Landscape type and species richness and composition of Arthropoda Part III. Devastated landscape

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ABSTRACT

The study reviews indirect factors affecting the species richness and species abundance of arthropods, as well as their bionomy, in a devastated landscape. An important factor which indirectly affects the arthropods is a widely understood economic activity of man and environmental pollution connected with it. In a devastated landscape similar types of pollution have been observed to those observed in a city landscape, but their concentration is many times higher. The effects of industrial pollution are inhomogeneous, and the impact which human activity has on the environment is difficult to foresee. An industrial landscape undergoes constant changes which strongly affect its biodiversity. Environmental pollution entails habitat alterations which, in consequence, result in changes in species richness and species composition of arthropods, leading to a clear prevalence of the arthropods with piercing-sucking mouthparts (scale insects, aphids, spider mites). The present study is the last one in a cycle of studies focusing on how arthropods are affected by changes taking place in an agricultural landscape, a city landscape and a devastated landscape. Factors which affect arthropods and which are present in each of the studied types of landscape include the transfer of alien species and widely understood human activity and environmental pollution connected with it. An anthropogenic landscape provides new living conditions for arthropods.

KEY WORDS: arthropods, devastated landscape, environmental pollution
INTRODUCTION

The influence of human activity on ecosystems has a global character. Its consequences can be observed even on a desert, at the tops of high mountains, in a jungle, in polar regions and at the bottom of an oceanic trench. Among the most serious threats to the environment Doblazańska et al. (2008) list chemization of the environment (industry, communication, agriculture), land use which destroys soil structure, decreasing biological diversity and shrinking of biologically active spaces in urbanized and industrial areas. Man-made technologies and their utilization constitute a major factor contributing to the alteration and destruction of the biosphere. Deaths of tree stands in Europe are connected with air pollution caused by the industry, but also by city life and by motor vehicles (Krzän & Skawinski, 1993). As for the eutrophization of water and soil, it is caused by a high content of nitrogen in the pollutants (Ilnicki, 2004).

The present paper is a continuation of two other papers in the series (Cichocka & Lubiarz, 2010; Lubiarz et al., 2011). The previous papers focused on factors affecting the species richness and abundance of arthropods, as well as the bionomy of particular arthropod species, exemplified mainly by hemipteran insects (Hemiptera). The papers studied an agricultural landscape and a city landscape, respectively. The present paper discusses the influence of industrial pollution and contamination on plants and arthropods inhabiting the plants.

DEVASTATED LANDSCAPE

Devastated landscape is a kind of landscape in which very serious changes have taken place as a result of industrial development, e.g. iron and steel industry, mining industry or chemical industry. Plants growing there are exposed to pollution similar to that found in other types of anthropogenic landscapes, but in devastated landscape the concentration of such pollution is many times higher. Typical landmarks of devastated landscape include industrial parks with high emitters, gallows frames of mines and spoil tips. Man is responsible for serious damage to the environment in the areas where natural resources are extracted, in the surroundings of chemical plants and power plants. Storage of industrial waste, air pollution and industrial emissions, as well as the contamination of water and soil, are the most visible results of human activity. Not only do they have an adverse effect on human health but also on plants, animals and their habitats (Doblazańska et al., 2008). Some plants become extinct and together with them there also become extinct the species of animals for which they were the only hosts (Fowler, 2004).

Furthermore, industrial waste has an adverse effect on physiological processes of plants and their metabolism, hampering their growth and development (Ernst
However, it has been proved, for instance, that short-term contamination with nitrogen oxides does not usually result in a disturbance of physiological processes, unless its concentration is very high (Mac Lean, 1977). Air pollution with sulphur and nitrogen compounds may also provide a source of nutritional elements to plants (Kontic et al., 1990). On the other hand, the increased levels of pollution in the atmosphere lead to unfavourable processes of acidization and eutrophisation. The acidization is caused by $\text{SO}_2$, $\text{NO}_2$ and $\text{NH}_4$, which are emitted as gases, undergo chemical changes in the atmosphere and afterwards reach water and soil together with dry and wet precipitation in the shape of ions or acids lowering the pH (Ilnicki, 2004). Substances found in precipitation water (i.e. acids) react with substances from the soil and also bind heavy metals found in the dust (Prusinkiewicz & Pokojska, 1989). If the pH is lower than 4.2, strongly toxic aluminium cations are released into the soil substrate, and heavy metals, such as Pb, Zn or Cd become more mobile and thus are easily absorbed by plants (Prusinkiewicz & Pokojska, 1989; Chlopecka et al., 1996; Gebski, 1998; Sady & Smoleń, 2004).

Heavy metals absorbed by plants from the soil, sulphur and nitrogen oxides in the air, changes in the soil pH and its salinization are only a few of negative factors which affect physiological processes of plants and their biochemical composition (Farmer, 2004; Fowler, 2004). Changes in the biochemical composition of plants affect the condition and development of animals which feed on them. The reaction of a particular tree or shrub to contamination depends on the species it belongs to and many other factors. Factors which accelerate devastation include, for example, draughts and mass appearances of arthropods. It was discovered that pine trees in the proximity of the chemical plant Zakłady Azotowe in the city of Puławy were more sensitive to pollution than oaks and their death coefficient was higher (Ostrowska, 1980). The growths of pine tree trunks were lower by 6-62%, while in the case of oaks they amounted to 60% on average (Oleksyn et al., 1993; 1994). The leaves of a pedunculate oak ($\text{Quercus robur}$ L.) growing in the proximity of the chemical plant Zakłady Azotowe in Puławy were irregular and warped. Even though no large numbers of insects with piercing mouthparts were observed on the trees, the leaf blades were scarred and discoloured and their parts were missing; these signs of damage already started to appear in spring. Furthermore, the trees bore very few fruits. Moreover, midsummer shoots and offshoots were observed, and their presence is known to seriously weaken trees (Lubiarz & Cichocka, 2003; Lubiarz, 2008b). Lubiarz (2006) discovered that in the leaves of a pedunculate oak in the proximity of the chemical plant Zakłady Azotowe in Puławy the nitrogen and protein content was over 14% higher in comparison with the Polesie National Park (PNP, Poleski Park Narodowy). The higher content of nitrogen in oak leaves in Puławy was, in all probability, due to the pollution of air with nitrogen dioxide, as its concentration was 3 to 4 times higher in Puławy than in the PNP (Lubiarz & Cichocka, 2005; Lubiarz, 2006; Lubiarz, 2008b).
Karolewski et al. (2005) observed that a nitrogen content in the leaves of oaks in the proximity of the chemical plant Zakłady Azotowe in Puławy was over 17% higher in comparison to a control locality in Kórnik. As has been suggested by Kontic et al. (1990), this may be due to the fact that the oaks utilize the NO₂ emitted by the plant as a nutritional element. In the leaves of oaks in Puławy there were recorded lower contents of P, K, Ca and Mg than in control localities (Karolewski et al., 2005), which my be another reason for the hampered growth of the studied trees, since phosphorus, potassium and magnesium are important nutritional elements. Potassium shortages limit biomass generation, while the shortages of K, Ca and Mg lower the levels of plant resistance against ground frost and draughts, are conducive to plant withering and may hamper their growth (Aronsson, 1980; Rikalä & Repo, 1997; Scheppard, 1994).

Rosada (1996) proved that plant contamination with heavy metals largely depends on the current contamination emissions and not only on the concentration of these metals in soil. An average lead and copper content in the above-ground parts of cultivated plants (corn, cannabis, broad beans, carrots, cabbages and lettuce) growing in the area affected by the copper works Huta Miedzi Głogów was clearly higher than in the case of plants cultivated in the soil also contaminated with heavy metals but situated in an area unaffected by emissions.

INFLUENCE OF INDUSTRIAL POLLUTION ON ARTHROPODS

Industrial pollution of air, travelling over long distances, is considered a major cause of a deteriorating condition of forests. According to the criteria applied in the European Union, the condition of a forest is assessed on the basis of the loss of assimilation apparatus. Dying out of vast forested spaces can be observed. Considerable losses of assimilation apparatus are visible to the naked eye. At the same time there can be observed mass gradations of pests which are harmful to the forests, including Lymantria monacha (Linnaeus, 1758), Bupalus piniaria (Linnaeus, 1758) and Tortrix viridana Linnaeus, 1758 (Smykala, 1996).

Numerous observations regarding the influence of chemical industry on arthropods inhabiting pedunculate oaks were made by Lubiarz (2006) who, in the years 2002 – 2004, studied the population of arthropods on these trees in the surroundings of the chemical plant Zaklady Azotowe in Puławy and in the Polesie National Park. The studied areas differed considerably with respect to the numbers of collected arthropod specimens. In Puławy Lubiarz (2006) collected 157 477 specimens, which constituted 90.86% of all collected arthropods, while in the PNP she found only 15 841 specimens. Thus, in Puławy the number of collected arthropods was ten times higher than in the PNP. At the same time it is noteworthy than in the proximity of the chemical plant Zaklady Azotowe in Puławy there were observed populations of Partenolecanium rufulum Cockerell,
1903 which were eighty times larger than populations of other scale insects on pedunculate oaks. There was observed a restructuring of the domination structure of scale insect population leading towards the superdominance of *Partenolecanium rufulum* (Lubiarz, 2009). Numerous individuals of this species inhabited oaks in Puławy (in 2003, on 100 leaves an average number of 1870 larvae were observed), while during the same period in the Polesie National Park the same species was not very numerous (in 2003, on 100 leaves an average number of merely 5 larvae were observed) (Lubiarz & Golan, 2005). It should also be mentioned that there were observed considerable differences in the species composition of arthropods inhabiting oaks in the described study areas. According to Lubiarz (2006), some species were observed solely in Puławy, while other species were noted solely in the PNP. For instance, no adult specimens of a cockchafer – *Melolontha melolontha* (Linnaeus, 1758) were observed in Puławy, while during the same period it appeared en masse in other regions of the Lublin voivodeship, including the Polesie National Park (Lubiarz, 2006).

The higher the level of environmental pollution, the higher the numbers of arthropods such as aphids, hemipteran suborders Fulgoromorpha and Cicadomorpha and spider mites (Boczek & Szlendak, 1992). Many researchers claim that industrial areas are inhabited by more abundant populations of aphids than other areas (Chłodny, 1976; Pfeffer, 1963; Wiąckowski, 1971; Witrylak, 1976). Charles & Villemant (1977) believe that particular aphids species inhabiting pine trees differ with respect to their reactions to pollution. Some species, such as *Protolachnus* spp., and *Cinara* spp. become more abundant as the level of pollution is increasing, while the reaction of *Schizolachnus* spp. and *Pineus* spp. is just the opposite. Lubiarz (2007; 2008a) observed that the populations of aphids representing the species of *Thelaxes dryophila* (Schrank, 1801) and *Phylloxera* spp. were several times more abundant in the proximity of the chemical plant Zakład Azotowe in Puławy than in the Polesie National Park. Jaworska & Gospodarek (2002) observed that the abundance of *Aphis fabae* Scopoli, 1763 was over thirty times higher on a fodder beet growing in the soil heavily contaminated with heavy metals than in a control locality situated far from the major sources of pollution. Similar data was obtained by Jaworska & Gospodarek (1999), who studied the development of this aphid species on a broad bean plant (*Vicia faba* L.).

Przybylski (1976; 1977; 1979) proved that in the environment of the Tarnobrzeg Sulphur District (Tarnobrzeskie Zagłębie Siarkowe) the abundance of aphids was higher than in other areas, but he discovered no correlation between the contamination with sulphur compounds and the abundance of spider mites in the same area. Kielpiewicz et al. (1997) studied the effect of industrial pollution on the appearance of the Eriophyoidea on field sagewort (*Artemisia campestris* L.) and tansy (*Tanacetum vulgare* L.). In the proximity of industrial plants such as the oil refinery Rafineria Płock, the chemical plant Zakład Azotowe in Puławy, the cogeneration plant Elektrociepłownia Żerań and the steelworks Huta Warszawa, the numbers of
the Eriophyoidea were several times higher than in a control locality. The authors also observed that the highest numbers of the Eriophyoidea were found in the proximity of the cogeneration plant Elektrociepłownia Żerań, where the leaves of a field sagewort had the highest content of soluble proteins and carbohydrates. SAHAJDAK et al. (1995) studied the influence of the environmental pollution in four industrial areas on aphids and mites (Tetranychidae, Eriophyoidea, Phytoseiidae) inhabiting apple trees, raspberry bushes, sageworts and tansies. On all plants in all industrial areas the recorded numbers of aphids were higher than in the control locality. It was the same in the case of the Eriophyoidea. As for the spider mite populations, in the polluted environment they were more numerous only on a raspberry bush and an apple tree, while the predatory mites Phytoseiidae did not react to industrial emissions. Similar data regarding the family Phytoseiidae was given by LUBIARZ (2006), as she observed these predatory mites on a pedunculate oak, in an assemblage of many species characteristic for them, both in the surroundings of the chemical plant Zakłady Azotowe in Puławy and in the Polesie National Park. In both localities the populations of these mites were of a similar size.

CICHOCKA & SAHAJDAK (1996), while studying the appearance of Aphis pomi de Geer, 1773 on apple trees growing in industrial areas, discovered that the abundance of the species was higher in the proximity of the steelworks Huta Warszawa, the cement factory Cementownia Warszawa, the cogeneration plant Elektrociepłownia Żerań, the chemical plant Petrochemia Płock and the chemical plant Zakłady Azotowe in Puławy than in the control locality. Furthermore, the authors studied the bionomy of Aphis pomi and came to a conclusion that the development of this species on apple tree leaves contaminated by the chemical plant Petrochemia Płock was shorter, and its fertility was higher in comparison to the control population, which resulted in an increase of the species abundance. GĘBICKI et al. (1977), analyzing aphid population in forests situated in industrial areas surrounding the steelworks Huta Katowice before it started operating, discovered that the dominant and subdominant species on birches was Euceraphis punctipennis (Zetterstedt, 1828). KLIMASZEWSKI et al. (1980), who continued the studies in the surroundings of the steelworks after it started functioning, observed that the dominance of Euceraphis punctipennis on birches was so clear that the species belonged to the subdominant class only in one locality, which was situated the furthest from the steelworks. These results show that the industry alters the environment in a way which triggers off changes in the structure of populations of herbivorous insects, such as aphids. GĘBICKI et al. (1977) noticed that wherever a plant grew in plant associations typical for them, they were inhabited by certain insect communities. On the other hand, when a plant was introduced to an environment where it was an alien, it usually resulted in a destruction of the structure of insect communities associated with this plant, and the insect communities observed on it had a totally accidental character KLIMASZEWSKI et al. (1989) oraz CZYŁOK et al. (1990) proved that the changes in aphid consortiums on a birch
and a pine tree might serve as a unique bioindicator of the condition of the natural environment.

The reasons for a growth in the abundance of aphids in contaminated areas might lie in the changes in plant immunity and biochemical changes in the plant juice, which are favourable to aphids and may increase their fertility and survival rates (Galecka, 1986). Galecka (1986) observed that in the surroundings of the town of Knurów, characterized by industrial pollution, the aphid species *Apis frangulae* Kaltenbach, 1845 was affected by two factors. Firstly, biochemical changes in its host plant, which were favourable, as they increased its abundance. Secondly, a hampered development of the host plant, which was unfavourable and contributed to a decrease in the abundance of the species.

**CONCLUSIONS**

Man’s impact on the natural environment is considerable, which is especially noticeable in a devastated landscape. Human activity results in contamination of the environment, which subsequently affects, in a significant way, plants and animals. The content of various substances (e.g. proteins, carbohydrates and heavy metals) in plants growing in the surroundings of industrial plants is often modified. Biochemical changes in plants result in alterations of the species composition and abundance of the entomofauna inhabiting these plants. Under the influence of industrial contamination, the abundance of herbivorous arthropods with piercing-sucking mouthparts clearly increases. The more polluted the environment, the weaker the plants, and the higher the abundance of piercing-sucking arthropods, such as scale insects, aphids or spider mites.

The present study is the last one in a cycle of works devoted to the influence exercised over arthropods by changes taking places in three types of landscape: an agricultural landscape, a city landscape and a devastated landscape. Factors which affect arthropods and can be encountered in each of these landscape types include widely understood human activity and the environmental pollution connected with it. The effect these factors have on arthropods is often exercised through the changes caused in host plants as a result of air, soil and water contamination. Thus, an anthropogenic landscape provides new living conditions for the arthropods.

**REFERENCES**


Lubiarz M. 2007. Life cycle and number dynamics of Phylloxera sp. on pedunculate oak (Quercus robur L.) in industrial and protected areas. Aphids and other Hemipterous Insects, 13: 137-144.


Sady W., Smolen S. 2004. Wpływ czynników gleboowych-nawozowych na akumulację metali ciężkich w roślinach. [In:] X Ogólnopolskie Sympozjum Naukowe „Efektywność stosowania nawozów w uprawach ogrodniczych”: 269-277.


Typ krajobrazu a liczebność i skład gatunkowy stawonógów
część III. krajobraz zdewastowany

STRESZCZENIE

Praca zawiera przegląd czynników pośrednich wpływających na liczbę gatunków stawonógów oraz ich liczebność i bionomię w krajobrazie zdewastowanym. Ważnym czynnikiem pośrednim wpływającym na stawonogi jest szeroko pojmowana działalność gospodarcza człowieka i związane z nią skażanie środowiska. W krajobrazie zdewastowanym stwierdzono oddziaływanie zanieczyszczeń podobnych do tych, które spotykamy w krajobrazie miejskim, jednak ich koncentracja jest wielokrotnie wyższa. Wpływ zanieczyszczeń przemysłowych nie jest jednorodny, a konsekwencje działalności człowieka w środowisku trudno do końca przewidzieć. Krajobraz przemysłowy stale podlega przekształceniom, które silnie wpływają na jego bioróżnorodność. Zanieczyszczenie środowiska pociąga za sobą przeobrażenia siedlisk, co z kolei powoduje zmiany w składzie gatunkowym i liczebności stawonógów, prowadząc do wyraźnej przewagi roślinnożernych stawonógów o kłująco-ssących aparatach gębowych (czerwce, mszyce, przedziorki).

Praca niniejsza zamyka cykl prac dotyczących wpływu na stawonogi zmian zachodzących w trzech typach krajobrazów: rolniczym, miejskim i zdewastowanym. Czynniki wpływające na stawonogi, których działanie możemy odnaleźć w każdym z opisanych krajobrazów to na przykład przenoszenie obcych gatunków czy szeroko pojmowana działalność człowieka i związane z nią zanieczyszczenie środowiska. Krajobraz zantropogenizowany stwarza nowe warunki dla życia stawonógów.