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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 Dobrzańska *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 (Krzan & Skawiński, 1993). As for the eutrophyzation 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 (Dobrzańska *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

& Joosse van Damme, 1989; Kontic *et al.*, 1990). 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 eutrophyzation. The acidization is caused by SO_2, NO_2 and 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; Gębski, 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 (*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). Also

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 NO_2 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; Rikala & 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 (Smykała, 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 Zakłady 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 Zakłady 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 Zakłady 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. Kiełkiewicz *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 Zakłady 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 Czylok *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 (Gałecka, 1986). Gałecka (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

Aronsson A. 1980. Frost hardiness in Scots pine (*Pinus silvestris* L.). II. Hardiness during winter and spring of different mineral nutrient status'. Stud. For. Suec., 155: 1-27.

Boczek J., Szlendak E. 1992. Wpływ stresów roślinnych na porażenie roslin przez szkodniki. Post. Nauk Roln.,2: 4-16.

Charles P.J., Villemant C. 1977. Modifications des niveaux de population d'insectes dans les jeunes plantations de pins sylvestres de la foret de Roumare (Seine-Maritime) soumis a la pollution atmospherique. C. R. Hebd. Seanc. Acad. Agic. Fr. (Paris), 63: 502-510.

Chłodny J. 1976. Liczebność mszyc (Aphididae) i fauny towarzyszącej w uprawach brzozy brodawkowatej (*Betula verrucosa*) na obszarze Górnośląskiego Okręgu Przemysłowego. [In:] Sandner H. (ed.) Entomologia a ochrona środowiska. PWN, Warszawa: 41-47.

Chlopecka, A., Bacon J.R., Wilson M.J., Kay J., 1996. Forms of cadmium, lead and zinc in soils from Southwest Poland. J. Environ. Qual., 25: 69-79.

Cichocka E., Lubiarz M. 2010. Landscape type and species richness and composition of Arthropoda Part. I. Agricultural landscape. Aphids and other Hemipterous Insects, 16: 59-77.

Cichocka E., Sahajdak A. 1996. Liczebność i rozwój mszycy jabłoniowej na jabłoniach o różnym stopniu zanieczyszczenia środowiska. Progress in Plant Prot., 36(2): 354-356.

Czylok A., Herczek A., Klimaszewski S., Wojciechowski W. 1990. Konsorcja mszyc na brzozach (*Betula pendula*) jako wskaźnik stanu środowiska w rejonie oddziaływania przemysłu aglomeracji Śląskiej i Krakowskiej. [In:] CPBP 04.10 Ochrona i Kształtowanie Środowiska Przyrodniczego. Zagrożenia i stan środowiska przyrodniczego rejonu śląsko-krakowskiego. Wyd. SGGW-AR, Warszawa, 62: 130-135.

Dobrzańska B., Dobrzański G., Kiełczewski D. 2008. Ochrona środowiska przyrodniczego. PWN, Warszawa, 495p.

Ernst W., Joosse van Damme E. 1989. Zanieczyszczenie środowiska substancjami mineralnymi. Skutki biologiczne. PWRiL, Warszawa, 320p.

Farmer A. 2004. Wpływ zanieczyszczeń pyłowych. [In:] Bell J.N.B. & Treshow M. (eds.) Zanieczyszczenie powietrza a życie roślin. WN-T, Warszawa, 209-222.

Fowler D. 2004 Depozycja zanieczyszczeń i przyswajanie ich przez rośliny. [In:] Bell J.N.B. & Treshow M. (ed.) Zanieczyszczenie powietrza a życie roślin. WN-T, Warszawa, 51-78.

Gałecka B. 1986. Układ roślina żywicielska (*Frangula Alnus* Mill.,)-mszyce (*Apis frangulae* Kalt.) w rejonie uprzemysłowionym ROW. Zesz. Prob.. Post. Nauk Rol., 329: 29-40.

Gębicki C., Głowacka E., Karwańska J., Klimaszewski S., Wojciechowski W. 1977. Zgrupowanie piewików, mszyc i koliszków (*Homoptera: Auchenorrhyncha, Aphidodea* i *Psyllodea*) wybranych środowisk rejonu huty „Katowice". Acta Biol., Katowice 4: 95-122.

Gębski M. 1998. Czynniki glebowe oraz nawozowe wpływające na przyswajanie metali ciężkich przez rośliny. Post. Nauk Roln. 5: 3-16.

Ilnicki P. 2004. Polskie rolnictwo a ochrona środowiska. Wydawnictwo AR w Poznaniu, 485p.

Jaworska M., Gospodarek J. 1999. Wpływ zanieczyszczenia gleby metalami ciężkimi na wrogów naturalnych mszycy trzmielinowo-burakowej (*Aphis fabae* Scop.). Chemia i Inżynieria Ekologiczna, 6:(5-6): 459-467.

Jaworska M., Gospodarek J. 2002. Wpływ zanieczyszczenia gleby metalami ciężkimi na mszycę trzmielinowo-burakową (*Aphis fabae* Scop.) na buraku pastewnym nasiennym (*Beta vulgaris* L.). Progress in Plant Prot. 42(2): 629-632.

Karolewski P., Giertych M.J., Oleksyn J., Żytkowiak R. 2005. Differential reaction of *Pinus sylvestris*, *Quercus robur* and *Quercus petraea* trees to nitrogen and sulfur pollution. Water, Air and Soil Pollution, 160: 95-108.

Kiełkiewicz M., Tomczyk A., Sahajdak A., Boczek J. 1997. Liczebność populacji szpecieli a skład chemiczny liści chwastów w przemysłowo zanieczyszczonym środowisku. Progress in Plant Prot., 37(2): 61-64.

Klimaszewski S.M., Czylok A., Herczek A., Wojciechowski W. 1989. An attempt to evaluate the degree of biocenosis disortion on the basis of qualitative and quantitative changes in aphid consortia (*Homoptera, Aphidoidea*). Archiwum Ochr. Środ. 1-2: 135-146.

Klimaszewski S.M., Wojciechowski W., Czylok A., Gębicki C., Herczek A., Jasińska J. 1980. Zgrupowanie wybranych grup pluskwiaków równoskrzydłych (*Homoptera*) i różnoskrzydłych (*Heteroptera*) w lasach rejonu huty „Katowice". Acta Biol., 8: 22-39.

Kontic R., Braker O.U., Nizon V., Müller R. 1990. Jährringanalytische Untersuchungen im Sihlwald, Schweizerische Zeitschrift Forstwessen 141: 55-76.

Krzan Z., Skawiński P. 1993. Prognoza degradacji drzewostanów Tatrzańskiego Parku Narodowego pod wpływem zanieczyszczeń powietrza. Prądnik, Prace i Materiały Muzeum im. Prof. Władysława Szafera, 7-8: 143–152.

Lubiarz M. 2006. Stawonogi na dębie szypułkowym (*Quercus robur* L.) na terenie przemysłowym i chronionym. Praca doktorska, KUL, Lublin, 228p.

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.

Lubiarz M. 2008a. Number dynamics of *Thelaxes dryophila* (Schrank, 1801) /Hemiptera, Aphidoidea/ on common oak (*Quercus robur*) in natural and degraded landscape. Aphids and other Hemipterous Insects, 14: 91-101.

Lubiarz M. 2008b. Stan zdrowotny dębów szypułkowych (*Quercus robur* L.) w krajobrazie naturalnym i zdegradowanym Lubelszczyzny. [In:] Janecki J. & Borkowski Z. (eds.). Krajobraz i ogród wiejski, 5: 221-235.

Lubiarz M. 2009. Domination structure of group of phytophagous hemipterous insects, aphids and scale insects on *Quercus robur* L. in natural and degraded landscape of the region of Lublin. Aphids and other Hemipterous Insects, 15: 133-150.

Lubiarz M., Cichocka E. 2003. Aphids and scale insects on pedunculate oak in two different environments, in Poleski National Park and in the neighbourhood of nitrogen fertilizers factory (Zakłady Azotowe in Puławy). Aphids and other Hemipterous Insects, 9: 69-91.

Lubiarz M., Cichocka E. 2005. Arthropods on pedunculate oak (*Quercus robur* L.) in Poleski National Park and in the neihbourhood of a nitrogen fertilizers factory in Puławy (Zakłady Azotowe in Puławy). Aphids and other Hemipterous Insects, 11: 85-94.

Lubiarz M., Cichocka E., Goszczyński W. 2011. Landscape type and species richness and composition of Arthropoda Part. II. Urban landscape. Aphids and other Hemipterous Insects, 17: 41-53.

Lubiarz M., Golan K. 2005. *Partenolecanium rufulum* (Cockerell) on pedunculate oak (*Quercus robur* L.) in the neighbourhood of the Nitrogen Fertilizer Factoring in Puławy and Poleski National Park. Aphids and other Hemipterous Insects, 11: 95-106.

Mac Lean D.C. 1977. Effects of nitrogen oxides on vegetation. [In:] Crocker T.T. (ed.), Nitrogen Oxides, National Academy of Sciences, Washington DC, 147-158.

Oleksyn J., Fritts H.S., Hughes M.K. 1993. Tree-ring analysis of different *Pinus sylvestris* provenances, *Quercus robur, Larix decidua* and *Larix decidua* x *L. kaempferi* affected by air pollution. Arboretum Kórnickie 38: 87-111.

Oleksyn J., Prus-Glowacki W., Giertych M., Reich P.B. 1994. Relation between genetic diversity and pollution impact in a 1912 experiment with East European *Pinus sylvestris* provenances. Can. J. For. Res. 24: 2390-2394.

Ostrowska A. 1980. Nitrogen accumulation in foliage, bark and wood of Scots pine in the vicinityof the nitrogen fertilizer factory in Pulawy. Roczniki Gleboznawcze 31: 117-131.

Pfeffer A. 1963. Insects parasites du sapin dans les zones soumises a une pollution atmospherique. Z. Angew. Ent., 51: 203-207.

Prusinkiewicz Z., Pokojska U. 1989. Wpływ eimisji przemysłowych na gleby. [In:] Białobok S. (ed.) Życie drzew w skażonym środowisku. PWN, Warszawa, 223-244.

Przybylski Z. 1976. Zimujące stadia rozwojowe szkodliwej fauny sadów w latach 1966, 1968, 1971, 1973 w rejonie Zakładów Przemysłowych Siarki w Machowie k. Tarnobrzega. [In:]: Sandner H. (ed.) Entomologia a ochrona środowiska. PWN, Warszawa: 55-64.

Przybylski Z. 1977. Wpływ skażeń przemysłowych związkami siarki na stawonogi występujące na plantacjach łąk i pszenicy ozimej w rejonie kopalń i zakładów przetwórczych siarki koło Tarnobrzega. Rocz. Nauk Rol., E: 55-65.

Przybylski Z. 1979. Badania nad wpływem na agrocenozy atmosfery skażonej związkami siarki. Prace Nauk. Inst. Ochr. Roślin, 21(1): 63-103.

Rikala R., Repo T. 1997. The effect of late summer fertilization on the frost hardening of second-year Scots pine seedlings. New Forests 14: 33-44.

Rosada J. 1996. Przyczyny zanieczyszczenia roślin metalami ciężkimi - skażone powietrze czy gleba? Progress in Plant Prot., 36(2): 351-353.

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

Sahajdak A., Boczek J., Cichocka E., Kropczyńska D. 1995. Liczebność mszyc i roztoczy w środowisku skażonym emisjami przemysłowymi Mat. XXXV Sesji Nauk. IOR, Poznań, II: 129-132.

Sheppard L.J. 1994. Causal mechanisms by which sulphate, nitrate and acidity influence frost hardiness in red spruce: Review and hypothesis. New Phytol. 127: 69-82.

Smykała J. 1996. Wyniki inwentaryzacji wielkopowierzchniowych stanu zdrowotnego i sanitarnego lasów w Polsce. [In:] Siwecki R. (ed.) Reakcje biologiczne drzew na zanieczyszczenia przemysłowe. PAN, Poznań, I: 61-74.

Wiąckowski S. 1971. Problem wpływu pyłów i gazów przemysłowych na biocenozy leśne i jego znaczenie dla ochrony zdrowia człowieka. Wiad. Ekol., 17: 270-283.

Witrylak M. 1976. Badania dynamiki populacji entomofauny modrzewia europejskiego (*Larix decidua* Mill.) w uprawach leśnych na terenach przemysłowych o różnym skażeniu powietrza. [In:] Sandner H. (ed.) Entomologia a ochrona środowiska. PWN, Warszawa: 49-51.

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

STRESZCZENIE

Praca zawiera przegląd czynników pośrednich wpływających na liczbę gatunków stawonogów 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 stawonogów, prowadząc do wyraźnej przewagi roślinożernych stawonogów o kłująco-ssących aparatach gębowych (czerwce, mszyce, przędziorki).

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 stawonogów.