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The freezing scree slopes and their arachnofauna

Blockhalden mit Frostvorkommen und ihre Spinnenfauna

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Abstract: All cases of spider communities studied in freezing scree slopes (block fields) in the Czech Republic are summarized and evaluated.

Ice can form at the lower margin of aerated talus slopes under two crucial conditions: (1) cold air flows downslope through stone accumulation and (2) affects lower margin for a longer time. Cold air can affect the lower margin of a talus for a longer time in these cases: A – the talus is sufficiently high and deep, so that the amount of accumulated cold air is sufficient for cooling the lower margin for the whole spring, B – the outflow of cold air is stopped by an opposite valley slope, C – cold air accumulates in a terrain depression, and D – cold air is closed within the talus by vegetation cover.

The maximal biological effect of the ice forming in boulder accumulations, i.e. the broadest offer of food and space niches for cold-adapted invertebrate species, manifests in the narrow strip of moss and lichen vegetation at the lower margin of the north oriented scree slopes. The occurrence of cold-adapted spider species and their high abundance in such habitats is documented.

Keywords: block fields, microclimate, ice formation, spiders

Kurzfassung: Alle Vorkommen von Spinnengemeinschaften auf Blockhalden mit Eis in der tschechischen Republik wurden zusammengefaßt und evaluiert.

Am Fuß von durchlüfteten Blockhalden kann sich unter zwei entscheidenden Bedingungen Eis bilden: (1) Kaltluft fließt durch die Gesteinspackung hangabwärts und (2) wirkt längere Zeit auf den Haldenfuß ein. In folgenden Fällen kann Kaltluft auf die Hangfüße längere Zeit einwirken: A – die Blockhalde ist ausreichend hoch und so mächtig gepackt, daß die Summe der akkumulierten Kaltluft ausreicht, den Hangfuß im Verlauf des gesamten Frühjahrs zu kühlen, B – das Ausströmen der Kaltluft wird durch einen gegenüberliegenden Talhang gestoppt, C – die Kaltluft sammelt sich in einer Geländemulde an, und D – die Kaltluft wird in der Halde durch die Vegetationsdecke eingeschlossen.

Die maximalen biologischen Effekte des in den Blockhalden befindlichen Eises werden in dem schmalen Streifen der Moos- und Flechtenvegetation am Hangfuß dieser nordexponierten Hänge erkennbar: ein breites Angebot an Nahrung sowie Lebensräume für kälteadaptierte Invertebraten. Das Auftreten kälteadaptierter Spinnenarten und ihre hohe Abundanz in diesen Habitaten werden dokumentiert.

Schlagworte: Blockhalden, Mikroklima, Spinnen, Eisbildung

1. Introduction

Within the talus slope, two microclimatic gradients play an ecological role encompassing internal spaces where air movements occur (RUZICKA et al. 1995). The first is a gradient between the exposed scree surface, with large daily and annual temperature fluctuations, and the sheltered internal space of the scree, where daily temperature changes are absent and annual temperature fluctuations are small.

A phenomen known in climatology as slope wind, which is based on the difference in specific gravity of air of various temperatures, causes the air to move within boulder accumulations (GEIGER 1966) and form the second gradient. The air trapped among the boulders is isolated by the surface air-and-boulder layer and forms within the accumulation a relatively autonomous microclimate (MOLENDA 1996). During winter, when the temperature of the inner environment is higher than the temperature of the surrounding, warm air flows upslope and can leave the talus in a form of vapour. During the spring and summer, when the temperature of the inner environment is lower than the temperature of the surrounding, cold air flows downslope. In the spring, when the temperature of the air is below the freezing point, the flowing water (from rain or melting snow) can form ice. The temperature point of the change in the air current is determined by the equilibrium of temperatures within the talus and outer space; the direction of air current changes obviously at a temperature of about 9 °C. Small changes in air current direction are caused by daily temperature changes and by wind during the transition period in the spring and autumn (MAREŠ 1959, KUBÁT 1971, VÁNE 1992). The temperature on the lower margin of the freezing talus never exceeds 7 °C, yet the inner space of the upper margin does not freeze at all during the winter.

2. Methods

The invertebrates were trapped in desk pitfall traps made of rigid plastic. They consist of a cylinder (about 13 cm high and 10.5 cm in diameter) and a desk fitting to the upper opening of the cylinder. The traps contained a mixture of 7 % formaldehyde and 10 % glycerol with a few drops of a surfactant (RÙZICKA 1982, 1988b). The traps within the scree were exposed for one year, the surface ones were emptied approximately at monthly intervals. Hand-picking was also applied as a supplementary method. The preserved catch was then processed in the laboratory.

3. Case studies

All cases of spider communities studied in freezing scree slopes in the Czech Republic are summarized and evaluated.

3.1. Kamenec hill

The northern slope of the Kamenec hill is situated above the Ploucnice river in the North Bohemia. The basalt scree accumulation at an elevation of about 330-360 m a.s.l. has an extension of ca. 100 x 100 m and is built by basalt stones about 30 cm in size on average. Ice forms at lower margin and in a terrain depression in the middle of the slope. We observed the ice among stones during spring months and even on 3rd September 1997; the inner space of the accumulation contains surely the permafrost core. 26 traps were positioned here from June 1993 to July 1995, predominantly on the surface with some of them located within the scree. The traps were located on transects between the lower and the upper margin of the debris field (RÙZICKA & HAJER 1996).

A total of 751 spider specimens belonging to 100 species were collected. Pronounced dependence on the microclimatic conditions in the various parts of the scree slope was observed. Northern species *Bathyphantes simillimus* (L. KOCH, 1879) (15 specimens), *Diplocentria bidentata* (EMERTON, 1882) (18 specimens) and *Latithorax faustus* (O.P.-CAMBRIDGE, 1900) (1 specimen) and montane species *Lepthyphantes tripartitus* MILLER & SVATON, 1978 (41 specimens) were collected exclusively in the traps situated in the places with ice formation. The upper border of the occurrence of these species lies only 10 metres above the scree slope foot.

3.2. Nadeje Ice Cave

The whole northern slope of the Suchý Vrch hill in the Luzické Hory Mountains is covered by phonolite boulders. Under the top, at an elevation of 620 m a.s.l., is a bare boulder accumulation, the slope is grown with a scree forest. At an elevation of 580 m a.s.l. is a pseudokarst ice cave, a vertical fissure in the copact phonolite, 1-2 m wide, 6 m deep and 30 m long. The ceiling of the cave is formed by stone blocks which are part of the block accumulation. This is the only cave in the Czech Republic where ice persists all the year round (MALIK 1998). 12 traps were positioned within bare and forested scree and in the cave from June 1993 to July 1994.

A total of 52 specimens belonging to 19 species were collected. One specimen of *Bathyphantes simillimus* was found in the cave.

3.3. Ceské Stredohorí Protected Landscape Area

Basalt scree field, exposed to the west, lies at 330-400 m a.s.l. in the valley above the village of Brná, near Ústí nad Labem in North Bohemia. It is about 70 m in length and in breadth. Four traps were laid at the upper margin, four in the middle and four at the lower margin of the scree field from May 1991 to May 1992 (RÙZICKA et al. 1995).

A total of 97 spider specimens belonging to 28 species were collected. The species *Lepthyphantes tripartitus* was observed across the entire profile between the surface and the depth of one metre at the lower margin of the scree slope.

3.4. Krivoklátsko Biosphere Reserve

The scree slope is located on the north slope of the Berounka River Valley, near the village of Branov (about 50 km west of Prague), 270 m a.s.l. This scree field is about 50 m wide and 20 m high. It consists of andesite stones about 10 cm in size on average. The lower half of the debris is covered by a thick layer of vegetation formed by moss and montane *Saxifraga rosacea* MOENCH. Four traps were set up on the lower margin of the

scree slope from May 1994 to May 1995. The spaces between the stones were filled with ice on the date of installing and on the date of removing the traps.

A total of 54 spider specimens belonging to six species were collected. *Lepthyphantes tripartitus* (41 specimens) was the most numerous.

3.5. Broumovsko Protected Landscape Area

Massive layers of Upper Cretaceous block sandstones jut out in Northeastern Bohemia, in the Bohemian Cretaceous Basin. Extensive systems of underground cavities accessible to man has evolved in the block accumulations in the Broumovsko Protected Landscape Area. The size of the blocks exceeds 10 m, the thickness of the soil-free block layer can attain 15 m. Ice filling appears every year in the Teplická Jeskyne and Pod Luciferem caves, both formed in the block accumulation situated at canyon bottoms. The spiders were collected by pitfall traps through 1990-1993 period (RUZICKA & KOPECKÝ 1994).

A total of 66 spider specimens, belonging to 16 species, were collected. *Bathyphantes simillimus* (17 specimens) and *Lepthyphantes tripartitus* (11 specimens) were found to be the most numerous. *Diplocentria bidentata* (38 specimens) was found in the rich moss polsters at the opening into the underground system of Teplická Jeskyne cave (RÙZICKA 1992).

3.6. Moravian Karst Protected Landscape Area

Blansko-Skalní Mlýn is situated about 25 km north of Brno. The scree field is about 50 m wide and 30 m high, consists of limestone stones about 20 cm in size on average. It is situated on the north-west slope of the Punkva River Valley, 350 m a.s.l. The upper part of the field is bare, the lower third (in which the ice formation was observed) is overgrown with mixed forest, while the transition zone between forest and bare debris is overgrown by moss. Six traps were positioned in various places from May 1993 to May 1994.

A total of 46 determinable spider specimens belonging to 11 species were collected with pitfall traps and by hand-picking. *Lepthyphantes tripartitus* occurs in the moss zone and on the lower margin, where ice forms during the spring.

3.7. Podyjí National Park

Some three km to the SE of the town Vranov nad Dyjí the river Dyje forms a meander bypassing a spur called "Ledové Sluje", which means "ice caves". The whole massif consists of heavily creviced orthogneiss. In its upper part the meander spur is rimmed by steep rock walls under which there stretches a ditch-like depression covered by broken rock blocks. Down the slope, gravitational motion of blocks of the creviced rock massif has given rise to a system of crevice-type caves, lying as deep as tens of metres. In some of them ice forms and persists till summer. Below this region of ice caves, a bare block field about 100 m long and 100 m broad lies on the northwestern slope. The blocks, which constitute a stony debris formation, are on average 250 cm in size. Appreciable cold air movement was observed under the blocks at the lower margin of the debris, but ice formation was not observed. Spiders were collected in 1992-1994 by hand picking and by using pitfall traps (RÙZICKA 1996).

A total of 268 spider individuals belonging to 76 species were collected. *Porrhomma egeria* SIMON, 1884 was to be found numerous in the places of ice formation in the depth of about 10 metres. Some psychrophilous species (e.g. *Agyneta conigera* (O. P.-CAMBRIDGE, 1863)) were found at the lower margin of the block debris.

4. Results and discussion

4.1. Subterranean ice formation

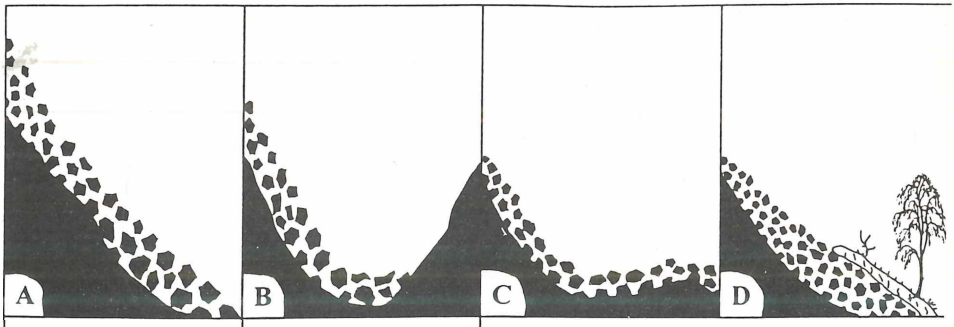
The formation and persistence of ice is based on two main conditions: (1) cold air must flow downslope through the accumulation in the lower part and (2) must affect there for a longer time.

1. The air movement among stones is influenced by several factors:

a. Slope angel. The greater slope angel, the greater predisposition for the rising of slope wind. MOLENDA (1996) gives 25° as the minimal necessary slope angel.

b. The height of scree field. The higher the scree field, the greater the air volume and increased possibility for air current. BRABEC (1973) gives 20 m as the minimal height required for a scree field.
c. The stone size. The soil, the sand, and/or the fine gravel represent very dense environment for air movement. According to our observations, air can move and ice can form in stone accumulations built by stones with diameter of only 10 cm (the case 3.4.). Scree slopes built by stones about 25-50 cm in size represent the most suitable environment for air movement and ice formation. The large spaces among big blocks make the air movement possible, but the blocks represent simultaneously the obstacle for air movement. Ice can form in the accumulations of big rock blocks under special conditions (the case 3.5.).
d. The shape of boulders. The closer the stone is to a sphere, the lower the environmental resistance. Numerous aerated tali arise in accumulations of basalt boulders, consisting from more or less isodiametric boulders. In an opposit, ice forming is not so obvious in accumulations built from desk phonolite stones; random accumulation of these boulders shows great resistance for air moving.

2. Air moves in numerous accumulations, but it does not affect them for a long time at the lower margin; if the boulders are not supercooled, ice is not formed. If the scree field is not sufficiently high, a small volume of cold air flows through the lower margin without effect. The lower margin is colder than the upper margin, but ice does not form. In accumulations built from big blocks, air flows quickly through great interspaces out of the accumulation; ice formation was not observed in slope accumultions of big blocks (the block accumulation in the case 3.7.).



Dynamic system	Semi-dynamic system	Dynamic systems with a static lower part	
Independent on orientation			Prevailingly on northern slopes
Formed by abiotic factors			Formed by abiotic and biotic factors

Figure 1. Four model types of the freezing scree slopes. A The scree slope is sufficiently hig B The scree slope is situtated in a valley, C The scree slope is situtated in a depre sion, D The lower part of the scree slope is overgrown with vegetation.

Ice can form on the lower margin of scree fields under various conditions. Four types freezing scree slopes are described (fig. 1). Concrete cases can represent a combinatic of these model types.

a. If the scree field is adequately high and deep, the reserve of cold air, which flows dow through the lower margin, can be sufficient for cooling the space and the formation ar persistance of ice for the entire spring. This is an example of most of the freezing ta described by KUBÁT (1971) in Ceské Stredohorí Mts. in North Bohemia (the case 3.

and partly 3.1.). In the case of a smaller-volume scree field, ice can form only if the outflowing cold air is stopped at the lower margin.

b. If the scree field is situated on a valley slope, the outflow of cold air is stopped by the opposite valley slope, and then by the boulders along the whole valley bottom. Night cooling in a valley supports cooling of the lower margin of a scree field (the case 3.5.).

c. Concave slope forms can be formed by various slope denudation processes (DEMEK et al. 1975). These depressions can be filled with boulders and bordered by a stony mound. A lake of cold air develops within accumulated boulders in these karoide depressions (the depression in the middle of the slope on Kamenec hill, the case 3.1.). MAREŠ (1959) and LOZEK (1972) describe these situations from Ceské Stredohorí Mts.

d. The lower margin of some scree slope can be overgrown with a layer of moss and lichens. This vegetation cover can partly or entirely enclose the space on the lower margin and form a pouch, in which cold air is closed. Cold air can cool the lower margin of the scree field for a long time (the case 3.4., partly the case 3.1.). Shrubs and trees can grow on the lower margin of a scree field during the succession of plant communities. The taller vegetation contributes to the lower temperature by shadowing the slope (the case 3.6.). In both these cases, ice-cold air escapes only from several small openings in the slope, which is continuously covered by vegetation. The great importance of insulating layer of vegetation and detritus, which forms over several years, is documented by the melting of ice caused by destruction of this insulating layer during building activities (ŠPALEK 1935, CHRISTIAN 1993) or prospecting for new underground spaces (LHOTSKÝ 1960).

The stony debris fields are situated on slopes of all orientations (KRÁL 1966) in the Ceské Stredohorí Mts. Freezing tali can be found on any of these slopes (KUBÁT 1971, BRABEC 1973). However, due to the demands of the initial moss communities on high humidity and shadowy environment, the fourth type of freezing talus is more likely to occur on slopes with a northern orientation.

The principle of cold-air currents in freezing aerated tali is the same, as in the case of ice caves. However, we cannot distinguish between univocal dynamic and static systems (OEDL 1923, GEIGER 1966). The whole system of aerated and freezing tali must be dynamic, but the outflow of cold air is restricted in the model type B, and it is more or less static in the lower part in the model types C and D.

4.2. Spiders

Northern species *Bathyphantes simillimus* occurs in Central Europe exclusively in boulder accumulations and in sandstone rocks (RÙZICKA 1992). Under the tree line, it occurs in the depth among the stones, its surface occurrence was recorded only at the lower margin of freezing scree slope at the Kamenec hill (the case 3.1.).

Northern species *Diplocentria bidentata* has only been found four times in the Czech Republic: at an altitute of 900 m in moss at the lower edge of the block scree slope in the Vydra river valley in the Šumava Mts., and in lower altitudes exclusively at lower margins of freezing scree slopes with moss cover – at Kamenec hill (the case 3.1.), near Teplická Jeskyne cave (the case 3.5.) and on the Plešivec hill in the Ceské Stredohorí Proteced Landscape Area (BUCHAR 1989).

Mountain species *Lepthyphantes tripartituts* was observed repeatedly at the lower margins of the scree fields in both, surface and inner spaces in numerous cases. This species occurs in scree field in Krkonoše Mts. at an altitude of 1.350 m (RUZICKA & ZACHARDA 1994). Under the tree line, it occurs exclusively at lower margins of freezing scree slopes.

The ice forms prevailingly in the depth of boulder accumulations. We can observe it personally in the accumulations of big blocks only, in pseudokarst ice caves. These extensive inner spaces form essential part of the entire system of aerated talus, but they are inhospitable for the invertebrates, they offer very limited food sources, as it is good known from the karst caves. Deep spaces in boulder accumulations can host only specialised species *Porrhomma egeria*, which is adapted to the life in the deep underground and inhabit all deep underground spaces in the Europe. RUZICKA (1996) documented the decreasing biomass and species diversity of the spiders with increasing depth of spaces

in the bare block scree slope and in the pseudokarst caves in Podyjí National Park (the case 3.7.). If we compare from this viewpoint our data about spiders from the freezing scree slopes, this dependence is more significant. On the gradient between the surface and the inner environment of the scree talus, the spider activity and the species richness reach its highest values on the surface with vegetation cover (fig. 2). The narrow strip of moss vegetation on the surface of the lower margin of freezing scree slopes (especially of scree slopes of model type D) represent the most suitable habitat for cold-adapted invertebrates. The moss and lichen polsters (which can be built by zonal vegetation, but which contain in several cases some northern or mountain elements) situated in the stream of outflowing cold air represent the habitat resembling the conditions in the alpine zone or in the arctic tundra.

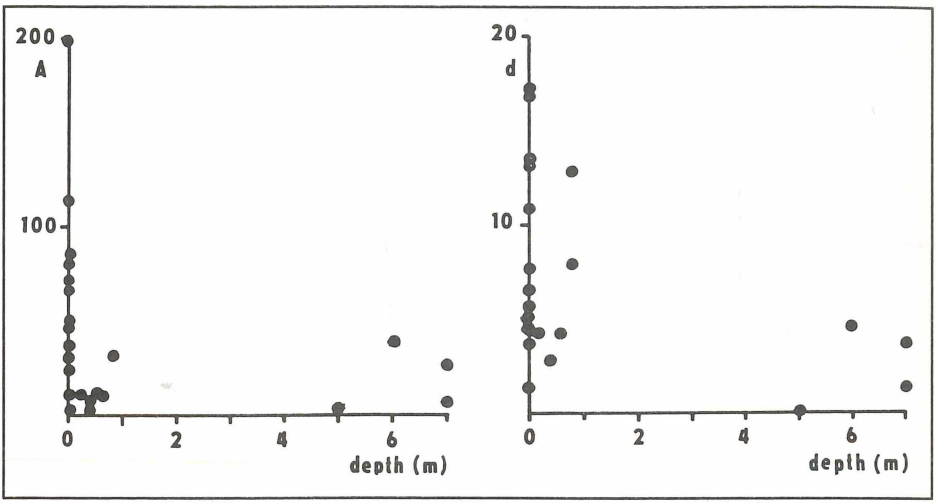


Figure 2. The spider activity (specimens/m/year) and the species richness (d = S^{-1}/ln N) in the dependence on the depth of spaces in freezing scree slopes. The activity according to RÙZICKA (1988a). S the species number, N the specimens number.

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