

Insect outbreak in relation to heavy metal deposition in the moss species

R. ŠOLTÉS

Research Coordination Centre, Tatra National Park,
059 60 Tatranská Lomnica, Slovakia

Abstract. In 1995, 3,746 hectare area of three north facing valleys was attacked by spruce bark beetle. Over the years 1986 - 1990, 112 moss samples were collected throughout the attacked area adjacent areas. To identify the most adverse agent for forests stands, results of chemical analyses (Pb, Cd, Cu, Zn, Cr, Fe, Mn, Mo) have been submitted to multivariate analyses. Pattern of heavy metal accumulation in attacked area have been compared to the pattern of heavy metal accumulation in not attacked area.

The following trends have been revealed:

- Disproportion between increasing concentration of Cr and the other elements.
- Increase of Mo in the tissues of moss samples collected on the southern slopes.
- Increase in Cd and Cr concentrations in the samples collected inside the insect outbreak area.

Key words: Insect outbreak, bryophytes, heavy metal deposition.

Introduction

In 1995, in some valleys of the Tatra National Park (Slovakia) a large scale insect outbreak occurred, caused by Spruce Bark Beetle (*Ips typographus*). During the years 1986 - 1990, moss samples were collected throughout the territory of the Tatra National Park in order to assess the environmental danger coming from heavy metal deposition. In 1990, we identified the most polluted area. Not surprisingly, its core was formed by the spruce stands attacked by insect. We particularly examined the way of metal accumulation in the mosses inside the attacked stands, and tried to identify the most adverse agent.

Study sites

The study site is located between 49° 11' - 49° 17' N and between 20° 11' - 20° 13' E at altitude of 1,000 - 1,700 m a.s.l. In accordance with its location in a transitional zone between oceanic and continental climates, polar oceanic air masses from the northwest are dominant. The climate of this area is cold, this is characterized by mean July temperatures, below 16° C. The annual rainfall is about 1,900 mm, with 70% of precipitation occurring

in the summer.

Material and methods

Three north facing valleys of 3,746 hectares in all, have been attacked by insect. Inside this area, 38 moss samples had been collected from five to nine years ago. Pattern of heavy metal accumulation in attacked area have been compared to pattern of heavy metal accumulation in not attacked area. To achieve the goal, an adjacent area (of about 4,500 hectares) where no attacks occurred were considered. In this area, 74 moss samples have been collected.

Further details on the sampling plots are mentioned in an interior research report (Šoltés *et al.*, 1990) and can be given on request.

The following moss species were used as bioindicators: *Bazzania trilobata* (L.) S. Gray, *Ptilidium pulcherrimum* (G. Web.) Vain., *Andreaea nivalis* Hook., *Aulacomnium palustre* (Hedw.) Schwaegr., *Dicranum scoparium* Hedw., *Hygrohypnum duriusculum* (De Not) Jameson, *Hylocomium splendens* (Hedw.) B.S.G., *Leucobryum glaucum* (Hedw.) Aongstr., *Mnium spinosum* (Voit) Schwaegr., *Polytrichum formosum* Hedw., *P. commune* Hedw., *P. juniperinum* Hedw., *P. strictum* Brid., *Sphagnum girgensohnii* Russow, *Sph. quinquefarium* (Lindb. ex Braithw.) Warnst., *Sph. capillifolium* (Ehrh.) Hedw., *Sph. centrale* C. Jens., *Sph. compactum* Dc., *Sph. russowii* Warnst., *Sph. recurvum* P. Beauv., *Plagiomnium affine* (Bland. ex Funck) T. Kop., *Paraleucobryum longifolium* (Hedw.) Loeske, *Pleurozium schreberi* (Brid.) Mitt., *Ptilium crista-castrensis* (Hedw.) De Not., *Rhytidiadelphus triquetrus* (Hedw.) Warnst., *Sanionia uncinata* (Hedw.) Loeske.

The majority of samples were collected from fairly open stands in forest ecosystems, the priority being given to sites of 60 - 70% canopy closure. Exceptionally, unless impossible in deep forests, sampling sites were more sheltered. The Tatra Mountains have a dense cover of trees.

Accumulation patterns in different habitats, selective input and increase of concentration of some elements with rising altitude have been shown in a previous paper (Šoltés 1992).

Chemical analyses

The following 8 heavy metals were determined: Pb, Cd, Cu, Zn, Cr, Fe, Mn, Mo. Elemental analysis was carried out in the Geoecological Laboratory Centre in Turčianske Teplice. The rough crushing was carried out on equip-

ment made from titanium steel, eliminating secondary contamination. The fine homogenization was carried out in an agitator. After ashing (450°C, 300 min.), the ash was digested in 20 ml 6 M HCl, the digest was gently evaporated dry. The evaporatiom residue was dissolved in 40 ml 0.2 M HCl, filtered hot and the filtrates brought to a volume of 100 ml with 0.2 M HCl. The chemical analysis for Mn, Cu, Zn, Pb, Cr and Cd was performed by atomic absorption spectrophotometry (Varian, Modell 1475). Deuterium background correction was applied in order to correct broad band absorption. Standards in 1 - 20 mg/kg range were prepared daily. The detection limit, defined as three times the background noise, was 2 mg/l for Mn, 3 mg/l for Cu, 1 mg/l for Zn, 10 mg/l for Pb, 6 mg/l for Cr and 2 mg/l for Cd. The repeatability of the measurements was at least 98% for every element. The conditions of determination were as follows (for Mn, Cu, Zn, Pb, Cr and Cd respectively): Wavelength (nm)= 279.5, 324.8, 213.9, 217.0, 357.9, 228.0; spectral band width (nm)=0.2, 0.5, 1.0, 1.0, 0.2, 0.5; lamp current (mA)= 5.0, 4.0, 5.0, 5.0, 7.0, 4.0; atomization temperature 2,125°C. An oxidizing flame was used for the atomization of each metal except chromium, in this case reducing flame was used. Iron was determined using the photometry method with sulphosalicylic acid (device SPECOL 11).

Statistical analysis

Principal component analysis has been used for the analysis of the structure of multivariate observation of heavy metal concentrations in sensu Nishida *et al.* (1985). We used a covariance matrix because the eigenvector PC1 extracted from such a covariance matrix describes relative changes in the increasing characters (Jolicouer 1963a). We used logarithmic transformation of data

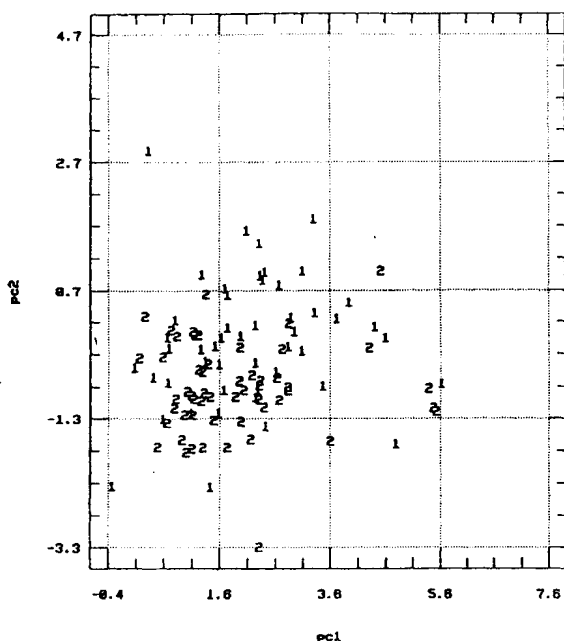


Fig. 1 Principal component scores of the first and second component derived from covariance matrix of metal measurements in mosses. (1) south aspect, (2) north aspect.

which leads in itself to make covariance matrix independent from magnitude and scaling (Jolicouer 1963b). The results of chemical analysis were sorted into groups with respect to sampling site. The differences between groups were identified with one-way analysis of variance (ANOVA) of the component scores (Somers 1986).

Results

112 moss samples were collected in Studená dolina, Skalnatá dolina (Rocky Valley), Dolina Bielej vody kežmarskej (White Water Valley), Belanian Tatra Mts. and Scepusian Magura Hills. Concentrations of metals in the samples were analysed by PCA. Then, the PC-scores were compared according to the following categories:

- A- samples collected outside the insect outbreak area (1),
samples collected inside the insect outbreak area (2).
- B - samples collected on the south slopes (1),
samples collected on the north slopes (2).

Component weights for eight original variables are shown in Table 1.

	PC1	PC2	PC3	PC4	PC5
Variance (%)	38.1	19.4	19.1	8.8	6.1
Pb	0.066	0.146	0.191	0.037	0.773
Cd	-0.492	0.397	0.682	-0.286	-0.149
Cu	0.019	0.166	0.052	0.030	-0.144
Zn	-0.068	0.109	0.148	0.195	-0.004
Cr	0.804	-0.015	0.454	-0.018	-0.283
Fe	0.261	0.166	0.166	0.055	0.488
Mn	0.012	0.122	0.229	0.915	-0.165
Mo	0.182	0.859	-0.433	-0.049	-0.111

Table 1. Component weights for eight original variables.

Discussion

The majority of component weights, except for Cd and Zn, in PC1 show positive values indicating mainly Cr increase at the sites of insect outbreak. We may call the component PC1 as the increasing trend of Cr versus Cd. About 38% of the total variance was explained by this first trend. Thus in applications of PC analysis, the first principal component was acceptable as an "increasing" vector.

One-way ANOVA identified significant separation ($P=0.0001$) on principal component 2 between samples collected on south and north slopes. This trend is attributed to Mo (Table 1). Thus, the second important trend (PC2) shows increase of Mo in the tissues of moss samples collected on the south slopes. About 19% of the total variance is explained by this second trend. The second principal component, indicating different accumulation pattern determined by exposition may be accepted as an "aspective" vector. Principal component scores of the first and second component derived from the covariance matrix of metal measurements in mosses collected at different slopes are shown in Fig. 1. Mean values of PC2-scores displaying different accumulation trends in Mo are shown in Fig. 2.

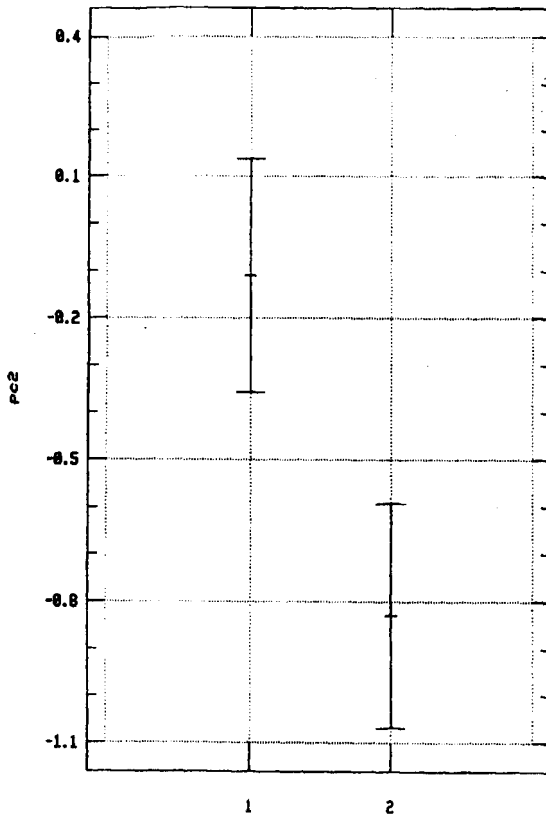


Fig. 2. Mean values of PC2-scores displaying different accumulation levels of Mo in the mosses growing on southern (1), or (2) northern slopes (95% confidence intervals for factor means).

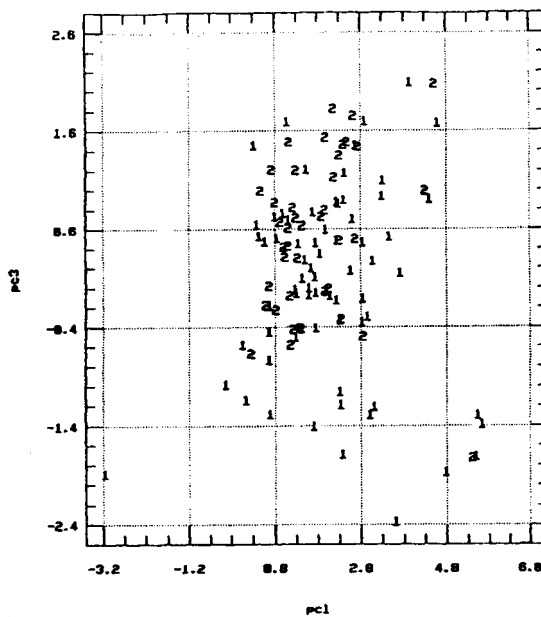


Fig. 3. Principal component scores of the first and third component derived from covariance matrix of metal measurements in mosses collected outside (1) and inside (2) the insect outbreak area.

On principal component 3, one-way ANOVA revealed statistically significant separation ($P=0.0045$) mainly in Cd (less Cr) concentrations (Table 1). The third important trend in PC3 is an increase in Cd and Cr concentrations in samples collected inside insect break area. This trend explains about 19% of the total variance and may be grasped as a "disaster" vector. Principal component scores of the first and third components derived from covariance matrix of metal measurements in the mosses collected outside and inside the insect outbreak area, are shown in Fig. 3. Mean values of PC3-scores, displaying different accumulation levels of Cd and Cr in mosses, are shown in Fig. 4.

From the point of view of forestry, this third trend is of the highest importance. Accumulation of Cd and Cr found in mosses in the spruce stands in 1990 correlated to the five-year later fell down caused by insect outbreak. We are aware of the fact that Cd and Cr accumulation is not the only reason of insect disaster. Nevertheless, it works together with other influences such as acid rain, SO_2 , ozone etc. and their synergic effect make forest stands weakened and prone to insect infection. It was known that heavy metal accumulation has an adverse effect on sanitary state of forest stands, but this research revealed a statistically significant relation between increase in Cd and Cr concentrations and insect breakout.

The obvious increase of Cd and Cr in the insect breakout area could be put down to various factors. Cd is released from combustion Diesel-engines, the highway to Poland passes nearby around. Cr is air-borne from long-distance sources situated in Slovakia and in neighbouring countries as well. It would be strongly tempting to assert that the combination of increased concentrations of Cd - Cr is possibly triggering this problem in conjunction with other synergic factors - acid

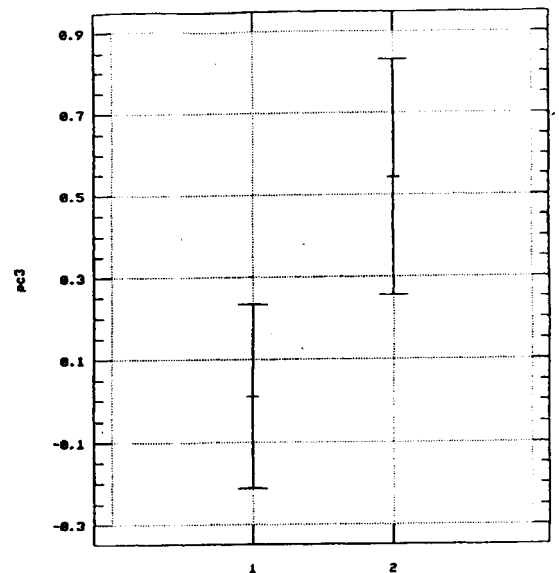


Fig. 4 Mean values of scores in PC3 displaying different accumulation levels of Cd and Cr in mosses collected outside (1), and inside (2) the insect outbreak area (95% confidence intervals for factor means).

rain, sulphur dioxide, ozone etc., but certainly it would be useful to focus attention to solve this puzzle.

References

- Jolicouer, P. 1963a: The multivariate generalization of the allometry equation. *Biometrics*, **19**: 497-499.
- Jolicouer, P. 1963b: Bilateral symmetry and asymmetry in limb bones of *Marthes americana* and man. *Revue Canadienne de Biologie*, **22**: 403 - 432.
- Nishida, T., Hayashi Y., Hashiguchi T. and Nansjaer S.S. 1985: Morphological identification and distribution of jungle fowls in Indonesia. *Japanese Journal of Zoototechnical Science*, **56**: 598 - 610.
- Somers, K.M., 1986: Multivariate allometry and removal of size with principal component analysis. *Systematic Zoology*, **35**: 359 - 368.
- Šoltés, R., 1992: Heavy metal concentrations in the mosses of the Tatra Mountains (Czecho-Slovakia): Multivariate analysis. *Oecologia Montana*, **1**: 31 - 36.
- Šoltés R., Šoltésová A., Kyselová Z. 1990: Immission influence upon non-forest vegetation of the Tatra National Park. *Final report of the research project*, mscr. Library of the Tatra National Park, Tatranská Lomnica.

Received 10 June 1996; revised 22 July 1996; accepted 19 August 1996.