POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	47	4	365–371	1999

Effect of industrial pollution and spruce forest decline on the biocenoses of Karkonosze Mts. (south-western Poland)

Eliza DĄBROWSKA-PROT

Department of Bioindication, Institute of Ecology, Polish Academy of Sciences
Dziekanów Leśny near Warsaw 05–092 Łomianki, Poland, e-mail: ekolog@warman.com.pl

ENVIRONMENTAL CHARACTERISTICS OF THE KARKONOSZE MTS. REGION AND THE PROBLEMS OF SPRUCE FOREST DECLINE

1. ENVIRONMENTAL CONDITIONS OF KARKONOSZE MTS.

Consequences of various types of anthropogenic pressure are particularly serious in mountain areas, because of environmental conditions prevailing there (severe climate, poor soils, water and wind erosion, short growing season, frequent catastrophic events such as avalanches and hurricanes). In recent years, industrial pollutants have been recognised as posing serious threat to forest ecosystems and leading to their degradation (Herrick and Friedland 1990, Hinrichsen 1986, Schulze et al. 1989, Tomlinson 1990). In mountainous areas these are principally coniferous monocultures, which are particularly susceptible to anthropogenic stress factors.

Such a situation takes place in Karkonosze Mts., the part of "black triangle" of Europe, where vast areas of spruce forests are being damaged by industrial air pollutants derived in 75% from the Czech Republic and Germany (Fig. 1), and only in 25% from Poland (Zwoździak et al. 1993). First symptoms of damage to the forests in south-western part of Poland were found in Izerskie Mts. 20 years ago. It has been documented by the studies on heavy metal deposition to peat soils on Hala Izerska. Lead and cadmium accumulation in the upper layers of the peat was found to be substantially increased (Strzyszcz and Chróst 1995). In

Karkonosze, first symptoms of spruce weakening appeared later than in Izerskie Mts., but the decline of forests proceeded there very rapidly. At present, the situation is considered as ecological disaster.

Karkonosze is the highest range (up to 1603 m a.s.l. – Śnieżka) of Sudeten Mts. located in south-western Poland (Fig. 1). An analysis of 30-year-series of climatic data (Migała et al. 1995) has shown that the region is characterised by considerable cloudiness, high precipitation sums (1422 mm annually) and high humidity (83.3–89.2%). Frequent occurrence of fogs and clouds in the uppermost parts of the mountain range limits solar radiation input and, thereby, elevational ranges of plants are shifted down in relation to other mountains (by some 300 m compared to Tatra Mts.). Submontane zone reaches its upper range of 400 m, above which lower montane forest belt extends up to 1000 m. Original vegetation of the latter belt has remained unchanged only in few places. Native tree stands have been completely removed from the remaining area and replaced by man-planted spruce forests. Upper montane zone lying between 1000 and 1300 m a.s.l. is covered by primeval spruce forests rich in understory species and with well developed moss layer. Subalpine vegetation characteristic of the elevation range from 1300 to 1560 m a.s.l. is composed of dwarf mountain-pine and grass communities. Alpine vegetation occurs solely in the uppermost part of Mt. Śnieżka and constitutes a narrow 30–50 m belt (Pawłowski 1959, Fabiszewski 1985).

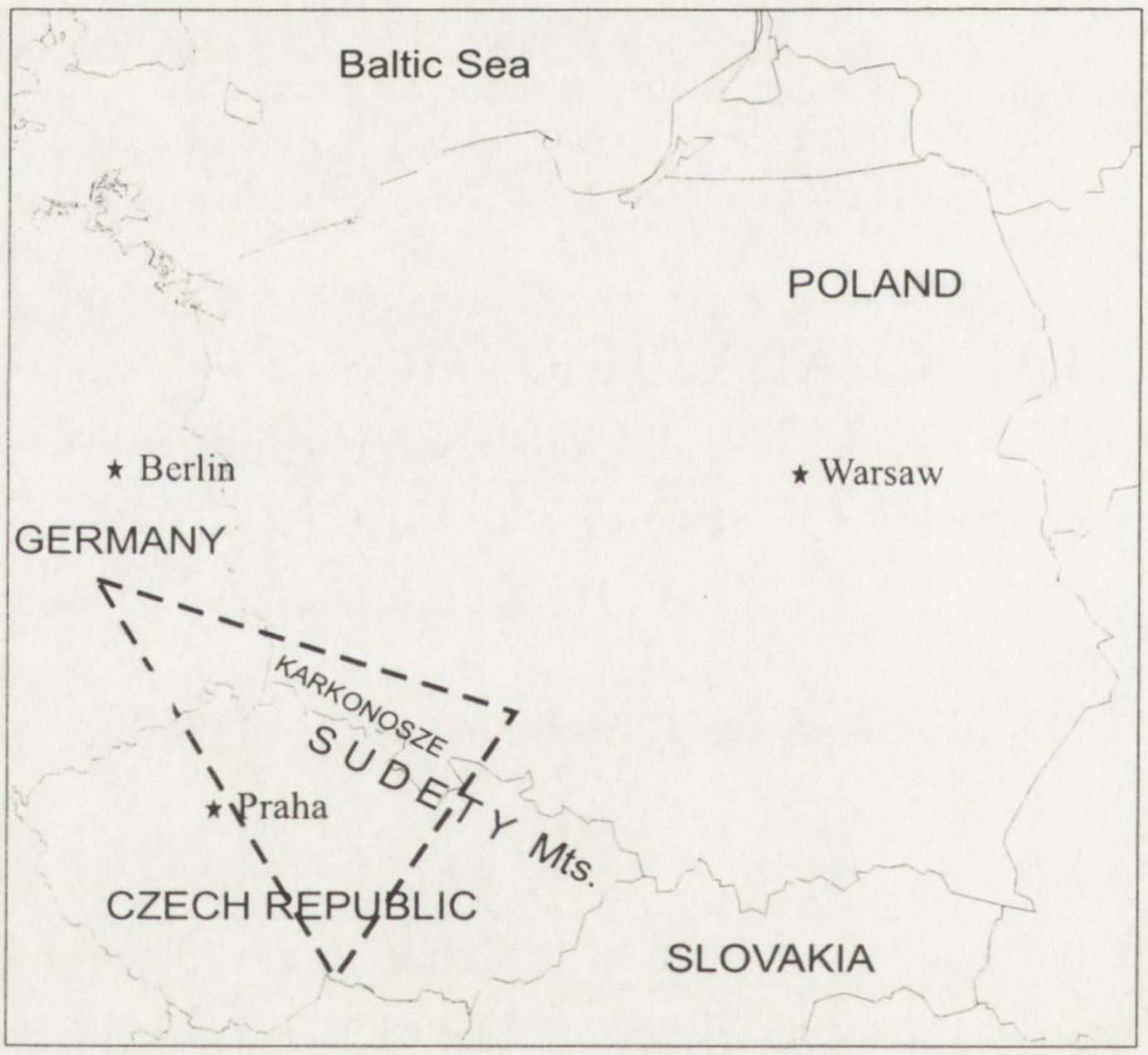

Fig. 1. The map of a part of Central Europe with locality of Sudety and Karkonosze Mts.
* – the capitals
- - - - – the "black triangle" of Europe

Climate is severe: average temperature maximum (July and August) is 13.6°C, minimum (in January) reaches –8.5°C, and minimum temperature at the ground level is –11°C. Frequent south-westerly winds of speeds up to 11.5 m s^{-1} bring industrial pollutants from other areas of Poland as well as from Germany and the Czech Republic. Snow cover usually stays from late November to late April, and sometimes

even to the second decade of May (about 160 days), and its depth ranges from 6 to 128 cm (Migała et al. 1995).

Karkonosze Mts. are formed from granite rocks containing considerable amounts of such elements as Al, Pb, As, Hg, Cd, F, U, Be that can be harmful or even toxic to living organisms (Sachanbiński 1995). Increased deposition of compounds containing sulphur has led to enhanced acidification of waters and soils of the region, and thereby, to higher leaching losses of parent rock constituents and mobilisation of many elements, mainly aluminium occurring previously in insoluble forms (Sachanbiński 1995). At pH=4.0–4.5 Al solubilises into forms readily available to living biota. In acid soils (pH=3.0–4.5) aluminium replaces other cations from exchange sites leading to losses of the nutrient elements from the soils. This process is particularly intensive in mineral layers of forest soils where Al ions may constitute as much as 90% of all cations. Geochemical peculiarity of Karkonosze Mts. consists in occurrence of available forms of extremely toxic Be ions in the soils (Sachanbiński 1995).

Seasonal variability in concentrations of air pollutants in Karkonosze Mts. is typically high. However, the mean pollution level by sulphur compounds and heavy metals is high and has not change for a few last years (Zwoździak et al. 1995). Thus, predictions for stability of spruce forests in Karkonosze Mts. are rather pessimistic.

A survey of natural resources of Western Sudety based on satellite images made in 1984 revealed that spruce forests cover as much as 60% of 35 thousand hectares of the area (of which 27% with visible symptoms of weakened vigour), deciduous and mixed forests – 10%, mountain-pine – 10%, and deforested areas – 20% (Zawiła-Niedźwiecki 1992).

The data show that spruce forests are the dominant component of the landscape, and their degradation results in radical changes in both the structure and functioning of the natural systems. Therefore, causes and effects of the decline are of particular concern of both foresters and scientists.

The increasing level of pollution has led not only to the spruce forest decline over Western Sudety Mts., but also to degradation of grasslands situated above the tree line (Wojtuń et al. 1995).

Coniferous forest decline has long been recognised to be an effect of climatic conditions, phytophage activity, or air pollution. Lately, much attention has also been given to nutritional disharmony (Blank 1985, Schulze et al. 1989 Żołnierz et. al. 1995). Some studies on spruce forest decline in Karkonosze have suggested that the main reason of the phenomenon is deficiency of nutrients N, K, Mg, Ca, imbalanced ratios of N:P and K:P, and toxic effects of Al and Pb on metabolism of the trees (Zimka et al. 1995). These factors reduce foliar chlorophyll content and foliage biomass, and inhibit mycorrhizae.

The above processes have led to deforestation of large areas of the Karkonosze Mts. A survey of forest resources in Karkonosze National Park performed in late 80-ties revealed that about 70% of high elevation forests were damaged, and one half of these would die in the nearest future (Raj 1992). Foresters' predictions are that the high elevation forests in Karkonosze Mts. may completely vanish, and subsequently, the tree line would be shifted down by 100–200 m (Boratyński et al. 1987).

2. GENERAL ASSUMPTIONS OF THE RESEARCH PROJECT

Having described transformations of the forest ecosystems in Karkonosze Mts. we pose the following question: how do these changes affect formation and functioning of animal communities? On the one hand, the communities have been formed under severe mountainous conditions (high elevation, severe climate, and short growing season). On the other hand, the communities have been influenced by drastic changes in the landscape structure. Spruce monocultures are replaced by a mosaic of habitats representing different stages of forest degeneration (from a healthy stand through various stages of tree damages to deforested areas with scarce stubs of tree stems) and regeneration (spruce thickets of different age). The objective of these studies, the results of which are presented in this issue is to assess the biocenotic effects of spruce monoculture transformations into the patchy landscape of mountainous habitats. The research project consisted of a few subprojects:

1. Assessment of the degree of forest ecosystem alteration due to degradation of the environment by using phytosociological indices of quality of herb layer vegetation,

2. Assessment of usefulness of *Vaccinium myrtillus* plants and soil Protozoa for monitoring environmental pollution level,

3. Evaluation of structure and dynamics of various invertebrate communities in degraded and regenerating coniferous habitats

Examination of the latest item was based upon responses of selected indicator animal communities: soil organisms (protozoans), organisms inhabiting soil surface (epigeic spiders) and plant surfaces (poorly mobile web spiders and highly mobile Diptera). As the groups of organisms differ with regard to their spatial distribution in the environment, they are exposed to different levels of adverse environmental factors, and have different abilities to avoid unfavourable conditions by migrations.

The studies were conducted on a slope of Mumlawski Wierch (1219 m a.s.l.) and in the valley of Kamienna river (900 m a.s.l.). In this relatively small area, all stages of spruce forest transformation could be found typical of other parts of the Karkonosze Mts. (Fig. 2). Until mid 70-ties, the entire area was covered by spruce forests. In subsequent years, a mosaic of habitats has been formed representing different stages of degradation as well as of regeneration of spruce ecosystems. This was an effect of a gradual streaked dieback of trees, and natural (spruce regeneration) or man-made (planting of spruce, larch, beech, maple and alder trees) secondary succession.

To make a comparison, 4 additional study sites were chosen in spruce forests on Szrenica Mt. (1362 m a.s.l.) situated at the elevation of 1200–1000 m corresponding to the uppermost part of Mumlawski Wierch (Fig. 2).

On Szrenica Mt., differently to Mumlawski Wierch, all typically montane elevational ranges of plants can be found. Additionally, tourists have frequently visited the mount since late 19th century. Szrenica Mt. is crossed by the oldest tourist track of the Karkonosze range, and since the beginning of 20th century a shelter has been established there. Tourism appears to be an additional factor affecting fauna and

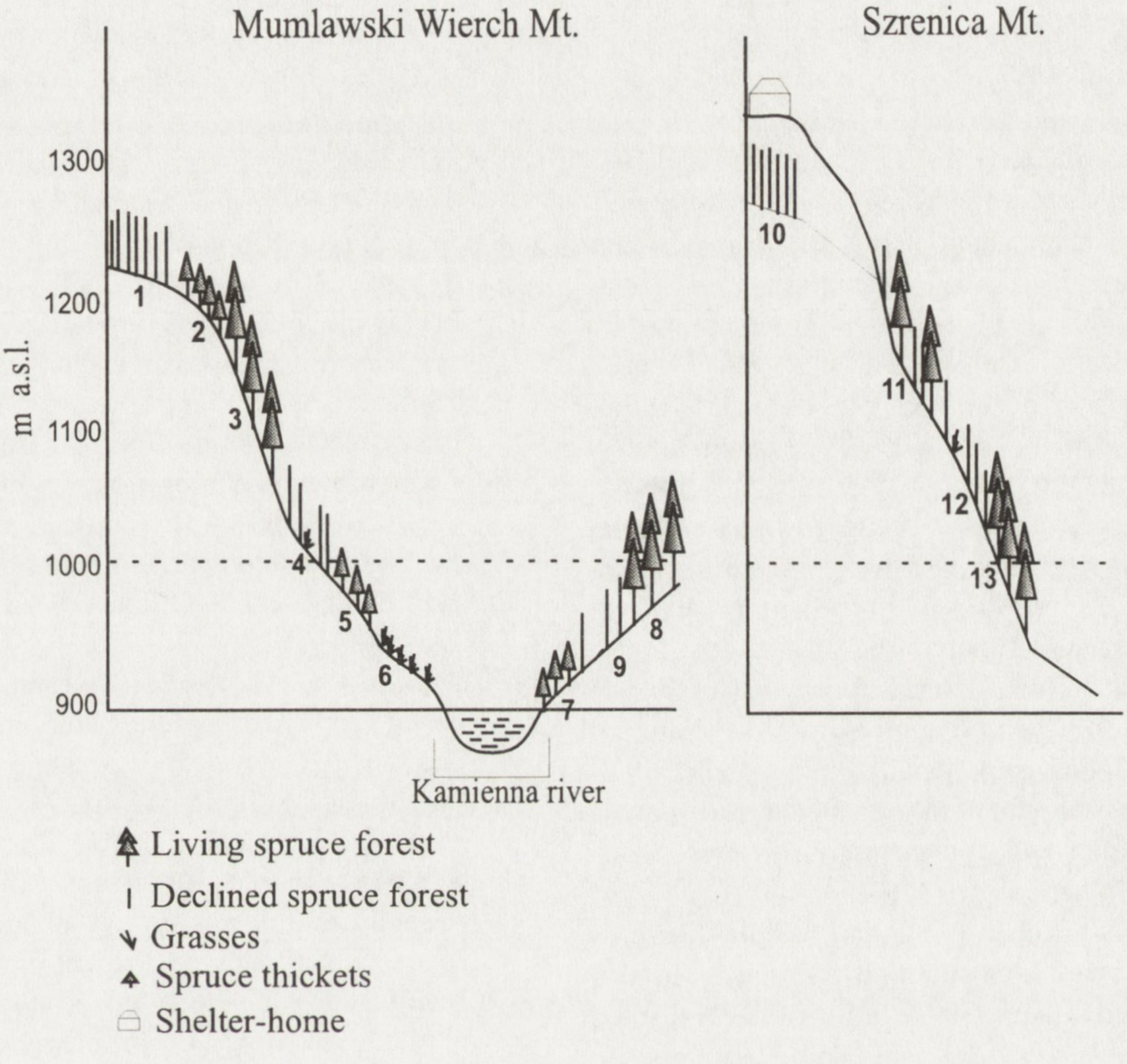

Fig. 2. Location of study sites on Mumlawski Wierch Mt., in the valley of Kamienna river, and on Szrenica Mt in Karkonosze Mts. The broken line denotes bordeline between the lower and upper montane zone. 1–13 – sample plots.

an additional factor affecting fauna and flora of the region. Herb and moss layers as well as insect communities have been found to be synanthropied.

Much difficulty in data interpretation is due to our fairly poor knowledge of Karkonosze fauna. We do not have complete ecological description of main animal groups of the region, and existing faunistic research is fragmentary (Kuźma 1989). Gądek (1981) has stated that Karkonosze National Park is one the least known among protected areas of the country. Therefore, we do not have any reference data from the period preceding the ecological disaster, which could have enabled us to verify our results in the view of the effects of the two principal factors: specific mountain environment and anthropogenic transformations. Nevertheless, there is an urgent need to examine at least some fauna components of this region, and to evaluate their chances to survive under conditions of the drastic environmental changes. This was one of the main reasons to undertake the studies presented below.

3. References

Blank L.W. 1985 – A new type of forest decline in Germany – Nature 314: 311–314

Boratyński A., Konca B., Zientarski J. 1987 – Sudeckie bory górnoreglowe, Plagiothecio - Piceetum hercynicum – warunki występowania, struktura zagrożenia przez zanieczyszczenia środowiska [High-elevation forests Plagiotecio-Piceetum hercynicum in Sudety Mts. – conditions of occurrence, structure of environmental pollution threats] – Arboretum Kórnickie 32: 163–205.

Fabiszewski J. 1985 – Szata roślinna [Vegetation] (In: Karkonosze Polskie [Polish Karkonosze Mts] Ed. A. Jahn) – Ossolineum, Wrocław, KTN Jelenia Góra, pp. 191–235.

Gądek K. 1981 – Badania entomologiczne w parkach narodowych południowej Polski [Entomological studies in national parks of southern Poland] (In: Entomologia a gospodarka narodowa [Entomology and state economy]) – PWN, Warszawa – Wrocław, pp. 37–49.

Herrick G.T., Friedland A. J. 1990 – Patterns of trace metal concentration and acidity in mountain forest soils of the north-western United States – Water, Air and Soil Pollution 53: 151–197.

Hinrichsen D. 1986 – Multiple pollutants and forest decline – Ambio 15: 258–265.

Kuźma J. 1989 – Bibliografia Karkonoszy Polskich [Bibliography of Polish Karkonosze Mts.] – Prace Karkonoskiego Tow. Nauk 42, 249 pp.

Migała K., Pereyma J., Sobik M., Szczepankiewicz-Szmyrka A. 1995 – Współczesne warunki klimatyczne i zróżnicowanie topoklimatyczne Karkonoszy [Present climatic conditions and topoclimatic variation of Karkonosze Mts.] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 51–78.

Pawłowski B. 1959 – Szata roślinna gór polskich [Vegetation of Polish mountains] (In: Szata roślinna Polski [Vegetation of Poland]) – Warszawa, pp. 189–252.

Raj A. 1992 – Obumieranie lasów w Karkonoskim Parku Narodowym [Forest decline in Karkonosze National Park] – Parki Narodowe 3: 5–6.

Sachanbiński M. 1995 – Środowisko geochemiczne Karkonoszy [Geochemical environment of Karkonosze Mts.] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 11–34.

Schulze E. D., Lange O. L., Oren R. Eds 1989 – Forest decline and air pollution – Ecol. Stud. 77, pp. 475.

Strzyszcz Z., Chróst L. 1995 – Określenie depozycji niektórych metali ciężkich na przykładzie torfowiska wysokiego na Hali Izerskiej [Assessment of deposition of some heavy metals to a peat bog on Hala Izerska] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 123–130.

Tomlinson G. H. 1990 – Nutrient disturbances in forest trees and the nature of the forest decline in Quebec and Germany – Water, Air and Soil Pollution 54: 61–74.

Wojtuń B., Fabiszewski J., Sobierajski Z., Matula J., Żołnierz L. 1995 – Współczesne przemiany wysokogórskich fitocenoz Karkonoszy [Present-day transformations of high-elevation phytocenoses of Karkonosze Mts.] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 213–246.

Zawiła-Niedźwiecki T. 1992 – Lasy – diagnoza z orbity [Forests – diagnosis from the orbit] – Wiedza i życie 11: 60–64.

Zimka J., Stachurski A., Kwiecień M. 1995 – Wskaźniki kondycji a status troficzny świerka (Picea abies) w Karkonoszach [Indices of health conditions and nutritional status of spruce (Picea abies) in Karkonosze Mts.] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 247–264.

Zwoździak J., Zwoździak A., Kmieć G., Kacperczyk K. 1993 – Przyczyny zanieczyszczenia atmosfery w wyższych partiach Sudetów [Causes of air pollution in upper parts of Sudety Mts.] (In: Karkonoskie badania ekologiczne [Ecological studies in Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 19–32.

Zwoździak J., Kmieć G., Zwoździak A., Kacperczyk K. 1995 – Presja zanieczyszczeń przemysłowych w ostatnim wieloleciu

a stan obecny [Long-term pressure and present state of industrial pollution] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 79–111.

Żołnierz L., Fabiszewski J., Wojtuń B., Matula J., Sobierajski Z. 1995 – Status troficzny świerka (Picea abies) w świetle problemu zamierania borów górnoreglowych w Karkonoszach [Nutritional status of spruce (Picea abies) in the light of decline of high-elevation forests of Karkonosze Mts.] (In: Problemy ekologiczne wysokogórskiej części Karkonoszy [Ecological problems of the high elevation parts of Karkonosze Mts.] Ed. Z. Fischer) – Oficyna Wyd. Instytutu Ekologii PAN, pp. 187–21.

(*Received after revising August 1999*)