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Short communication

State of Carabid assemblages in forest ecosystem previously affected by high levels of heavy metals Cu and Pb

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Abstract

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Human activities in industrial areas have released into the atmosphere solids of different nature, including heavy metals. The center of the Spiš region belongs to the foremost polluted areas in Slovakia. The Copper Smelting Plant Krompachy contaminated surrounding areas around this town by metals mainly by copper and lead. Despite significant improvement of environmental situation in the 1990s, resistant pollutant load from the mentioned pollution source continues to negatively impact on the surrounding countryside. The residual pollutant load has persisted for more than 20 years. Species diversity and cumulative abundance of Carabids in all stands in the contaminated environment was extremely low due to synergic effect of three factors, acidity of substrate, southern exposition and discontinuity of the vegetation coverage that resulted in forming of two assemblages. The open stands were inhabited by heliophilous species of genera *Cicindela*, *Harpalus* and *Microlestes*. The characteristic forest species did not occur there or penetrated here only rarely. In the closed stand, only three mesohygrohilous forest species *Carabus violaceus*, *Carabus hortensis* and *Pterostichus oblongopunctatus* were recorded.

Key words

Carabids, contamination, forest ecosystems, heavy metals, soil

The worst polluted areas affected by air pollutants in Slovakia include also the center of Spiš region, where the largest exhalation resources have comprised metallurgical and mining-processing units of iron mines (Želba) in Rudňany town and the Copper Smelting Plant Krompachy (Banásová and Lackovičová, 2004; Hronec et al., 2008; Takáč et al., 2008). In the vicinity of these resources increased concentrations of all heavy metals (HM) except for Mn (Lackovičová et al., 1994; Hančuľák et al., 2006) were found.

Increased concentrations of risk elements in forest ecosystems deteriorated the health state of forest tree species and other ecosystem components. This critical situation was not improved even after the closure of the plant in Rudňany town in 1993.

The effect of residual components of elevated concentrations of HM on ecosystems in the central Spiš region was studied after elimination or a significant reduction of emissions from those exhalation sources (Hronec and Szabová, 1995; Konôpka and Paulenka, 1996; Konôpka et al., 1997). After 10 years, the heavy metals contamination in the soil around Rudňany was not noticeable reduced (Machava, 2002, 2003).

Environmental pollution has diverse effects on different living organisms, including insects. It relates also to the ground beetles (*Coleoptera, Carabidae*) closely

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bound to the litter and ground surface. Some of the especially important chemical and physical properties of the soil which might exert an influence on the distribution of Carabids include humidity, shadowing by vegetation, pH value, calcium content, and pollutant load. Carabids can be considered as bioindicators of human practices, including pollution sensitive species (Basedow, 1990). Environmental change can cause different kinds of effect in the indicator species.

Increase or decrease of species number or abundance might be caused directly by changes in abiotic and/or biotic factors (Blake et al., 1996). Carabids represent a component of the ground-dwelling fauna strongly linked to soil characteristics. They are a well-studied group, frequently discussed in studies concerning the effects of environmental changes (Avgin and Luff, 2010).

Carabids play an important role in trophic chains, nutrition cycling and energy flow. They contribute to maintaining balance and stability of ecosystems. Anthropogenic actions lead to changes in soil properties, and are reflected by changes species diversity and abundance of individual species. Literary reviews of soil organisms lay emphasis on bioindicative ability of *Carabidae* in various forest habitats differently changed by human actions (Ranio and Niemela, 2003; Avgin and Luff, 2010; Koivula, 2011).

In this work the environmental situation on the research plot of Dubie was investigated after the 20-year period after the ceasing of high pollutant load. The total concentrations of heavy metals were determined and the occurrence of Carabids was observed in the studied environment strongly affected by high levels of Cu and Pb.

In April 2014, A open, B and C partly-open and D closed habitats close to the top of Dubie hill (around 562 m asl) near Krompachy town were established. The stands are located north of emission source of the Copper Smelting Plant Krompachy, at a distance of 1 km, at the relative altitude 180 m above the pollutants source, located just below the top hill on a southerly exposed slope with a 5% inclination. The herbaceous cover is formed mainly by *Calamagrostis epigeios* (a generating wooden vegetation of about 20 years old; A), *Pleurozium schreberi*, *Vaccinium vitis–idaea, Calamagrostis epigeios* and *Vaccinium myrtillus* (only herbs and shrub floor; B and C), *Acetosella vulgaris*, *Vaccinium myrtillus*, *Milium effusum, Luzula luzuloides* and *Convallaria majalis* (a forest habitat of 80 years old, D).

Six pitfall traps were installed in all sites at distances of 10 m. This number of traps is considered to be sufficient to record about 70% of species living in a habitat (Obrtel, 1971; Niemelä et. al., 1990). On the stand D, traps placement respected the patchy structure of vegetation. The traps were exposed from 1st April to 30th June and from 1st July to 23rd September in 2014. The species were identified by the keys by Hůrka (1996) and Trautner and Geigenmueler (1987). The data on species ecology were taken from Burmeister (1939) and Lindroth (1949).

In the autumn 2014, two soil profiles were dug up on the stands A and D, from which soil samples were taken to determine the actual elevated concentrations of heavy metals (Cu and Pb). Soil samples were collected from individual horizons of the prepared soil profiles (Societas pedologica Slovaca, 2014), dried at a laboratory temperature, ground, sieved through a sieve of 2 mm mesh to prepare a fine earth. The basic pedologic characteristics of the soil were measured. Soil pH was determined by a potentiometric method using the multifunction equipment 340i WTW. Total contents Cu and Pb were determined by atomic absorption spectroscopy using the GBC SensAA spectrometer. Prior to elements determination, soil samples were processed – 0.5 g of fine earth was digested with 5 ml of concentrated HNO_3, p.a. in the microwave oven Speedwave MWS-2, co. Berghof. The cumulative abundance of Carabid species and concentrations of Cu and Pb were evaluated by Pearson correlation coefficient *r* using the statistical package SPSS. An independent variable has a certain relationship with dependent variables when coefficient *r* is greater than 0.3.

The concentrations of Cu and Pb on the open stand A in the soil pit 1 were extremely high. Total Cu levels recorded in Oh and Ao horizons were around 1,900 mg kg^{-1} (Fig. 1), which was approximately 30 times higher than the limit value for very acid Cambisol. Concentrations of Pb in Oh and A horizons have exceeded the limit value more than 13 times.

Cu and Pb concentrations in Ol horizon in the second soil pit excavated in the closed stand D were comparable with those of the first soil pit (Fig. 1). However, the levels of both elements in the A horizon were higher about 1,000 mg kg^{-1}, which is a clear evidence of the higher previous pollutant load. This place was more influenced by the west-eastern wind flow and that is why higher levels of examined elements were found in the soil there. Soil pH values fluctuated between 4.33 (Bv1) to 4.49 (A), only the Oh horizon was acidic (pH = 4.74). This acidic environment resulted in higher mobility of extremely high Cu and Pb contents which negatively influenced the behaviour of Carabidae and massively reduced their abundance. No significant correlation was observed between the cumulative abundance of Carabids and total Cu and Pb concentration in the soil.

In all studied stands 52 individuals of Carabids belonging to 10 species were recorded. In individual stands, number of species ranged from 3 to 6, while number of individuals from 5 to 21. All catches from June were 2–5-times richer than those from September (Fig 2.). The strongest decline of number of individuals, to about on half or third of the values recorded in June, was observed especially in *Cicindela sylvicola*. The observed decline in number of individuals corresponds with the typical course of seasonal dynamics of Carabids that always culminates approximately in June to July and considerably declines in August and September (Novák 1973; Thiele 1977). In the most

abundant *Cicindela sylvicola* the decline of number of individuals in September also might result from the rainy weather in that month that inhibited activity of this heliophilous species.

In spite of very low number of species and individuals, the community structure perfectly reflects the state of the canopy in each stand and its distance from sites with closer canopy and less insolated and dried soil surface. Thus, in the larger open site A only the heliophilous species (*Cicindela sylvicola, Cicindela germanica* and *Harpalus luteicornis*) were recorded.

Among them the all *Cicindela* species even require discontinuous herbage vegetation for their enormous flight activity. In the stand B forming a strip between two closed patches of wooden vegetation, only the heliophilous species form the catch from June, while a typical forest species *Pterostichus oblongopunctatus* co-occurred there in September, when the humidity and temperature gradient between the open and closer stand was not so steep. In the less open stand C, the heliophilous species (*Cicindela sylvicola*, *Cicindela campestris, Harpalus luteicornis* and the xerophilous species *Microlestes minutulus*) still predominated, but out of *Pterostichus oblongopunctatus* the community was enriched by further forests species *Carabus hortensis* in the June sample. Unlike the open or half-open stands, in the almost completely closed stand D there only three mesohygrophilous forests species occurred such as *Carabus hortensis, Carabus violaceus* and *Pterostichus oblongopunctatus* being accompanied by the eurytopic *Notiophilus biguttatus* in the sample from September. The same relationship is also illustrated by representation of flying species that are mostly characteristic for open habitats or for disintegrated forests and by wingless, non-flying species predominating in closed continuous forests.

The highest species diversity was observed in the open or partly open stands (A, B and C), where well-flying predatory tiger-beetles *Cicindela germanica, Cicindela sylvicola* and *Cicindela campestris* predominated. Their characteristic habitats are open landscape with discontinuous herbage vegetation or in *Cicindela sylvicola* also sparse well insolated forests (Hůrka, 1996). They were accompanied by *Harpalus*

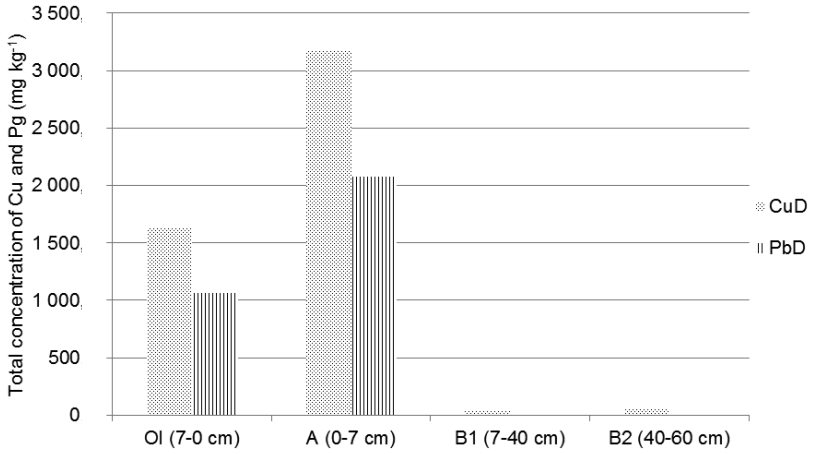

Fig. 1. Total concentrations of Cu and Pb in the stand D (forested area).

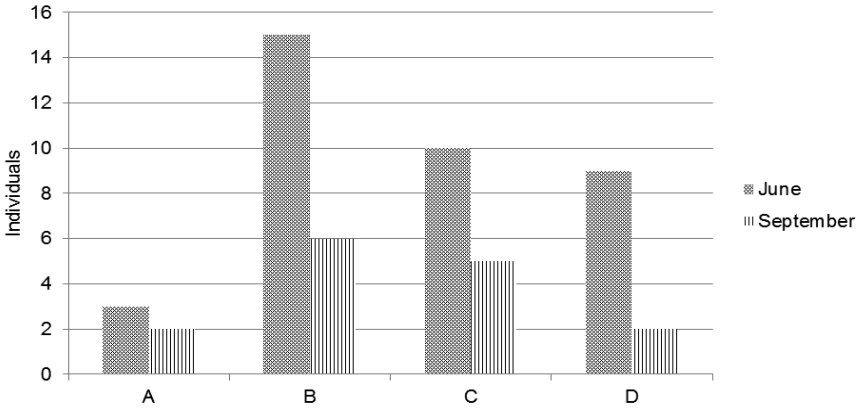

Fig. 2. Cumulative abundance of Carabids in June (J) and September (S) in four study sites A–D

luteicornis and *Harpalus affinis* representing characteristic component of faunal of arable land, meadows. All these species are well flying, are able to migrate on large distances and easily occupy the new sites, even in the city centers (Šustek, 1999).

The results obtained illustrate the procedure of gradual species turnover, which flexibly follows the ecological state of the habitat segments and the subsequent changes in them. On an ecologically clean meadow habitat, there at least 10–12 species of Carabids should be found (Koivula, 2011), but usually the number of species exceeds 40–60 (Louda 1973; Obertel 1968), more than on our investigated stand.

The results serve as an example that anthropogenic deterioration of environment can lead not only to serious damaging of plant and animal communities, but can simultaneously create conditions for highly specialized and even rare species like tiger-beetles in this case.

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