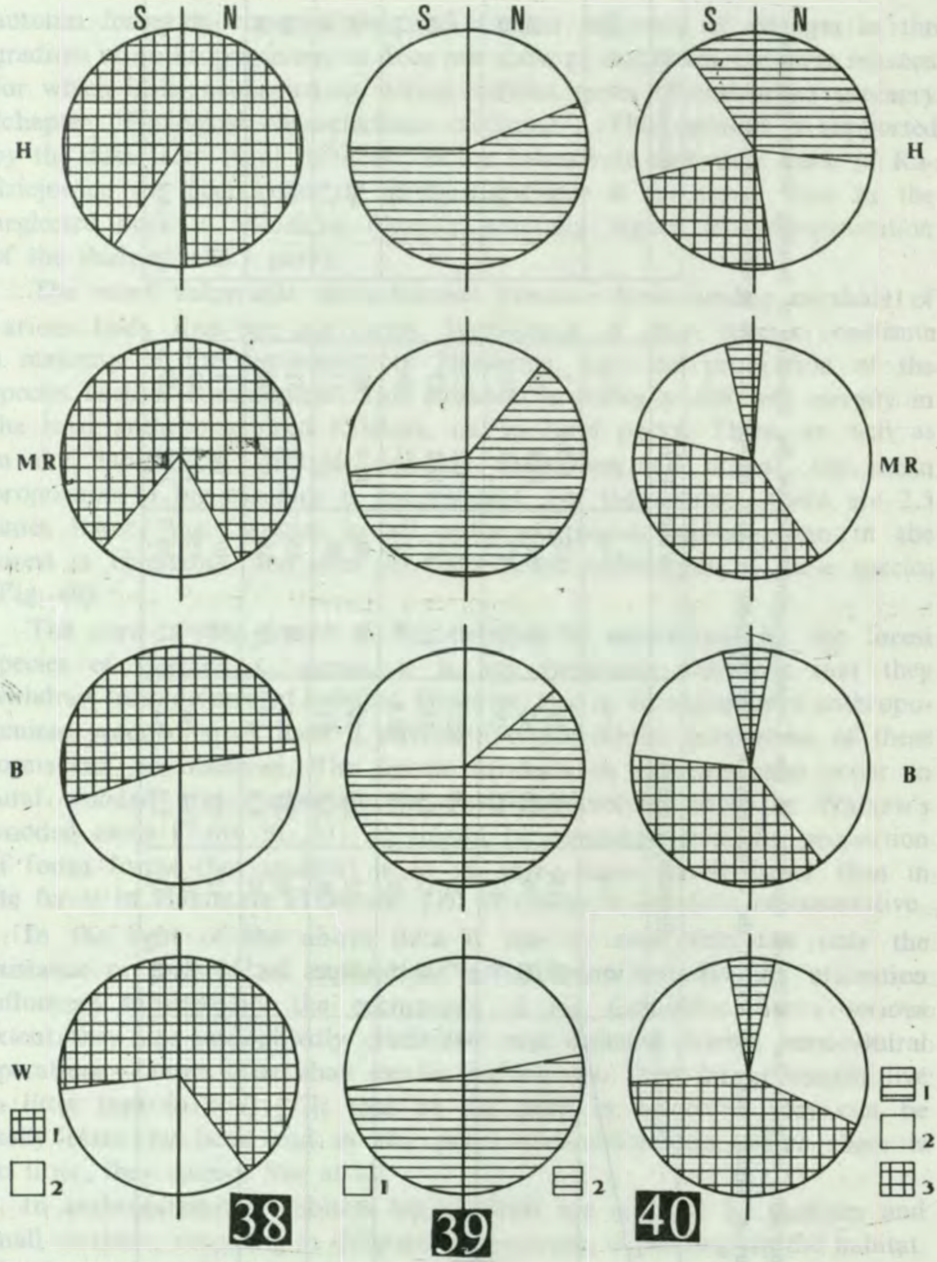
The core of the group of big carabids is constituted by the forest species of *Carabus* L. genus, it is not surprising therefore that they withdraw from deforested habitats. However, also in the sequence of anthropogenized wooded areas itself a serious decrease in the proportion of these forms can be observed. The fewest carabids in this sequence occur in rural wooded areas, especially in Radziejowice, the most in Warsaw's wooded areas (Tabs 30, 31). It should be remarked that the proportion of forest forms (but smaller) is in all these areas barely lower than in the forest in Hamernia (Tabs 30, 31). Selection is therefore representative.

In the light of the above data it can be seen that not only the existance or lack of an appropriate environment, but also its utilization influences substantially the occurrence of big *Carabidae*. To a serious extent they are undoubtedly eliminated mechanically during horticultural operations — more often than smaller individuals. Their larvae usually live in litter (not in soil) [57]; thus in the park in Młochów they can be easily eaten by hens and in the park in Radziejowice, where there is no litter, they cannot live at all.

In anthropogenized habitats big carabids are replaced by medium and small carabids, occurring in different proportions, depending on the habitat. The proportion of small individuals, which are not numerous in the forest in Hamernia, is greatest in the urban greenery (Fig. 40). In particular Warsaw's study areas the proportions of these forms are very uneven. It is significant that small-sized carabids are not numerous in lawns of the urban park. Anyhow, the proportions of these carabids in lawns of the rural parks are also relatively low (Tab. 32). Their occurrence is probably restricted by horticultural operations carried out in the parks' lawns.

Tabs 33 and 34. Proportions of particular ecological elements in the *Carabidae* communities of the sequence of housing estates greenery — suburban and urban habitat (tab. 33) and in the community of street greenery — urban habitat (tab. 34) (symbols as in tab. 30)

Ecological elements / Study area	Białołęka-meadow				Warsaw-H 6				Warsaw-St 8	
	S	%S	N	%N	S	%S	N	%N	N	%N
Forest	3	13	1.5	19	3	17	0.5	2	—	—
Open areas	16	70	5.0	62	12	66	17.3	79	5.7	86
Ubiquitous	4	17	1.5	19	3	17	4.1	19	0.9	14
Hygrophilous	5	22	1.8	22.5	2	11	0.2	1	—	—
Mesohygrophilous	12	52	4.4	55	11	57	18.2	83	3.5	53
Xerophilous	6	26	1.8	22.5	6	32	3.5	16	3.1	47
Zoophagous	13	52	3.2	39	14	70	18.4	83	4.2	64
Pantophagous	12	48	5.0	61	6	30	3.7	17	2.4	36
Spring	13	50	2.7	33	11	55	11.2	51	4.3	65
Autumn	13	50	5.5	67	9	45	10.9	49	2.3	35
Large	3	12	0.1	1	2	10	0.3	1	—	—
Medium	9	35	5.4	66	7	35	10.8	49	2.2	33
Small	14	53	2.7	33	11	55	11.0	50	4.4	67



Figs 38—40. The changes of the proportions of particular ecological elements in the carabid fauna under the influence of settlement pressure — food specialization (Fig. 38); 1 — zoophagans; 2 — pantophagists;
phenology (Fig. 39): 1 — spring forms; 2 — autumn forms;
size of the body (Fig. 40): 1 — big forms; 2 — medium forms; 3 — small forms (other symbols as in Figs 36 and 37)

It is likely that due to their small size they cannot escape successfully and are removed with the stacks of mowed grass to a greater extent than the carabids of medium size. *Carabidae* are very sensitive to the approach of man and their reaction is quickly to escape (big carabids) or to become immobilized (small carabids) [39].

CHANGES OF SEASONAL DYNAMICS

It has been shown in the analysis of the seasonal dynamics of carabids in urban greenery that it is different in various habitats. Differences, sometimes very important, occur also between the communities in habitats transformed to various extent by settlement pressure.

The *Carabidae* of the lime-oak-hornbeam forest in Hamernia reach their maximum activity in August and September. Autumn forms prevail there decisively. The spring peak (in May) is incommensurably weaker (Fig. 41). Communities in anthropogenized habitats show smaller or greater deviations from this pattern of dynamics. There are determined regularities, in accord with the gradient of environments; natural — rural — suburban — urban. An increase in settlement pressure causes the gradual strengthening of the spring peak and accordingly the weakening of the autumn peak. As a result there is the equation of both peaks in the urban greenery The increase of the significance of the spring peak is in precise concord with the increase of the pressure. In all the anthropogenized habitats the spring maximum of numbers is delayed by a month in relation to the state in the forest in Hamernia — it comes in June (Fig. 41). Regardless of this, *Carabidae* in anthropogenized habitats become active earlier in spring than in a natural forest. In the urban study areas 7.7% of all individuals were caught in April, whereas in Hamernia only 2.3%. The reason for this are undoubtedly the differences in climatic conditions, especially thermic, in these areas. It is colder in forest than in the more or less open anthropogenized areas. Within the urban habitats themselves the situation is different (communities in wooded areas are activated very early), there are, however, specific conditions for the exchange of heat with the surroundings, as well as for the daily temperature oscillation (chapter "The seasonal cycle").

The speed of the autumn inactivation of communities seems, on the one hand, correlated with the thermic conditions of a habitat and, on the other hand, with a longer or shorter vegetation period. In anthropogenized non-urban habitats (rural and suburban) carabids remain active for the longest time. Of all the individuals caught there, 21.2% and 10.6% respectively were caught in October. In the forest in Hamernia (where it is colder) only 6%. Still less, only 4.7% of the material of the whole season were collected in October in the urban study areas (Fig. 41), where the temperatures are highest but the vegetation period is shortened by urbanization factors.

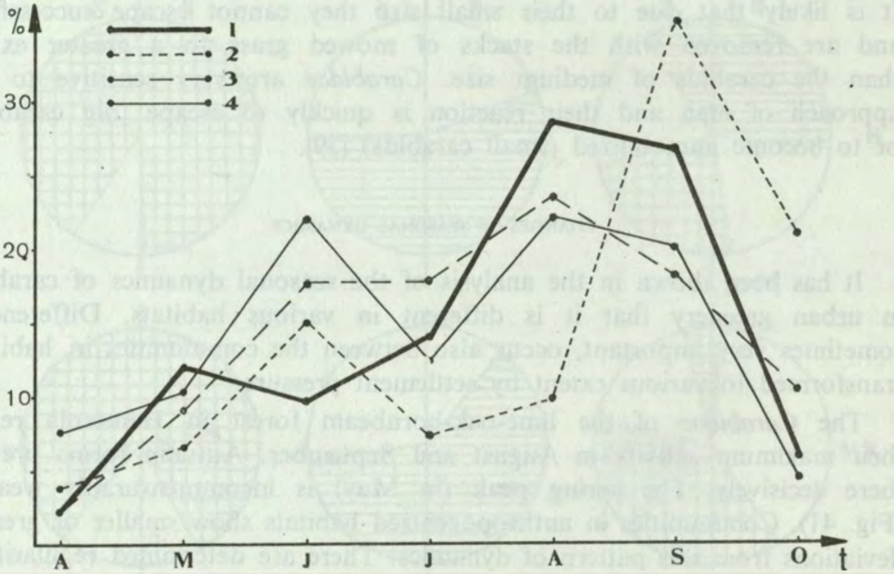


Fig. 41. The seasonal dynamics of carabids in environments of various anthropogenization degrees.
1 — natural environment; 2 — rural parks; 3 — suburban environment; 4 — urban greenery (t — time in months; % — percentage of individuals caught)

The χ^2 test has shown high significance of the differentiation of carabid dynamics within the group of habitats in question. The χ^2 value = 45.56 (total for the natural, rural, suburban, and urban environment) corresponds to the probability $P < 0.001$. The critical value of χ^2 at level of significance 0.05 is 21.03.

Particular types of environments differ between themselves to various degrees. The dynamics of carabids differs in a highly significant way ($P < 0.001$) between the following environments: natural and rural, rural and suburban, and rural and urban. The difference between the natural and urban environments reaches the limit of significance ($P \approx 0.05$). Non-significant are the differences between the natural environment and suburban environments, as well as between suburban and urban environments (Tab. 35).

Tab. 35. Values of χ^2 depicting differentiation of *Carabidae* seasonal dynamics within habitats anthropogenized to a different extent

Environment	Natural	Rural	Suburban	Urban
Natural		22.19^{+++}	6.14	8.77
Rural	22.19^{+++}		28.96^{+++}	24.46^{+++}
Suburban	6.14	28.96^{+++}		5.09
Urban	8.77	24.46^{+++}	5.09	

$^{+++}$ Value higher than critical at P = 0,001; in other cases the differences are insignificant.

SUMMARY AND CONCLUSIONS

Human settlement, and especially the urbanization of the environment, restricts the occurrence of carabids. Within the administrative borders of Warsaw there occur 276 carabid species (85% of the carabid fauna of Mazovian Lowland), but most of them inhabit only scarcely built-up or underdeveloped suburbs. Only 113 species (41% of the fauna of the whole town; 35% of the fauna of Mazovia) were found in the typical urban greenery, within built-up areas.

The density of carabids in the urbanized zone is usually very low although the way of horticultural landscaping of an area substantially influences the abundance of communities. The low numbers of *Carabidae* are mostly caused by mechanical and chemical agrotechnical operations which destroy carabids directly and also limit their food base. The systematic removal of dead organic matter from the surface of ground leads to the decrease in the number of saprophagans with which *Carabidae* are trophically linked. Changes in the communities of *Carabidae* are aggravated by the influence of toxic pollution of soil and air, but this is rather an indirect influence (destruction of vegetation, aridization of soil).

The most numerous and, at the same time, the most common species of *Carabidae* in the greenery of Warsaw are *Pterostichus vulgaris, Nebria brevicollis, Calathus fuscipes, Harpalus rufipes, Bembidion properans, Amara aenea, Harpalus affinis, Carabus nemoralis,* and *Pterostichus virens*. The first four are species which are even markedly favoured by settlement pressure. The rest are species which react well to anthropogenic influences and may locally reach high numbers.

The urban greenery fauna of *Carabidae* differs from the fauna of the nearby non-urbanized areas by its zoogeographical and ecological profile. The urbanization barrier is most easily broken by the species of the greatest ranges: Holarctic, Palaearctic, and Eurosiberian. Selection comprising the species of narrower areas is proportional to the intensity of urbanization influence. Adaptation to living in the town is easiest also for carabids of the greatest ecological amplitude — eurytopic and polytopic, and from among the species of various habitat requirements — field *Carabidae*. The main feature of the urban fauna of carabids is the increased proportions of these species as compared with the non-urban fauna. The core of Warsaw's fauna of carabids is constituted on the quantitative score by Eurosiberian and Palaearctic forms, and on the ecological score, field polytopic forms connected with poor clay and sandy soils, zoophagous, medium-sized, and of the autumn type of breeding.

In particular urban habitats, differently cultivated and utilized, the differentiation of the fauna of *Carabidae* is quite considerable. In the lawn type greenery polytopic field forms prevail, in the wooded areas — polytopic forest forms. There are many xerophilous forms in the street greenery.

The proportions of pantophagists is relatively high in the lawn greenery, and big *Carabidae* occur numerously only in the wooded areas. Autumn carabids constitute (on the score of numbers) 3/4 of all the urban greenery's *Carabidae*; spring carabids are relatively numerous only in the wooded areas (reverse to natural forests). The general character of the urban environment favours spring carabids, although their occurrence is restricted as a result of intensive agrotechnical operations.

The differences in the proportions of spring and autumn carabids are the reason of the differentiation of seasonal dynamics in the communities of natural and variously anthropogenized habitats. The proportion of spring species generally increasing together with growing anthropogenization causes the appearance and gradual increase of significance of the spring peak of *Carabidae's* activity. Regardless of this, there is also a direct influence of local conditions on the dynamics of communities. This takes place in urban greenery where the acceleration and the shortening of the vegetation period are one of the general natural effects of urbanization, the form of a shift in the cycle of carabids' activity.

The communities of *Carabidae* in urban greenery, and also in non--urban habitats under settlement pressure, usually have a deformed, unfavourable structure. They usually show a high disproportion between the proportion of the dominant and the proportions of the remaining species, the decreased number of accessory species and a low index of species diversity. The relatively most proper structure is retained by communities in, both urban and suburban, areas landscaped in the housing estate manner, and then in the park greenery. The ones most unfavourably structured are the communities from anthropogenized wooded areas; their structure is worse even than that of the majority of communities in the greenery of roads.

The most deformed in relation to the fauna of a potential natural environmental (a lime-oak-hornbeam forest), on the score of species composition and structure, are the carabid communities in urban street greenery. In relation to the size of their deformation, considered as 100%, communities in the urban wooded areas are modified in 80%, in the housing estates' greenery — in 60%, and in the park greenery — in 55%. The degree of the communities' deformation is not proportional to the intensity of urbanization pressure in a given habitat; carabids from various urban habitats react differently to anthropogenic influence. The most sensitive to pressure is the forest association from wooded areas. Communities in the lawn greenery (especially of parks and housing estates), dominated by the species of open areas, are more resistant.

The communities from the urban wooded areas are not only strongly deformed but also seriously degraded. It is an unfavourable phenomenon because of the role which these habitats play in the urban ecosystem. They are the refuge of the forest fauna, not only carabids [14, 15], original for most of the area. This fauna, by means of spontaneous migrations, may enrich the neighbouring communities, increasing homeostatic capabilities of local biocoenoses. Thus, the possibility of improving the situation seems simple. It is enough to limit the intensity of horticultural cultivation within wooded areas, especially the removing of litter and destroying seminatural herb layer in these areas.

Agrotechnical operations induced by asthetic reasons are in general, besides the way of landscaping greenery, the factor of the greatest influence on *Carabidae* from among anthropogenic factors accompaying human settlement. In general, the more "neglected" the greenery, the more numerous, more diversified and, what is most important, most proper the structure of communities which inhabit it.

Treating the condition of carabid communities as an index of the condition of the environment (this is justified by bioindicational properties of *Carabidae*) one may put forward general postulates concerning the landscaping and cultivation of urban green areas. It would be advisable to landscape urban greenery in such a way as to create most complex structure, both on the score of the differentiation of plant cover (stratification of greenery, spinneys and trees in lawns) and in the spatial sense (connections between complexes of greenery enabling the exchange of fauna). For in thus landscaped greenery the communities of carabids have the most proper structure. It is especially advisable to restrict the intensity of mechanical and chemical cultivation in lawns and wooded areas (mowing, raking, the use of pesticides). This would increase the luxuriance and qualitative variability of herbaceous vegetation and, consequently, improve the condition of zoocoenoses.

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REFERENCES

1. Adis, J. 1979. Problems of interpreting arthropod sampling with pitfall traps. Zool. Anz., 202: 177—184.
2. Becker, J. 1975. Art und Ursachen der Habitatbindung von Bodenarthropoden (*Carabidae-Coleoptera, Diplopoda, Isopoda*) xerothermer Standorte in der Eifel. Landespflege Rhld.—Pflaz., 4: 89—140.
3. Bednarek, A., Huculak, W., Lech, A., Makowiec, M. 1976. Badania mikroklimatu wybranych środowisk zieleni miejskiej Warszawy. In: Wpływ zieleni na kształtowanie się środowiska miejskiego. Warszawa (ms).
4. Biuro Planowania Rozwoju Warszawy. 1976. Ocena przydatności badań terenowych problemu 114 z lat 1972—76 w aspekcie zagospodarowania przestrzennego terenów miejskich. Warszawa (ms).
5. Boness, M. 1953. Die Fauna der Wiessen, unter besonderer Berücksichtigung der Mahd. Z. Morphol. Oekol. Tiere, 42: 255—277.

6. Bray, J. R., Curtis, C. T. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr., 27: 325—349.
7. Breymeyer., A. 1961. Uwagi o stosowaniu różnych ilości pułapek Barbera. Ekol. Pol. Ser. B, 7: 103—110.
8. Burakowski, B., Mroczkowski, M., Stefańska, J. 1973. Chrząszcze — *Coleoptera*. Biegaczowate — *Carabidae* (part 1). Kat. Fauny Pol., 20.
9. Burakowski B., Mroczkowski, M., Stefańska J. 1974. Chrząszcze — *Coleoptera*. Biegaczowate — *Carabidae* (part 2). Kat. Fauny Pol., 22.
10. Chmielewski, W., Gastman, B. 1979. Zmiany w rozwoju fenologicznym drzew rosnących w różnych warunkach miejskich Warszawy. In: Warunki rozwoju drzew i ich fauny w Warszawie (ed. by Ossolineum), pp. 21—32.
11. Ciborowski, A. 1976. Współczesne rozwiązania urbanistyczne wielkich aglomeracji miejskich a kształtowanie środowiska. In: Ekologiczne problemy miasta (ed. by K. Czarnota and D. Żukowska-Wieszczek), pp. 17—25.
12. Czarnowska, K. 1975. Występowanie metali ciężkich w glebach zieleńców warszawskich. Rocz. Nauk Roln. Ser. A Prod. Rosl., 101: 159—163.
13. Czechowski, W. 1979. *Trechus austriacus* Dej. (*Coleoptera*, *Carabidae*) w Warszawie. Przegl. Zool., 23: 151—153.
14. Czechowski, W. 1979. Urban woodland areas as the refuge of invertebrate fauna. Bull. Pol. Sci. Ser. Sci. Biol., 27: 179—182.
15. Czechowski, W. 1979. Sampling of *Carabidae* (*Coleoptera*) by Barber's traps and biocenometric method in urban envinronment. Ibid., 27: 461—465.
16. Czechowski, W. 1980. Influence of the manner of managing park areas and their situation on the formation of the communities of carabid beetles (*Coleoptera*, *Carabidae*). Fragm. Faun. (Warszawa) 25: 199—219.
17. Czechowski, W. 1980. Carabids (*Coleoptera*, *Carabidae*) of the Vistula escarpment in Warsaw. Ibid., 25: 293—316.
18. Czechowski, W. 1981. Carabids (*Coleoptera*, *Carabidae*) of Warsaw and Mazovia. Memorabilia Zool., 34: 119—144.
19. Czechowski, W. 1981. Biegaczowate (*Coleoptera*, *Carabidae*). In: Zoocenologiczne podstawy kształtowania środowiska przyrodniczego osiedla mieszkaniowego Białołęka Dworska w Warszawie. Part. 1. Skład gatunkowy i struktura fauny terenu projektowanego osiedla mieszkaniowego. Fragm. Faun. (Warszawa) 26: 193—216.
20. Czechowski, W., Mikołajczyk, W. 1981. Methods for the study of urban fauna. Memorabilia Zool., 34: 49—58.
21. Edington, J. M., Edington, M. A. 1977. Ecology and environmental planning. London.
22. Evers, A. 1977. Rote Liste der im nördlichen Rheinland gefährdeten Käferarten (*Coleoptera*) mit einer Liste von Bioindikatoren. Entomol. Bl. Biol. Syst. Kaefer, 73.
23. Frankie, G. W. Koehler, C. S. 1978. Perpectives in urban entomology. New York—San Francisco—London.
24. Greenslade, P. J. M. 1964. Pitfall trapping as a method for studying populations of *Carabidae* (*Coleoptera*). J. Anim. Ecol. 33: 301—310.
25. Greenslade, P. J. M. 1964. The distribution, dispersal and size of a population of *Nebria brevicollis* (F.). Ibid., 33: 311—333.
26. Greenslade, P. J. M. 1965. On the ecology of some British carabid beetles with special reference to life histories. Trans. Soc. Brit. Entomol., 16: 149—179.
27. Grüm, L. 1976. An attempt to characterize matter transfer by carabid communities inhabiting forests. Ekol. Pol., 24: 365—375.
28. Grüm, L. 1978. Mechanisms governing rate and direction of energy flow through carabid populations. Pol. Ecol. Stud., 4: 129—175.
29. Heydemann, B. 1955. Carabiden der Kulturfelder als ökologische Indikatoren. Ber. 7. Wand. samml. Dtsch. Entomol., pp. 172—185.

30. Hildt, L. 1907. Spis owadów znalezionych pod Warszawą, oraz w okolicach w promieniu 40 kilometrów odległych. Pamiet. Fizyogr., 19: 59—80

31. Jørum, P. 1976. Life cycle and population density of *Nebria brevicollis* F. (*Coleoptera, Carabidae*) in a Danish beech forest. Vidensk. Medd. Dan. Naturhist. Forem., 139: 245—261.

32. Jørum, P. 1976. En undrsøgelse af lø bebillefaunaens sammensaeting og saesonaktivitet i en dansk bøgeskov (*Coleoptera, Carabidae*). Entomol. Medd., 44: 81—99.

33. Kabacik-Wasylik, D. 1970. Ökologische Analyse der Laufkäfer (*Carabidae*) einiger Agrarkulturen. Ekol. Pol., 18: 137—209.

34. Kajak. A. 1962. Comparison of spider fauna in artificial and natural meadows. Ekol., Pol. Ser. A, 10: 1—20.

35. Knie, J. 1975. Vergleichend-ökologische Unterschungen der Carabidenfauna Verschieiener Standorte des Kottenforste bei Bonn. Decheniana, 128: 3—19.

36. Koch, L., Sollmann, A. 1977. Durch Umwelteinflüsse bedingte Veränderungen der Käferfauna eines Waldgebietes in Meerbusch bei Düsseldorf. Ibid., 20: 30—74.

37. Kowalska, J. 1979. Zieleń Warszawy w ocenie Miejskiego Przedsiębiorstwa Robót Ogrodniczych. In: Warunki rozwoju drzew i ich fauny w Warszawie (ed. by Ossolineum), pp. 5—8.

38. Larsson, S. G. 1939. Entwicklungstypen und Entwicklungszeiten der dänischen Carabiden. Entomol, Medd., 20: 277—560.

39. Leśniak, A. 1975. Metody odłowu epigeicznych *Carabidae Col.* w środowiskach leśnych. Pr. Kom. Nauk. PTG, III/15: 3—15.

40. Łomnicki, M. 1913. Wykaz chrząszczów czyli Tęgopokrywych (*Coleoptera*) ziem polskich. (Catalogus coteopterorum Poloniae). Kosmos, 38: 21—155.

41. Makólski, J. 1952. Rodzina *Carabidae* w zbiorze Wojciecha Mączyńskiego (*Coleoptera*). Fragm. Faun. Mus. Zool. Pol., 6: 207—241.

42. Matuszkiewicz, W. 1966. Potencjalna roślinność naturalna Kotliny Warszawskiej. Mater. Zakł. Fitosoc. Stos. UW.

43. Mitchell, B. 1963. Ecology of two carabid beetles, *Bembidion lampros* (Herbst) and *Trechus quadristriatus* (Schrank). II. Studies on populations of adults in the field, with special reference to the technique of pitfall traping. J. Anim. Ecol., 32: 377—392.

44. Müller, P., Klomann, U., Nagel, P., Reis, H., Schäfer, A. 1975. Indikatorwert unterschiedlicher biotischer Diversität im Verdichtungsraum von Saarbrücken. Verh. Ges. Oekol. Saarbrücken, pp. 113—128.

45. Nowakowski, E. 1979. Skarpa warszawska jako teren ostojowy dla fauny — na przykładzie sprężyków glebowych (*Coleoptera, Elateridae*). Fragm. Faun. (Warszawa), 23: 335—341.

46. Nowakowski. E. 1981. Physiographical characteristics of Warsaw and the Mazovia Lowland. Memorabilia Zool., 34: 13—31.

47. Obrtel, R. 1971. Number of pitfall traps in relation to the structure of the catch of soil surface *Coleoptera*. Acta Soc. Entomol. Cech., 68: 300—309.

48. Odum, E. P. 1977. Podstawy ekologii. Warszawa.

49. Pauer, R. 1975. Zur Ausbreitung der Carabiden in der Agrarlundschaft, unter besonderer Berücksichtigung der Grenzbereiche verschiedener Feldkulturen. Z. Angew. Zool., 62: 457—489.

50. Pawłowski. J. 1967. Chrząszcze (*Coleoptera*) Babiej Góry. Acta Zool. Cracov., 12: 419—665.

51. Petruška, F. 1967. Střevlikovití jako součást entomofauny řepných polí. Uničovské roviny (*Col. Carabidae*). Acta Univ. Palacki. Olomuc., Fac. Rerum Nat. Biol., 25: 121—243.

52. Petruška, F. 1971. Vliv pěstované plodiny na vývoj populaci polnich střevlíkovítých (*Col. Carabidae*). Ibid., 34: 151—191.

53. Petruška, F. 1974. K dynamice disperze některých druhu střevlíkovitých na políosetém cukrouvkou (*Col. Carabidae*). Ibid., 47: 145—178.
54. Pisarski, B. 1979. Presja urbanizacyjna a zespoły fauny. In: Warunki rozwoju drzew i ich fauny w Warszawie (ed. by Ossolineum), pp. 116—120.
55. Pisarski, B., Trojan, P. 1976. Zoocenozy obszarów zurbanizowanych. Wiad. Ekol., 22: 338—344.
56. Plath, D., Witzke, G. 1972. Beitrag zur Coleopterenfauna von Schwabenheim/Selz. *Carabidae* und *Catopidae*. Dtsch. Entomol., 19: 335—356.
57. Sharova, I. H. 1960. Morfo-ekologicheskije tipy lichinok zhuzhelic (*Carabidae*). Zool. Zh., 39: 691—708.
58. Schweiger, H. 1962. Die Insektenfauna des Wiener Stadtgebietes als Beispiel einer kontinentalen Gross-Stadtfauna. In: Proc. 11th Internat. Congr. Entomol., Wien 1960, 3: 184—193.
59. Skuhravý, V., Louda, J., Sýkora, J. 1971. Zur Verteilung der Laufkäfer in Feldmonokulturen. Beitr. Entomol., 21: 539—546.
60. Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and application to analyses of the vegetation on Danish commons. Biol, Skr., 5: 1—34.
61. Szyszko, J. 1974. Relationship between the occurrence of epigeic carabids (*Coleoptera, Carabidae*), certain soil properties and species composition of a forest stand. Ekol. Pol., 22: 237—274.
62. Szyszko, J. 1975. Metodyczne trudności określenia ilościowo-jakościowych różnic między zgrupowaniami biegaczowatych (*Col., Carabidae*) różnych środowisk leśnych. Pr. Kom. Nauk. PTG, III/16: 161—172.
63. Tenenbaum, Sz. 1923. Przybytki do fauny chrząszczów Polski od roku 1913. Rozpr. Wiad. Muz. Dzieduszyckich, 7—8: 136—186.
64. Thiele, H.-U. 1969. Zusammenhänge zwischen Tagesrhythmic, Jahresrhythmic und Habitatbindung bei Carabiden. Oekologia, 3: 227—229.
65. Thiele, H.-U. 1977. Carabid beetles in their environment. A study on habitat selection by adaptations in physiology and behaviour. In: Zoophysiology and ecology, 10, Berlin—Heidelberg—New York.
66. Thomas, D. B. Jr., Sleeper, E. L. 1977. The use of pitfall traps for estimating the abundance of arthropods, with special reference to the *Tenebrionidae* (*Coleoptera*). Ann. Entomol. Soc. Am., 70: 242—248.
67. Tischler. W. 1966. Unterschungen über das *Hypolithion* einer Hausterrasse. Pedobiologia, 6: 13—26.
68. Tischler, W. 1971. Agroekologia. Warszawa.
69. Topp. W. 1971. Zur Ökologie der Müllhalden. Ann. Zool. Fenn., 8: 194—222.
70. Topp, W. 1972. Die Besiedlung eines Stadtparks durch Käfer. Pedobiologia, 12: 336—346.
71. Trojan, P. 1975. Ekologia ogólna. Warszawa.
72. Williams, G. 1959. Seasonal and diurnal activity of *Carabidae*, with particular reference to *Nebria*. *Notiophilus* and *Feronia*, J. Anim. Ecol., 28: 309—330.
73. Witkowski, Z. 1978. Wpływ wyboru kryterium oceny pozycji gatunku w zespole na wartość wskaźnika różnorodności gatunkowej. Wiad. Ekol., 24: 391—398.
74. Wójcicka, J. 1973. Miasto a przekształcenia środowiska przyrodniczego. In: Problemy kształtowania środowiska. Biul. Inst. Urban. Architekt., 32: 25—42.
75. Wysocki, C., Zimny, H. Żukowska-Wieszczek, D. 1979. Functioning of grassy systems in urban habitats. Memorabilia Zool., 32: 69—77.
76. Zaremba, P. 1978. Postęp techniczny, architektura i ekologia w procesie urbanizacji kraju. Nauka Pol. PAN, 26: 19—35.
77. Zimny, H., Wysocki, C. 1974. Produktywność trawników na terenie Warszawy. Przegl. Inform. Zieleń Miejska, 10: 23—46.

WYSTĘPOWANIE BIEGACZOWATYCH (*COLEOPTERA*, CARABIDAE) W ZIELENI MIEJSKIEJ WARSZAWY W ZALEŻNOŚCI OD SPOSOBU ZAGOSPODAROWANIA TERENU

STRESZCZENIE

W strefie zwartej zabudowy zieleni miejskiej Warszawy występuje 113 gatunków *Carabidae* — 41% fauny biegaczowatych całego miasta, a 35% fauny Mazowsza. Zagęszczenie *Carabidae* na trawnikach miejskich wynosi przeciętnie 1,3 osobnika na 1 m^2. Liczebność zgrupowań jest bardzo zróżnicowana — ogromne znaczenie ma tu sposób zagospodarowania i użytkowania terenu. Umowny wskaźnik liczebności wynosi: w zieleni parkowej — 6,8, osiedlowej — 25,8, ulicznej — 6,0, w zadrzewieniach — 10,1, w ogródkach działkowych — 52,3. Głównym czynnikiem ograniczającym liczebność *Carabidae* są mechaniczne zabiegi agrotechniczne. Wpływ toksycznych zanieczyszczeń gleby i powietrza jest niewielki i raczej pośredni (zniszczenie roślinności, przesuszenie gleby, ograniczenie bazy pokarmowej).

W środowiskach trawnikowych Warszawy występuje jeden względnie stały zespół *Carabidae*, którego wiodącymi gatunkami są: *Pterostichus vulgaris*, *Calathus fuscipes*, *Bembidion properans*, *Nebria brevicollis*, *Harpalus rufipes* i *Amara aenea* — głównie gatunki terenów otwartych. W zadrzewieniach miejskich występuje leśny zespół *Carabidae* z głównymi gatunkami: *Nebria brevicollis*, *Carabus nemoralis* i *Pterostichus oblongopunctatus*. Zgrupowania z poszczególnych obiektów zadrzewionych są znacznie bardziej względem siebie zróżnicowane aniżeli zunifikowane zgrupowania z trawników. Wskazuje to na stosunkowo dużą wrażliwość zespołu leśnego na zmienność warunków środowiskowych.

Zgrupowania *Carabidae* z zieleni miejskiej mają na ogół odkształconą, niekorzystną strukturę. Przejawia się to znaczną dysproporcją między udziałem dominanta i pozostałych gatunków, zmniejszoną liczbą gatunków akcesorycznych oraz niskimi wskaźnikami różnorodności i równomierności. Najbardziej niekorzystnie są ukształtowane zgrupowania z miejskich zadrzewień — gorzej nawet niż z zieleni ulicznej.

Zgrupowania *Carabidae* z poszczególnych środowisk zieleni miejskiej różnią się między sobą dynamiką sezonową. Różnice dotyczą terminów i wzajemnych relacji między szczytami aktywności wiosennej i jesiennej oraz tempa aktywizacji i inaktywacji zgrupowań na początku i końcu sezonu wegetacyjnego. Wiąże się to z lokalnymi warunkami mikroklimatycznymi.

Fauna *Carabidae* zieleni miejskiej wyróżnia się spośród fauny okolicznych obszarów nie zurbanizowanych swoim profilem zoogeograficznym i ekologicznym. Selekcjonujące działanie presji urbanizacyjnej sprawia, że w mieście utrzymują się przede wszystkim formy o szerokich zasięgach: holarktyczne, palearktyczne i eurosyberyjskie. Pod względem ekologicznym preferowane są m.in. *Carabidae* o największej tolerancji — eurytopowe i politopowe, polne lub ubikwistyczne, sucholubne, pantofagiczne i związane z glebami ubogimi.

W tendencjach przebudowy zgrupowań *Carabidae*, następującej pod wpływem gospodarki osiedleńczej, rozpatrywanej w układzie: środowisko naturalne — wiejskie — podmiejskie — miejskie, zarysowują się te same cechy, jakimi odznaczają się zgrupowania z poszczególnych rodzajów zieleni Warszawy — pogorszeniu ulega struktura zgrupowań, zmienia się ich profil ekologiczny i dynamika sezonowa. Wielkość tych zmian jest różna w różnych typach środowisk. Najpoważniejsze dokonują się w zgrupowaniach z zantropogenizowanych zadrzewień, mniejsze w środowiskach trawnikowych.

Analiza miejskich zgrupowań *Carabidae* z obiektów w różnym stopniu podlegających określonym formom presji urbanizacyjnej oraz zgrupowań ze środowisk pozamiejskich, także w różnym stopniu i w różny sposób zantropogenizowanych, wykazała, że podstawowymi czynnikami określającymi stan fauny *Carabidae* w warunkach presji osadniczej są: struktura zieleni i intensywność ogrodniczych zabiegów pielęgnacyjnych.

ВСТРЕЧАЕМОСТЬ ЖУЖЕЛИЦ (*COLEOPTERA, CARABIDAE*) В ГОРОДСКИХ ЗЕЛЕНЫХ НАСАЖДЕНИЯХ ВАРШАВЫ В ЗАВИСИМОСТИ ОТ СПОСОБА БЛАГОУСТРОЙСТВА ТЕРРИТОРИИ

РЕЗЮМЕ

В работе всесторонне охарактеризована фауна *Carabidae* из урбанизированной среды (Варшавы) и указывается на ее специфичность по сравнению с фауной региона (Мазовецкой низменностью). Определена зависимость между встречаемостью *Carabidae* и способом устройства и использования городских зеленых территорий с обозначением тех антропогенных факторов, которые имеют решающее значение для формирования и особенностей городских сообществ *Carabidae*. Обозначены основные тенденции перестройки сообществ под влиянием действием прогрессирующего заселения. Путем биоиндикационной оценки определены качественные свойства различных биотопов городской зелени, исходя из присущих им сообществ, что дало возможность выдвинуть предложения относительно способов устройства и использования зеленых территорий, которые позволили бы этим сообществам оптимально функционировать. Это проделано путем анализа и сравнения видового состава, численности и структуры сообществ *Carabidae* из городских биотопов, пригородных, сельских и природных (биотонов, соотвествующих груду), сезонной динамики сообществ, а также зоогеографического и экологического состава фауны *Carabidae*. Исследования были проведены в 1971—1978 г.г. Всего было собрано около 16 000 имаго *Carabidae*, принадлежащих к 122 видам. Собран был материал в основном по методу ловушек Барбера.

OCCURRENCE OF CARABIDS (*COLEOPTERA*, *CARABIDAE*) IN THE URBAN GREENERY OF WARSAW ACCORDING TO THE LAND UTILIZATION AND CULTIVATION

CONTENTS

ERRATA

On page 97 of the present volume Table 34 has been printed incomplete. Below is the correct version of this table.

Warsaw-St 8			
S	%S	N	%N
—	—	—	—
7	87,5	5,7	86
1	13,5	0,9	14
—	—	—	—
3	37,5	3,5	53
5	62,5	3,1	47
2	25	4,2	64
6	75	2,4	36
3	37,5	4,3	65
5	62,5	2,3	35
—	—	—	—
4	50	2,2	33
4	50	4,4	67

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Tables: should be typed on separate sheets, numbered with arabic numerals, have brief titles and be reffered to in the text as (Tab. 1), etc.

References: these should be checked with the original articles and referred to in the text by key numbers. in parentheses. They should be listed on a separate sheet with their numbers, in alphabetical order and in the form used in the current number of the journal. Titles of journals should be abbreviated according to the World List of Serials.

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