Phyton (Horn, Austria) Special issue: "Bioindication ..."	Vol. 36	Fasc. 3	(85)-(90)	15.09.96

Bioindication of Air Pollution by Epiphytic Lichens in Forest Decline Studies in Slovenia

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Key words: Bioindication, air pollution, epiphytic lichens, forest decline, Slovenia.

Summary

BATIČ F. & MAYRHOFER H. 1996. Bioindication of air pollution by epiphytic lichens in forest decline studies in Slovenia. - Phyton (Horn, Austria) 36 (3): (85) - (90).

Initial studies were based on mapping of cover and frequency of crustose, foliose and fructicose epiphytic lichens on trees and these were also assessed for decline symptoms. Since 1985 the epiphytic lichen vegetation has been assessed by such methods and the results, expressed as a lichen map of Slovenia were used as an air quality indicator for plots of forest die-back inventory. In collaboration with lichenologists from Graz University, Austria, all epiphytic lichen species were mapped in order to obtain better measures of air quality in the area studied. Very polluted and clean, well preserved forest were investigated. From the material collected and determined, a lichen herbarium has been established in the Slovenian Forestry Institute. Possibilities for further research and the use of epiphytic lichens as air quality indicators are discussed.

Introduction

Bioindicators are organisms which respond to environmental factors through their life functions (ARNDT & al. 1987). This definition extends to bioindicators of air pollution. Epiphytic lichens are among the best known and extensively used bioindicators of air pollution (SKYE 1968, FERRY & al. 1973, HAWKSWORTH & ROSE 1976, DERUELLE 1978, NASH & WIRTH 1988, RICHARDSON 1988). They have been used as passive and active bioindicators of air pollution in many urban and industrial regions of Europe, North America and elsewhere in the world (SCHUBERT 1985, ARNDT & al. 1987). Recently they have also been used as air quality indicators in forest decline studies (WESTMAN 1987, WITTMANN & TÜRK

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1988, BARTHOLMESS & al. 1987, BATIČ & KRALJ 1989, GRILL & SCARDELLI 1990, GLIEMEROTH 1990, RAITIO 1990, BATIČ 1991). The greater sensitivity of epiphytic lichens to air pollution in comparison with higher plants can be attributed to their primitive structure (PFANZ & al. 1987, AHMADJIAN 1993), their adaptation to epiphytic life (BARKMAN 1958, SKYE 1968, GILBERT 1969, FERRY & al. 1973), and their longevity and associated physiological activity in the cooler and moister winter part of the year with a high air pollution load (FERRY & al. 1973, HAWKSWORTH & ROSE 1976, MUIR & MCCUNE 1988, NASH & WIRTH 1988).

In Slovenia, bioindication of air pollution with epiphytic lichens has a relatively short history. Initial observations on the disappearance of lichens from urban and industrialised areas were recorded about forty years ago by school teachers. Due to the lack of trained lichenologists the first mapping of lichens around polluted areas was carried out in the late seventies (BATIČ & al. 1979, BATIČ & MARTINČIČ 1982) when comparisons were made in virgin forest reserves (HOČEVAR & al. 1985). As the lichen flora was poorly known, lichen thalli types were mapped throughout Slovenia in several school projects supported by industry, in order to improve overall ecological knowledge of children (BATIČ 1984). The same method, e.g. mapping of epiphytic lichen thalli types, was latter adopted and modified for forest decline inventories where epiphytic lichen vegetation was used regularly as an air quality indicator on the plots used for forest decline studies (BATIČ & KRALJ 1989, BATIČ 1991, BATIČ & KRALJ 1995).

Material and Methods

Epiphytic lichens can be used in different ways as air quality bioindicators. There is an extensive literature about the use of species mapping in urban and industrialised areas (FERRY & al. 1973, DERUELLE 1978, NASH & WIRTH 1988, RICHARDSON 1988, KIRSCHBAUM & WIRTH 1995, etc.). As species mapping includes the specific sensitivity of all lichen species, this method is still the most widely accepted air pollution bioindication method utilicing lichens. In this method lichens are used as passive bioindicators (SCHUBERT 1985, ARNDT & al. 1987). The use of this method demands a well trained lichenologist, and if possible, good historical records about the lichen flora of the area under consideration. As that was not the case in Slovenia, a simplified bioindication method of monitoring air pollution using epiphytic lichens was developed (see discussion above), where mapping of thalli types (i.e. crustose, foliose and fruticose) was implemented, as well as considering the cover and frequency of all thalli and also the height of the trees where lichens were observed. A very simple quantification of the assessment of these parameters was introduced, and by using a formula, an index of atmospheric purity was calculated for each observation plot (BATIČ 1991, 1992, BATIČ & KRALJ 1995). After each forest decline inventory a "lichen map" of Slovenia was obtained, which provided an overview of the richness of epiphytic lichen growth in the forest stands investigated. In comparison with known sources of air pollution and the measurement of air pollutants at limited sites, these maps give an approximate picture of air quality in Slovenian forests.

In case studies where more precise data on the progress of forest decline were necessary, we started mapping of particular lichen species. At first, the idea was to map epiphytic lichens within the 16 km x 16 km bioindication grid, considering all epiphytic species found within a radius up to 500 m from the plot. Later the mapping activities were oriented to the surroundings of major sources of air pollution such as thermal power plants and industrial centres. During such studies we were faced with the lack of a reference lichen herbarium in Ljubljana, and of a well trained lichenologist, familiar with the microlichens. Fortunately at that time a research collaboration between Slovenia

and Austria began in the field of forest decline. From the beginning we started a successful collaboration with lichenologists from Graz University where POELTs well known group was established. This collaboration was later extended within the TEMPUS project in which bioindication methods for monitoring forest pollution were developed and exchanged between the universities in Ljubljana (Slovenia), Graz (Austria), München (Germany) and Cambridge (UK).

Through collaboration with the lichenologists in Graz we obtained reference herbarium material, collected in Slovenia and determined in Graz, and so that we could continue our planned lichen mapping. The overall grid mapping was postponed, and under mutual agreement, we started to map the Pohorje area. This area is influenced by pollution from the Šoštanj power plant, and early records are available from the end of the last century KERNSTOCK 1889, 1893 thus making comparison with todays situation possible. Other mapping activities were concentrated on the Dinaric forests with relatively clean air, a flourishing lichen vegetation, and with historically conatural forestry. Here, we expected to obtain insight into a rich epiphytic lichen flora, little influenced by air pollution and forest management, which had not been investigated previously (KUŠAN 1953). Epiphytic lichens were investigated in a profile on Notranjski Snežnik, on Goteniški Snežnik and a third from the river Kolpa over Krokar to Grčarice. Two final lichenological activities arising from this collaboration were a reinvestigation of epiphytic lichens in Trnovski gozd, which has been investigated by GLOWACKI & ARNOLD 1870 and GLOWACKI 1871, 1874 in the last century, and a continuation of mapping within the emission zone of the thermal power plant at Šoštanj in the Uršlja gora area. A preliminary investigation has also started along a profile in the Julian Alps within the Triglav National Park.

Results and Discussion

Within forest die-back inventories, epiphytic lichen vegetation has been mapped regularly since 1985. On the basis of the assessment of cover and frequency of crustose, foliose and fructicose lichens on trees (which were also assessed for decline symptoms) several lichen maps were constructed. All provide a reasonable accurate picture of the general air quality in Slovenia. Two examples of such maps are presented in Fig. 1 and Fig. 2, for observations on common beech (*Fagus sylvatica* L.) and the second for all trees, regardless of species.

Data were taken from the 1991 forest decline inventory. From a knowledge of the air pollution situation in Slovenia, forest conditions and general meteorological circumstances, the maps correspond well with the expected and in part, also with the measured air pollution. In general the epiphytic lichen flora looks quite poor, especially mainly on beech. Species mapping was carried out in the above areas mainly by graduate and postgraduate students from Graz and Ljubljana. It revealed that there is still quite a rich epiphytic vegetation in protected and unpolluted forests, indicated by thalli mapping. Several new species were recorded for Slovenia, and some for an even broader area. Most of these data have yet to be published because the mapping and determinations are incomplete. However, it was observed that the impact of air pollution on lichen vegetation was well expressed around major point pollution sources in Slovenia, but at higher elevations in the western and southern part of the country, transboundary pollution takes place. The sensitivity of species to air pollutants is generally similar to that observed elsewhere in Europe (HAWKSWORTH & ROSE 1976, WITTMANN & TÜRK 1988), but some species, specific for Slovenia, were selected for bioindication. Apart from air

pollution, the type of forest management has been found to be very important for the survival of epiphytic lichens.

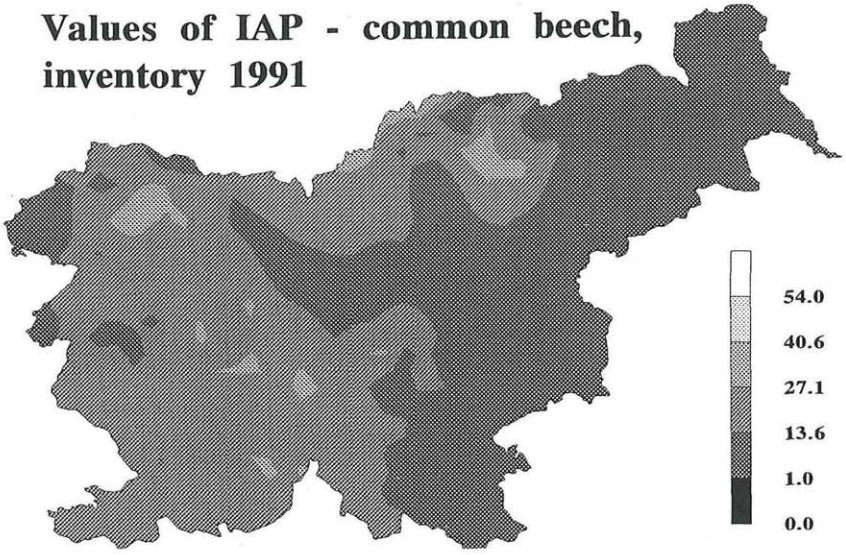

Fig. 1. Lichen map of Slovenia drawn on the basis of the epiphytic lichen vegetation assessment in the forest decline inventory of 1991. Observations were on all tree species. Dark area represent very poor epiphytic lichen vegetation and presumably highly polluted air.

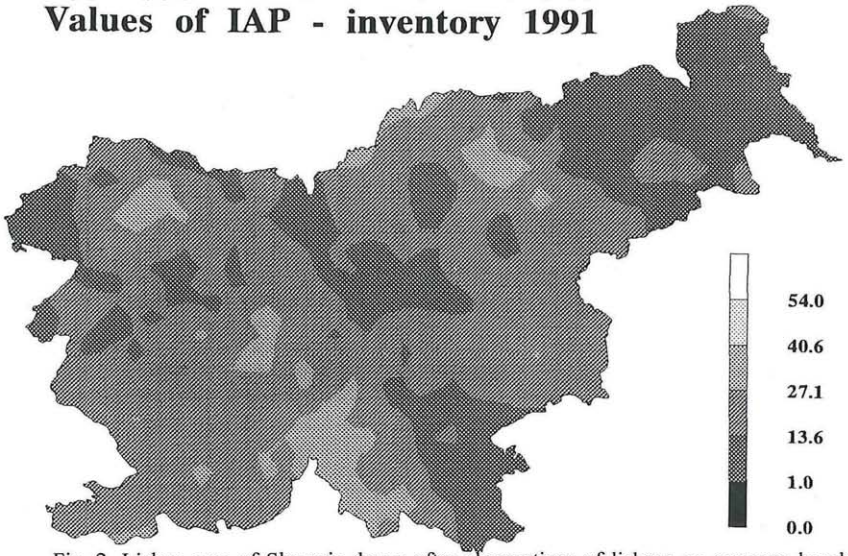

Fig. 2. Lichen map of Slovenia drawn after observations of lichens on common beech (*Fagus sylvatica* L.) in the forest decline inventory of 1991. Due to the type of crown and polluted precipitation influenced by stemflow, the cover of epiphytic lichens is much worse that than observed on other trees or when the data are presented regardless tree species.

Where single tree felling has been practised, the lichen flora remains much richer in comparison with areas where clear felling type of forest dominated (GRUBE & al. 1995). A very important consequence of the above activities has been the establishment of a new lichen herbarium at the Slovenian Institute for Forestry, which well enable further work to be carried out in the fields of lichen taxonomy and bioindication.

Acknowledgements

All participating students, M. KOCH, B. KRUHAR, U. SUPPAN, J. PRÜGGER and M. GRUBE are thanked for their past and future contributions to this topic. We thank V. RAJH for assistance in the herbarium, and T. SINKOVIČ for help in field transportations. Prof. J.A. ELIX (Canberra) is acknowledged for reading the manuscript. The study was supported by the Slovenian Ministry of Science and Technology, the Slovenian Ministry for Agriculture, Forestry and Food Technology, the Austrian Ministry for Science and Research, and the European Community through the TEMPUS project JEP 4667.

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