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Landscape type and species richness and composition of Arthropoda Part II. Urban landscape

Magdalena Lubiarz[1], Elżbieta Cichocka[2], Wojciech Goszczyński[3]

[1,2]Department of Nature Preservation, [3]Department of Plant and Landscape Protection
The John Paul II Catholic University of Lublin
Konstantynów 1H, 20-708 Lublin, Poland
[1]lubiarz@kul.pl

ABSTRACT

The study provides a review of indirect factors which influence the number of arthropod species, as well as their abundance and bionomy in an urban landscape, exemplified mainly by hemipteran insects (Hemiptera). Factors which directly influence arthropods in an urban landscape include: urbanization, designing urban vegetation in such a way that only one plant species is present within a plant community, as well as an accidental introduction of alien plant and animal species. The influence exercised by these factors is inhomogeneous and the impact which human activity has on the environment may be difficult to foresee. An urban landscape constantly undergoes reshaping; the environmental structure of a city is liable to change and thus the richness and composition of arthropod species are liable to change as well. The piercing and sucking arthropods are most abundant in trees growing along the streets in cities, while in community green spaces and in parks they are less abundant.

KEY WORDS: arthropods, urban landscape, urban greenery

INTRODUCTION

The present study is a continuation of a paper (Cichocka & Lubiarz, 2010) which was published in Volume 16 of "Aphids and Other Hemipterous Insects". It provided a review of factors which, in an agricultural landscape, influenced the abundance of

arthropods, as well as the richness and bionomy of particular species during a vegetation season, exemplified mainly by hemipteran insects (Hemiptera). The present paper focuses on changes taking place in an urban landscape and how they affect urban vegetation and the arthropods inhabiting this type of vegetation.

The shaping of city entomofauna under the influence of urbanization pressure has been investigated since the 1970s (Ebeling, 1976; Frankie & Ehler, 1978; Frankie & Koehler, 1978). These studies made it understood that decisive factors for population numbers and insect survival in cities included the abundance of nutrition sources and various aspects of human activity. During the same period, Polish studies on the subject were initiated (Chudzicka, 1979; Pisarski, 1979; Rychlik, 1979; Cichocka & Goszczyński, 1991). They proved that together with an increasing urbanization pressure the numbers of saprophages, zoophages and some phytophages with biting mouthparts were diminishing, while the numbers of herbivores with piercing-sucking mouthparts were on the increase.

URBAN LANDSCAPE

An urban landscape is understood as the conditions found in large and medium-sized cities. A city is characterized by a specific climate. The studies on local climates of cities which have been conducted for over 150 years in Europe confirm that the influence of a city on a local climate is significant (Lewińska, 1991). For instance, a city climate is characterized by a higher air temperature. One of the reasons for this is the fact that in a city open areas covered by vegetation are smaller in comparison to insulated areas covered by asphalt or concrete (Zimny, 1993; 2005). A temperature difference between a locality at an edge of a city park and a locality in its centre amounts to 2 degrees and the relative humidity differs by 10-13%. Furthermore, the degree of pollution with exhaust fumes is lower in the centre of a city park than in localities adjoining the streets. The level of pollution is the highest along the streets, while towards the centre of a city park the level of pollution is gradually diminishing (Czechowska *et al.,* 1979). A significant influence over a city climate is exercised by air pollution (Kollender-Szych *et al.*, 2008). Moreover, the functioning of a city leads to the reshaping of surface layers of soil. The soil is polluted with heavy metals, sodium chloride, rubble, etc. Such changes result in the development of soils which are unique for urban areas (Czerwiński & Pracz, 1990ab). In a city, greenery acts as a filter for air pollution, filtering out the gas and dust pollutants from the air (Lewińska, 1991). Tree crowns at the height of 5-15m filter out all kinds of air pollutants, especially ones originating from low height emission sources (Orzeszek-Gajewska, 1982). Furthermore, with the help of greenery it is also possible to shape the temperature and humidity conditions during a warm season. Tall greenery, providing good shade, contributes to lowering the ground temperature (Bednarek, 1990ab; Lewińska, 1991; 2000).

A city is characterized by densely built-up residential and industrial areas, well-developed communication infrastructure and disseverance of green spaces. Plants growing in cities are exposed to the influence of many unfavourable conditions, such as excessive xerization, as well as toxification of soil and air (Zimny, 2005). Bytnerowicz (1979) investigated the absorption of pollution by trees in a city and discovered that in the leaves of trees lining the roads the accumulation of sulphur was twice as high as in the leaves of trees in the control group, while the accumulation of Pb was over a dozen times higher. Also the contents of Fe, Zn and Cu in tree leaves were higher in localities adjoining the roads than in the control group. The highest concentration of pollution was found in the leaves of a *Robinia pseudoacacia* L. and a *Ulmus laevis* Pall. And it was observed in the case of *Tilia platyphyllos* L. that the further from the road they were located, the lower was the chlorine content in their leaves. In the case of many tree species (e.g. *Acer platanoides* L., *Platanus* x *acerifolia* (Aiton) Willd., *Tilia platyphyllos*, *Ulmus laevis* and *Robinia pseudoacacia*), the leaves of trees growing beside the roads contained from several to over a dozen times more lead than the control group. In linden leaves the lead content was considerably lower in the case of trees growing in the park than in the leaves of trees growing beside the roads. An increased Fe, Zn and Cu content was also discovered in the leaves of investigated trees, and was the most significant in trees growing beside the roads. The necessity to prevent the surface of the road from becoming slippery in winter requires the application of sodium chloride NaCl and calcium chloride CaCl, and entails a number of harmful side effects affecting plants. It has been proved that a chloride ion is the most harmful, as it is absorbed from the soil substrate by the roots of plants which have no physiological mechanism regulating its intake (Molski & Sitarski, 1979). Then, the element accumulates in the overground parts of a plant and the process of water photolysis accompanying the photosynthesis taking place in the leaves is disturbed. An external symptom of such a disturbance is the discoloration of leaves followed by their necrosis (Strogonow, 1970). Together with rain water the chlorides are transferred into deeper soil layers, which alters its chemism by decreasing its salinity (Musierowicz *et al.*, 1957). If, as a result of soil compression, the process is interrupted, plant roots will not be able to absorb mineral salts and the rain water will evaporate instead of being soaked up by the soil. As a result of this, the plants wither partially (branches) or completely, which might be observed in the streets of Warsaw (Molski & Sitarski, 1979). Salt used to facilitate snow removal from city streets limits leaf growth, causes leaves to wrinkle, leads to chlorosis and necrosis, and sometimes even to the death of leaves and twigs. After a longer period of salt application the whole trees may die. Excessive salinity results in an increase of chloride content in the leaves of *Tilia* spp. (Supłat, 1996). Discoloration and necroses were observed as early as in the middle of the vegetation season and the damaged leaves were inhabited by large numbers of aphids and spider mites. As a result, towards the end of September 30% of trees were leafless (Supłat, 1991). What is more, the presence of discolorations and

necroses is responsible for slowing down the pace of assimilation and reserve accumulation, which leads to diminishing the annual growth of trees. The results of this may be observed in spring, when the development and growth of trees is belated and the water intake is limited. Insufficient water intake causes the appearance of new necroses, which have an impact on further disturbances in the following vegetation season (Hoster, 1982). Among trees which are not sensitive to excessive salinity there are *Populus simonii* Carr. and *Populus nigra* L., while *Acer pseudoplatanus* L. shows a high level of sensitivity and should not be planted in localities adjoining the roads (Molski & Sitarski, 1979).

In cities there is a high level of dust in the air, which is also polluted with sulphur dioxide and nitrogen oxides. Tykarska (2002) discovered that the levels of pollution with these substances were higher in Gdańsk than in Warsaw. Higher concentrations of SO_2 and NO_X were registered in the proximity of busy roads and at crossroads (Grzegorczyk *et al.*, 2001). Air pollution affects the condition of soil in urban areas. Sulphur dioxide and nitrogen oxides get into the soil as the so-called acid precipitation. Lowering the soil pH so that it becomes acidic results in an increased concentration of mobile forms of heavy metals in soil, and they are easily absorbed by plants (Gębski, 1998; Sady & Smoleń, 2004). In the surface soil layer in cities there can be found a high concentration of heavy metals, especially Zn, Pb and Cu (Tykarska, 2002). The highest concentrations of heavy metals have been recorded beside the roads, and the further away from the roads the lower these concentrations were becoming (Czarnowska & Konecka-Betley, 1977; Biernacka & Czerwiński, 1990; Czerwiński & Pracz, 1990ab; Minoranskij & Wojciechowski, 1991). Furthermore, it was observed that the presence of chloride, sulphur and lead in tree leaves affected the occurrence and length of phenological phases (Chmielewski, 1996). In the case of city trees, it was observed that the opening of buds and appearance of leaves was correlated with their sulphur content, while the changes of leaf colour, as well as the beginning and end of the period of their falling were correlated with their chloride and lead contents. The vegetation activity of *Tilia* 'Euchlora' was observed to shorten while comparing specimens growing on the outskirts of Warsaw (where the vegetation activity was the longest) with the ones growing in the city centre. The shortest vegetation period was observed in trees lining the streets in the city centre – in some cases it was even 25 days shorter than in trees growing on the outskirts of the city. The pace at which chloride ions are accumulated in the leaves of *Tilia cordata* and *Acer platanoides* is almost directly proportional to the concentration of chlordide ions in soil substrates (Czerwiński, 1973). This is the result of anthropopressure and degradation of the environment (Feige *et al.*, 1980; Lipińska, 1977; Łukaszewicz, 1978), leading to a lower annual growth of tree trunks in the proximity of city streets in the city centre as compared to the areas outside the city and even the city parks.

The excessive presence of heavy metals in the roadside soil entails their accumulation in plants. Minoranskij & Wojciechowski (1991) proved that in the road-

side zone, in soil, as well as in the internal parts of *Cichorium intybus* L. and the body of the beetle *Opatrum sabulosum* (Linnaeus, 1760), the contents of heavy metals, such as Zn, Mn, Cu, Fe and Ni was visibly heightened.

EFFECT OF URBANISATION PRESSURE IN CITIES ON ARTHROPODS

It is believed that urban vegetation has, to a large extent, lost its natural immunity against the attacks of herbivores. Some species of herbivorous arthropods multiply extraordinarily fast (e.g. spider mites, aphids) and reach such enormous numbers in cities as were previously observed only in areas of intensive agriculture or gardening. In a natural landscape the numbers of arthropods are balanced and mass appearance of some particular species is rare (Lubiarz & Cichocka, 2005). In urbanized areas it is just the opposite. The largest numbers of arthropods inhabiting trees and shrubs which constitute part of urban greenery can be found in the roadside zone (Chudzicka, 1979; Czechowska *et al.*, 1979; Pisarski, 1979; Rychlik, 1979; Winiarska, 1979; Cichocka *et al.*, 1990; Cichocka & Goszczyński, 1991; Cichocka *et al.*, 1998; Jaśkiewicz, 2006; Łagowska, 1998). Many researchers (Chudzicka, 1978; Rychlik, 1979; Cichocka *et al*., 1990; Tykarska, 2001) recorded the presence of aphid populations on trees growing in parks which were ten-odd or several dozen less numerous compared to the populations of aphids found on trees growing beside the roads. The more urbanized an area, the fewer arthropods with biting mouthparts are observed, while at the same time the number of the arthropods with piercing-sucking mouthparts is increasing (i.e. aphids, scale insects, psyllids, hemipteran suborders Fulgoromorpha and Cicadomorpha, spider mites). The arthropods with piercing-sucking mouthparts are present in large numbers on plants growing along the roads because road pollution modifies the biochemical composition of these plants, causing an increase of nitrogen and amino acid content in their tissues, and this stimulates the development of such arthropods. Additionally, the plants are weakened by the presence of heavy metals and other toxic substances in the soil in which they grow (Cichocka & Goszczyński, 2008). Aphids, being insects with piercing-sucking mouthparts, are not exposed to the influence of road pollution since they usually obtain nutrition straight from the phloem. What is more, the increase of aphid population is not accompanied by a simultaneous increase of their natural enemies, because the roadside environment is not conducive to the development of such enemies (Minoranskij & Wojciechowski, 1988). Rychlik (1979) noted that an average seasonal aphid density (on one hundred leaves of *Quercus robur* L.) amounted, in a control sample, to 4-7 specimens, while in Warsaw localities it amounted to 100-5500. Further disparities were connected with various city localities from where the particular leaf samples were collected. The least significant difference in comparison to the control sample was recorded between the number of aphids recorded in the

control sample and the numbers recorded in large parks (10 times), community green spaces (40-100 times) and yard greenery (500 times). Also the domination of a particular aphid species depended on the type of greenery and the degree of urban pressure affecting the investigated oaks. In some cases *Tuberculatus annulatus* (Hartig, 1841) was a dominant species, while in others it was *Phylloxera* spp. Aphids representing the genus *Phylloxera* were observed in larger numbers on oaks in roadside localities, while *Tuberculatus annulatus* was more abundant in large parks. It is also noteworthy that large parks, unlike roadside localities, were inhabited by a rich variety of insects belonging to various trophic groups. Tykarska (2002), conducting a research on the fauna of hawthorn *Crataegus x media* Bechst.) in Warsaw and Gdańsk, discovered that the largest trophic group was that of phytophages (over 50%). Among the phytophages, 99.9% were arthropods with piercing-sucking mouthparts. Psyllids, more numerous in Gdańsk, and aphids, slightly more numerous in Warsaw, dominated in this group. The numbers of these hemipteran insects were so high that the honeydew they secreted covered leaves and shoots of hawthorn plants. Wilkaniec (1994) observed that the numbers of aphids on a *Acer palatanoides* in roadside localities in Poznań were significantly higher than in parks. According to Chudzicka (1979), the shrinking of green areas resulted in the impoverishment of species composition of the entomofauna inhabiting *Tilia* spp. At the same time, as the level of anthropopressure was growing, there was taking place a reshaping of the domination structure of phytophages moving towards a scenario where just a single species dominated. As the pollution level was growing, the numbers of herbivorous insects on lindens were also growing, and the numbers of predatory insects were decreasing. Similar data referring to Warsaw was given by Draber-Mońko *et al.* (1979). The shrinking of green areas and the increasing pollution resulted in a drop in predatory species richness and composition and the increase of the numbers of herbivores. The factors which contributed to this situation included: lower humidity, higher pollution, greater temperature fluctuations and the decreased diversification of vegetation (Draber-Mońko *et al*., 1979).

Łagowska (1998) observed that the city environment of Lublin was conducive to the development of scale insects. This was conditioned by such factors as the warm and dry climate of the city, as well as the abundant presence of plants representing just one genus, or even a single species. What is more, in Lublin there were also recorded larger numbers of aphids on roses growing in roadside localities as compared to roses growing in parks and in housing estates (Jaśkiewicz & Kmieć, 1998; Jaśkiewicz, 2004; Jaśkiewicz, 2005; Kmieć, 2006; Kmieć, 2007). Jaśkiewicz & Kot (2007) discovered that *Cotoneaster divaricatus* Rehder et E.H. Wilson was inhabited by larger numbers of *Aphis pomi* de Geer, 1773 in the roadside localities than in the parks of Lublin. However, Mackoś (2010) recorded large numbers of Thysanoptera on *Tilia cordata* Mill. in the housing estate localities, but recorded none in the roadside localities.

Some of the herbivorous arthropods inhabiting hawthorns in cities, when they are present in large numbers, spoil the decorative character of trees (Tykarska, 2002). Psyllids and aphids excrete large amounts of honeydew which covers the leaves of hawthorns and is conducive to the development of saprophytic fungi, the so-called "sooty mould". As for aphids, wheat midges and some mites, they deform leaves. The abundance of aphids on barberries, roses and junipers in the urban greenery of Lublin lowered the decorative value of these shrubs (Jaśkiewicz, 1999). Furthermore, aphids inhabiting decorative trees and plants lower their decorative value also by producing galases: *Eriosoma ulmi* Linnaeus, 1758*, Eriosoma lanuginosum* (Hartwig, 1839)*, Tetraneura ulmi* (Linnaeus, 1758)*, Colopha compressa* (Koch, 1856) and several species representing the genus *Dysaphis*. *Brachycaudus spiraeae* Börner, 1932 strongly deform the leaves of a bridewart (*Spiraea salicifolia* L.) (Soika & Łabanowski, 1999). Deformations of trees and shrubs in cities and gardens are also caused by many other aphid species; miniature varieties of trees and shrubs are especially vulnerable to their attack. Jaśkiewicz *et al.* (2001) observed that the large numbers of *Maculolachnus submacula* (Walker, 1848) on the shoots of *Rosa canina* L. in Lublin resulted in a stunted growth and deformation of young shoots, and sometimes even their death. This lead to a considerable diminishing of the decorative value of roses. Aphids inhabiting, in large numbers, the trimmed hedges of *Prunus cerasifera* Ehrh. in Lublin caused significant drying of leaves and shoots, which seriously affected the decorative character and functionality of the hedges (Cichocka & Lubiarz, 2003).

Trees planted in large numbers in the urbanized areas of Latvia (Juronis, 2003) belong to the genera: *Abies* (*A. alba* Mill., *A. balsamea* (L.) Mill., *A. sibirica* Ledeb. and *A. concolor* (Gordon et Glend.) Lindl. ex. Hildeb.). These trees are inhabited by large numbers of three aphid species: *Aphrastasia pectinatae* (Cholodkovsky, 1889), *Dreyfusia piceae* (Ratzeburg, 1844) and *Mindarinus abietinus* Koch, 1857. *Dreyfusia piceae*, turned out to be a particularly dangerous species, which caused the death of firs after 3-4 years. Budzińska & Goszczyński (2010) observed that the presence of numerous aphid colonies on coniferous plants in the urban greenery of Lublin resulted in yellowing and falling down of needles of the investigated plants. Jaśkiewicz (2006) studied the influence exercised by the feeding of numerous aphid populations on the decorative character of selected shrubs in Lublin. Her studies confirmed that the largest numbers of these insects were observed on shrubs growing directly by the roadside. Aphids were responsible for various types of damage to the plants: deformation of young shoots, misdevelopment of flowers, as well as deformations and discolorations of leaves resulting from the feeding of aphids on dogwoods, privets and barberries.

CONCLUSIONS

Plants growing in a city are exposed to the influence of urbanization pressure: the pollution of soil with heavy metals or chloride and air pollution. Heavy metals absorbed by leaves of trees affect the phenological phases of trees, e.g. shedding leaves nearly a month earlier than it would take place under normal conditions. Chemical pollution of soil results in the absorption of some chemical elements by plants, for instance chloride, since the plants are not equipped with any mechanisms which would protect them against an excessive intake of these elements. Then their leaves develop patches, which subsequently turn into necroses. The soil in which these plants grow is usually compressed and the rain water cannot seep into deeper layers. As a result, tree roots do not acquire a sufficient amount of water and they are unable to absorb a sufficient amount of mineral soils, which gradually leads to the death of trees. In the leaves of city trees, especially those trees which grew along the roads, an increased protein content was observed, which was conducive to the development of large populations of herbivorous insects with piercing-sucking mouthparts (aphids, scale insects, psyllids, and the hemipteran suborders Fulgoromorpha and Cicadomorpha). In spite of heavier pollution in roadside localities, on the trees growing in such localities the numbers of herbivorous insects with piercing-sucking mouthparts exceeded many times the numbers of these insects found on plants growing in parks or within housing estates. Abundant populations of such insects not only damage trees but also lower their decorative value.

Trees growing in larger green areas of a city, such as parks or community green spaces, enjoy better conditions for development than trees lining city streets. This is why trees in roadside localities die quicker than trees growing in other localities and the populations of herbivorous arthropods inhabiting them are much higher in comparison with trees found in parks or within housing estates.

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Typ krajobrazu a liczebność i skład gatunkowy stawonogów część II. krajobraz miejski

STRESZCZENIE

Praca zawiera przegląd czynników pośrednich wpływających na liczbę gatunków stawonogów oraz ich liczebność i bionomię w krajobrazie miejskim, głównie na przykładzie pluskwiaków (Hemiptera). Do czynników pośrednich wpływających na stawonogi w krajobrazie miejskim zaliczyć należy urbanizację, tworzenie jednogatunkowych skupisk

roślinności w miastach czy przenoszenie obcych gatunków roślin i zwierząt. Wpływ tych wszystkich czynników nie jest jednorodny, a konsekwencje działalności człowieka w środowisku trudno do końca przewidzieć. Krajobraz miejski stale podlega przekształceniom, miasta zmieniają swoją strukturę przyrodniczą co pociąga za sobą zmiany w składzie i liczebności stawonogów. Najliczniej stawonogi kłująco-ssące zasiedlają drzewa rosnące wzdłuż ulic w miastach, a mniej licznie w zieleni osiedlowej i w parkach.