Arachnol. Mitt. 14:40-50 Basel, Dezember 1997

# Changes in epigeic spider community in primary succession on a brown-coal dump

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**Abstract: Changes in epigeic spider community in primary succession on a brown-coal dump.** A descriptive model of primary succession of spiders on a brown-coal dump i presented. Multivariate methods (cluster analysis and detrended correspondence analysis) and community indexes were applied to evaluate changes in community composition o epigeic spiders. Two different rehabilitation age stages were investigated. The cluste analysis helped to determine a case of horizontal asynchronous succession. The DCA wa able to distinguish divergent trends of succession from the initial stage. Successional trend in species replacements were observed. In all aspects of succession there was found to b directional towards a „ruderal steppe" subclimax.

**Key words:** Primary succession, spiders, mine dump, diversity, ordination, cluster analysis Slovakia

## INTRODUCTION

Consideration of ecological succession has attracted ecologists for almost a hundred years. In recent decades, more and more attention has been paid to newly formed or disturbed sites resulting from human activity (e.g. MAJER 1990). Mining, particularly for coal, is one of the most disturbing human activities in central Europe. The side product of mining activity is dumped on huge dumps which can dominate the landscape. In Bohemia, for instance, there are about 200 km$^2$ of such sites (PRACH 1987). These areas have to be restored, therefore monitoring of community development is necessary.

The succession of many taxa has been studied on mine dumps in Europe. Most frequently studied groups were the plants (e.g. PRACH 1987), followed by beetles (e.g. VOGEL & DUNGER 1991), soil invertebrates (e.g. DUNGER 1991), vertebrates (e.g. BEJČEK 1983) and also spiders (e.g. BROEN & MORITZ 1965). Consequently, a number of models describing succession have been proposed (LEPŠ 1988). Descriptive models have been most frequently used for a description of succession of terrestrial invertebrates (e.g. HEJKAL 1985, DUNGER 1991).

The aim of this paper is to present the results of succession of spiders on a mine dump in Slovakia.

## MATERIAL AND METHODS

The brown-coal (lignite) dump, operated by the deep mining company Baňa Nováky, is situated in the district of town Nováky (middle Slovakian region). The local altitude is 272 m a.s.l. The average annual temperature was 9.4°C in 1990, and 9.9°C in 1992, and the annual precipitation was 591 mm in 1990, and 629 mm in 1992 (Prievidza Meteorological station). The dump consists of tuff (65%), clays (25%), lignite coal (5%) and dark coal slate (5%).

Older stage: 22- years old. The shape of the main dump is conical, with the top part cut away. The top of the dump (0.78 ha) is 30 m above the ground, and was abandoned in 1968. Since then, a reclamation in late seventies was carried out, resulting in the planting of *Betula pendula* R. trees on S and W slopes. Except the birches, several individuals of *Populus nigra* L., *P. tremula* L., *Pinus sylvestris* L. and *Salix caprea* L. were naturally established. The trees attained no more than 4 m in height. Six types of sites (O1, ... O6) were recognized, here, according to the habitat-structure and location (the description of the vegetation-structure is not precise):

O1 - a site on W margin of the dump, trees: *P. sylvestris, B. pendula* - 5%, weeds: *Calamagrostis epigejos* (L.)R. - 70%, *Tanacetum vulgare* L., *Orobanche lutea* B., *Epilobium collinum* G., *Crepis setosa* H., *Trifolium arvense* L., *Melilotus officinalis* (L.)P. - altogether 5%, ground: mosses and lichens (*Cladonia fimbriata* (L.)Fr.) - 20%

O2 - a site on S margin, without trees, weeds: *C. epigejos* - 85%, *T. vulgare* and others as in O1 - 10%, ground: barren - 5%

O3 - a site on E margin, trees: *P. nigra*, *P. tremula* and *S. caprea* - 30%, weeds: *Tussilago farfara* L. - 5%, *C. epigejos* - 5%, ground: barren with leaf litter - 60%

O4 - a site on N margin, trees: *P. nigra*, *S. caprea* - 50%, weeds: *T. farfara* -15%, *C. epigejos* - 5%, ground: barren with leaf litter - 20%, mosses and lichens - 10%

O5 - a site in N center, trees: *P. nigra*, *S. caprea*, *P. tremula*, *P. sylvestris* - 20%, weeds: *T. farfara* - 20%, *C. epigejos* - 10%, ground: barren with leaf litter - 20%, mosses and lichens - 30%

O6 - a site in S center, trees: *P. sylvestris* - 10%, weeds: *C. epigejos* - 40% ground: barren with leaf litter - 10%, mosses and lichens - 40%

Initial stage: 2- years old. Smaller conical dump arising on the side of the main dump. The top part (0.35 ha) was abandoned in 1990. Withou reclamation, there were no trees. Two types of sites (I1, I2) were recognised here (the description of the vegetation-structure is not precise):

I1 - a site close to the older stage, weeds: *C. epigejos* - 70%, *T. vulgare* - 10%, *Asperula arvensis* L. - 5%, *Apera spica-venti* (L.)B. - 5% ground: barren - 10 %

I2 - a site on margin far from the older stage, weeds: *C. epigejos* - 30 % *T. vulgare* -10 %, *A. arvensis* - 10%, ground: barren - 50%

The study was performed separately in two years: the older stage in 1990 while the initial stage in 1992. As field-work had to be restricted to one fixed day a month, pitfall traps (plastic cups of 0.2 l volume, ∅ 7 cm, formaldehyde fluid) were used. The traps were placed in lines (10 m apart) and were emptied monthly, from March to October. On each site 6 traps were set out. The data, i.e. summed annual capture taken from 6 traps on each site, were transformed into percentage values before the agglomerative hierarchical classification (cluster analysis) by the complete linkage rule. The dissimilarity between classes was measured as Euclidean distance. Detrended correspondence analysis (DCA) was used for ordination of species (HILL 1979). The Chi-square test ($\chi^2$) was used to determine preference for a stage. Diversity was calculated using the Shannon-Weaver index (ODUM 1977), eveness according to PIELOU (1966).

## RESULTS

Two main clusters were separated by cluster analysis (Fig. 1) revealing that sites O1 and O2 are more closely related to the initial stage sites (I1, I2) than to the rest of O sites. Further hierarchical levels show subdivision into groups: O3+O4+O5+O6, O1+O2 and I1+I2. Within O3..6 group, O3 is the most markedly separated, while O4 and O5 are grouped close together. According to the distance matrix I1 is more closely related to O1 and O2 than

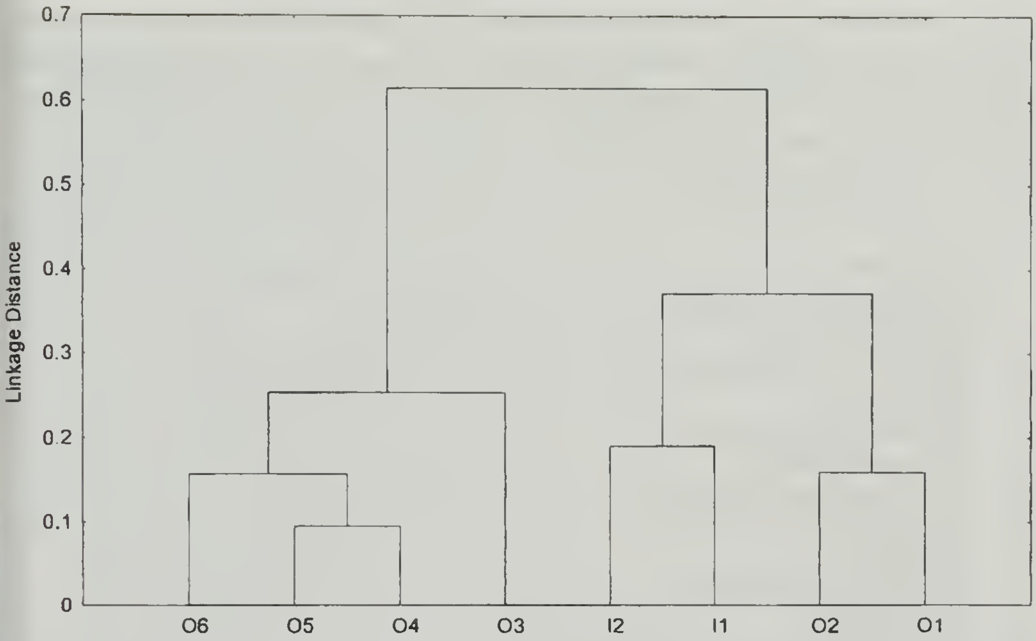

Fig. 1: Tree diagram of the sites derived from spider species composition.

2, and O4+5 are less distinct from O1 than from O2. The results of the luster analysis suggest to consider three distinct groups: I1+2, O1+2 and 3..6.

A comparison of captures (Tab. 1) show that higher annual capture per ap was recorded in initial sites of rehabilitation (34 inds. on an average) an in all O sites (27 inds. on an average in O1+2 and O3..6). Similarly, a tle higher number of species was obtained from sites of the initial stage an from sites of the older stage. Consequently, higher diversity and veness indexes were obtained for the initial sites than for the older ones. roup O1+2 was found to have a higher diversity and eveness than O3..6.

## pecies preference

ata on annual abundance (Tab. 1) of species were processed by DCA ig. 2). Obtained eigenvalues ($\lambda$) measure the separation of species along dination axes (HILL 1979). Axis 1 ($\lambda_1 = 0.511$) distinguishes species ccording to the age of habitats. On the right side, at length 1.0 and more ere are species that occurred exclusively in the initial stage, namely: *odarion rubidum* (5), *Xysticus kochi* (24), *Oedothorax apicatus* (6),

Tab.1: Review of spiders collected on all sites of the mining dump (the numbers are summed annual captures), annual total of individuals per site (annual capture from 6 traps), total of species, Shannon-Weaver Index o diversity ($H_s$) and evenness (E).

| code | species and family status | I1 | I2 | O1 | O2 | O3 | O4 | O5 | O6 |
|---|---|---|---|---|---|---|---|---|---|
| | **Pholcidae** | | | | | | | | |
| 4 | *Pholcus opilionides* (Schr.) | | | 2 | | | | 1 | |
| | **Dysderidae** | | | | | | | | |
| 64 | *Harpactea rubicunda* (C.L.K.) | 1 | | 10 | 3 | 3 | 1 | | 2 |
| | **Zodariidae** | | | | | | | | |
| 5 | *Zodarion rubidum* Simon | 16 | 11 | 1 | 1 | 1 | | | |
| | **Tetragnathidae** | | | | | | | | |
| 25 | *Pachygnatha degeeri* Sund. | 38 | 12 | | | | | | |
| 55 | *Tetragnatha pinicola* L.K. | 1 | | | 1 | | | | |
| | **Araneidae** | | | | | | | | |
| 19 | *Mangora acalypha* (Walck.) | 1 | | | | | | | |
| | **Linyphiidae** | | | | | | | | |
| 16 | *Centromerita bicolor* (Black.) | 1 | | | | | | | |
| 30 | *Centromerus sylvaticus* (Black.) | | | | 1 | | | | |
| 13 | *Dicymbium nigrum* (Black.) | | 1 | | | | | | |
| 38 | *Diplostyla concolor* (Wider) | | | 2 | | 1 | 1 | | |
| 22 | *Erigone atra* (Black.) | 1 | | | | | | | |
| 23 | *Erigone dentipalpis* (Wider) | 5 | 3 | | | | | | |
| 28 | *Microlinyphia pusilla* (Sund.) | | | | | 1 | | | |
| 56 | *Meioneta rurestris* (C.L.K.) | 6 | 1 | 3 | 2 | | | 1 | |
| 57 | *Mioxena blanda* (Simon) | 1 | | | | | 1 | | |
| 8 | *Micrargus subaequalis* (West.) | | | 1 | 1 | 1 | | 1 | |
| 58 | *Ostearius melanopygius* (O.P.-C.) | 1 | | | | | | | 1 |
| 6 | *Oedothorax apicatus* (Black.) | 9 | 4 | | 1 | | | | |
| 14 | *Pocadicnemis pumila* (Black.) | | 1 | | | | | | |
| 26 | *Porrhomma microphthalmum* (O.P.-C.) | 6 | 5 | | | | | | |
| 2 | *Walckenaeria capito* (West.) | | | | 1 | 2 | 2 | | 1 |
| | **Theridiidae** | | | | | | | | |
| 21 | *Enoplognatha thoracica* (Hahn) | 3 | | | | | | | |
| 17 | *Robertus arundineti* (O.P.-C.) | 13 | 16 | | | | | | |
| 18 | *Robertus neglectus* (O.P.-C.) | 2 | | | | | | | |
| | **Lycosidae** | | | | | | | | |
| 49 | *Alopecosa cuneata* (Clerck) | | | | | | 2 | | |
| 39 | *Alopecosa pulverulenta* (Clerck) | | | 10 | 11 | 7 | | 6 | 2 |
| 37 | *Aulonia albimana* (Walck.) | 1 | 2 | 11 | 1 | 1 | | | 4 |
| 12 | *Pardosa agrestis* (West.) | 4 | 7 | | | | | | |
| 54 | *Pardosa hortensis* (Thor.) | 1 | | | | 1 | | | |
| 62 | *Pardosa pullata* (Clerck) | 1 | 6 | | | | | | 2 |
| 15 | *Pirata latitans* (Black.) | | 1 | | | | | | |
| 44 | *Trochosa ruricola* (Degeer) | 5 | 2 | 15 | 4 | 6 | 15 | 15 | 14 |
| 45 | *Xerolycosa miniata* (C.L.K.) | 47 | 16 | 65 | 28 | 80 | 68 | 86 | 159 |
| 42 | *Xerolycosa nemoralis* (West.) | 3 | 2 | 14 | 4 | 4 | 8 | 3 | 13 |

| code | species and family status | I1 | I2 | O1 | O2 | O3 | O4 | O5 | O6 |
|---|---|---|---|---|---|---|---|---|---|
| | **Agelenidae** | | | | | | | | |
| 48 | *Cicurina cicur* (Fab.) | | 1 | 1 | 3 | | | | 1 |
| 61 | *Tegenaria agrestis* (Walck.) | 4 | 1 | 1 | | | | | |
| | **Hahniidae** | | | | | | | | |
| 32 | *Hahnia nava* (Black.) | | | | 1 | | | | |
| | **Dictynidae** | | | | | | | | |
| 59 | *Argenna subnigra* (O.P.-C.) | 6 | 5 | 2 | 1 | 1 | 1 | 3 | |
| | **Clubionidae** | | | | | | | | |
| 46 | *Cheiracanthium virescens* (Sund.) | | | | | 2 | 1 | | |
| 7 | *Clubiona compta* C.L.K. | | | 1 | | 1 | | 1 | |
| | **Gnaphosidae** | | | | | | | | |
| 9 | *Callilepis nocturna* (L.) | | | 2 | 4 | 2 | 2 | | |
| 50 | *Drassodes lapidosus* (Walck.) | 1 | 2 | | 3 | 3 | 1 | 2 | 1 |
| 40 | *Drassodes pubescens* (Thor.) | 1 | | 7 | | 2 | 3 | | 4 |
| 47 | *Haplodrassus signifer* (C.L.K.) | 4 | 3 | 10 | 13 | 1 | | 5 | 4 |
| 34 | *Micaria fulgens* (Walck.) | | | 5 | | | | 1 | |
| 60 | *Zelotes aeneus* (Simon) | 14 | 19 | 4 | 5 | 4 | 1 | 4 | |
| 52 | *Zelotes pusillus* (C.L.K.) | 4 | | 3 | 1 | 1 | | 2 | |
| 51 | *Zelotes villicus* (Thor.) | 1 | 1 | | 6 | | | | 2 |
| | **Zoridae** | | | | | | | | |
| 43 | *Zora spinimana* (Sund.) | | | | 2 | | 1 | | |
| | **Philodromidae** | | | | | | | | |
| 33 | *Tibellus oblongus* (Walck.) | | | 1 | | | | | |
| | **Thomisidae** | | | | | | | | |
| 4 | *Xysticus kochi* Thor. | 26 | 46 | | | 1 | | 1 | 1 |
| | **Salticidae** | | | | | | | | |
| 0 | *Bianor aurocinctus* (Ohlert) | 1 | | 1 | | | | | |
| 1 | *Chalcoscirtus pseudoinfimus* Ovtsh. | 1 | | 1 | | | | | |
| 1 | *Euophrys frontalis* (Walck.) | 3 | 4 | 29 | 13 | 31 | 10 | 14 | 14 |
| 11 | *Heliophanus auratus* C.L.K. | | | | 1 | | | | |
| 7 | *Heliophanus cupreus* (Walck.) | | | | | 1 | | | |
| 0 | *Marpissa nivoyi* (Luc.) | 1 | | | | | | | |
| 6 | *Neon reticulatus* (Black.) | | | 1 | 1 | | | | |
| 3 | *Phlegra fasciata* (Hahn) | | | 2 | 1 | | 2 | | 1 |
| 9 | *Salticus scenicus* (Cerck.) | | | | | 1 | | | |
| 3 | *Sitticus penicilatus* (Simon) | 1 | 1 | | 2 | 1 | | | |
| | *Synageles venator* (Luc.) | | | | | 1 | | | 1 |
| | *Talavera aequipes* (O.P.-C.) | | | 1 | | 1 | | | |
| 5 | *Talavera thorelli* (Kulcz.) | | | 1 | 1 | | | | |
| | annual total of individuals / site | 235 | 173 | 207 | 117 | 162 | 120 | 146 | 227 |
| | total of species / site | 37 | 26 | 29 | 29 | 29 | 17 | 16 | 18 |
| | $H_s$ | 1.225 | 1.132 | 1.093 | 0.875 | 0.856 | 0.718 | 0.694 | 0.566 |
| | E | 0.781 | 0.800 | 0.747 | 0.598 | 0.585 | 0.583 | 0.576 | 0.451 |

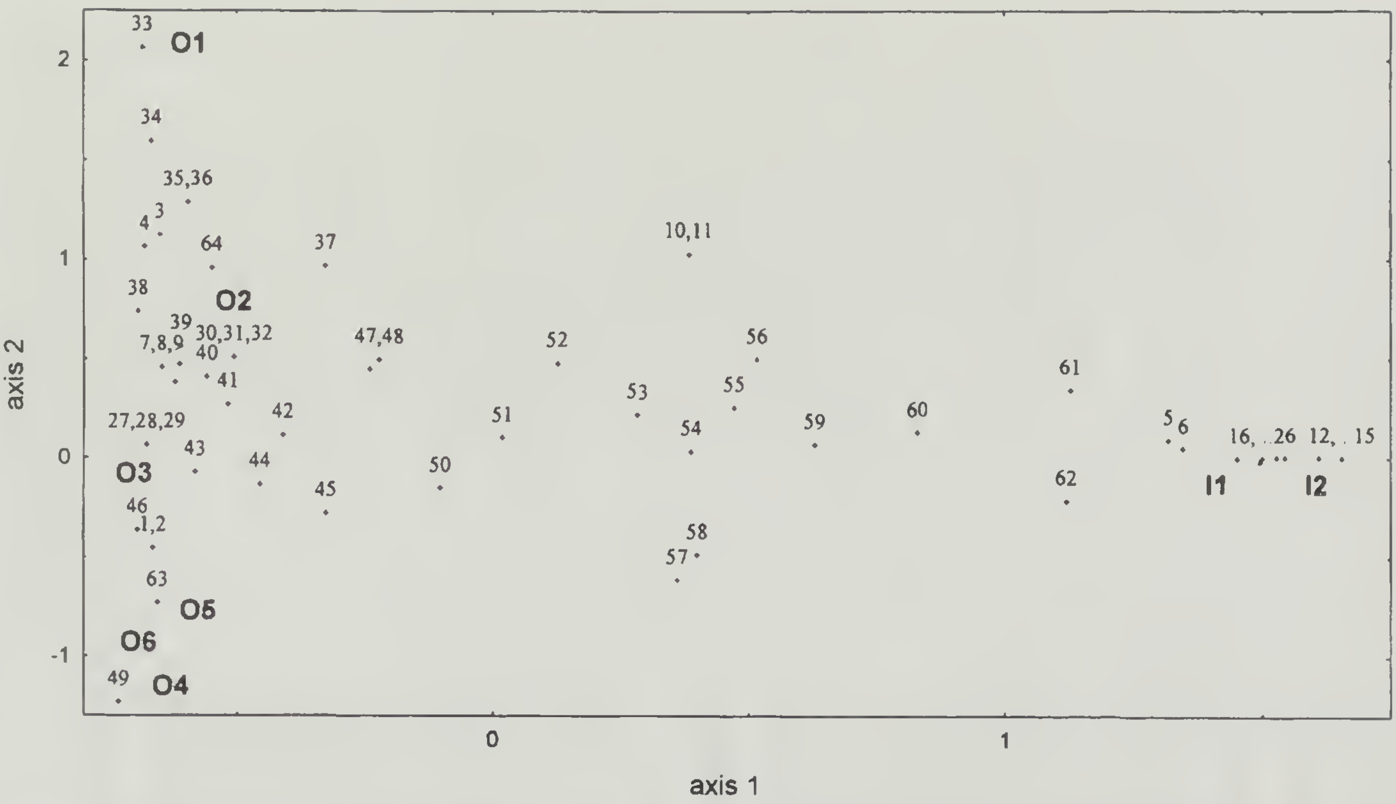

Fig. 2: Ordination of sites and spiders. 1- *S. venator*, 2- *W. capito*, 3- *T. aequipes*, 4- *P. opilionoides*, 5- *Z. rubidum*, 6- *O. apicatus*, 7- *C. compta*, 8- *M. subaequalis*, 9- *C. nocturna*, 10- *B. aurocinctus*, 11- *C. pseudoinfimus*, 12- *P. agrestis*, 13- *D. nigrum*, , 14- *P. pumila*, 15- *P. latitans*, 16- *C. bicolor*, 17- *R. arundineti*, 18- *R. neglectus*, 19- *M. acalypha*, 20- *M. nivoyi*, 21- *E. thoracica*, 22- *E. atra*, 23- *E. dentipalpis*, 24- *X. kochi*, 25- *P. degeeri*, 26- *P. microphthalmum*, 27- *H. cupreus*, 28- *M. pusilla*, 29- *S. scenicus*, 30- *C. sylvaticus*, 31- *H. auratus*, 32- *H. nava*, 33- *T. oblongus*, 34- *M. fulgens*, 35- *T. thorelli*, 36- *N. reticulatus*, 37- *A. albimana*, 38- *D. concolor*, 39- *A. pulverulenta*, 40- *D. pubescens*, 41- *E. frontalis*, 42- *X. nemoralis*, 43- *Z. spinimana*, 44- *T. ruricola*, 45- *X. miniata*, 46- *C. virescens*, 47- *H. signifer*, 48- *C. cicur*, 49- *A. cuneata*, 50- *D. lapidosus*, 51- *Z. villicus*, 52- *Z. pusillus*, 53- *S. penicilatus*, 54- *P. hortensis*, 55- *T. pinicola*, 56- *M. rurestris*, 57- *M. blanda*, 58- *O. melanopygius*, 59- *A. subnigra*, 60- *Z. aeneus*, 61- *T. agrestis*, 62- *P. pullata*, 63- *P. fasciata*, 64- *H. rubicunda*

*Pachygnatha degeeri* (25), *Erigone dentipalpis* (23), *Porrhomma microphthalmum* (26) and *Pardosa agrestis* (12). On the left, below -0.5 length, there are species recorded only in the older stage (O1..6). Axis 2 ($\lambda_2$ = 0.126) separates species of the older stage. Habitat structure seems to be the most likely environmental aspect of this axis. Above 1.0 length there are species present only in O1 and O2, namely: *Tibellus oblongus* (33), *Micaria fulgens* (34), *Talavera thorelli* (35), *Talavera aequipes* (3), *Pholcus opilionoides* (4), and below 0.3 length species characteristic of the O3..6 group: *Alopecosa cuneata* (49), *Phlegra fasciata* (63) and *Synageles venator* (1). The ordination diagram visualizes divergent trends in succession from the initial stage (I1+2) to older stage (O1+2 *versus* O3..6).

Species, displayed in the middle of the ordination diagram, occurred at different frequencies in all three groups and were tested for preference for a certain stage (Tab. 2). It was found that *Zelotes aeneus* was dominant in the initial stage but has decreased in abundance in both groups of the older stage ($\chi^2$=6.56, $p<0.05$). *Callilepis nocturna* ($\chi^{22}$=22.02, $p<0.05$) and *Haplodrassus signifer* ($\chi^2$=5.99, $p<0.10$), on the other hand, were eudominant in the O1+2 group. *Xerolycosa miniata* and *Euophrys frontalis* are characteristic for the O3..6 group. *Xerolycosa miniata* ($\chi^2$=24.02, $p<0.05$), the most abundant species in the initial stage was also eudominant in O1+2, and after 22 years of recovery it reached 60%. *E. frontalis* ($\chi^2$=8.45, $p<0.05$) showed parallel trend in the course of time.

Tab.2: Comparison of the dominance relations (%) of the principal species in the particular stages (as a proportion in total annual captures from 6 traps)

| | **I1+2** | **O1+2** | **O3..6** |
|---|---|---|---|
| *Zelotes aeneus* | 7.77 | 3.10 | 1.51 |
| *Callilepis nocturna* | 0.00 | 2.19 | 0.73 |
| *Haplodrassus signifer* | 1.28 | 7.97 | 1.45 |
| *Xerolycosa nemoralis* | 1.21 | 5.09 | 4.23 |
| *Euophrys frontalis* | 2.33 | 12.56 | 10.81 |
| *Xerolycosa miniata* | 19.28 | 27.67 | 58.75 |

## DISCUSSION

The composition of spiders on sites O1 and O2 was found to be more similar to that on the initial stage sites than to the composition of the rest of older stage sites. It seems that O1+2 group is an example of horizontal asynchronous succession, as PRACH (1987) speaks of sites of later phases where species of the initial stages re-appear. The disturbance, here, might have occurred a number of years ago, and caused these sites to develop into an anomaly uniform stage prefered by species of open habitat. Dense stands of *Calamagrostis epigejos* - a robust perennial plant that produce a considerable amount of hardly-degradable litter - competitively excludes other seedlings (PRACH 1988), e.g. inhibit invasion by deciduous trees. Similar inhibitory effects of *Acacia extensa* that resulted in uniform vegetation were recorded by MAWSON (1986) on Australian bauxite dumps. It is reasonable to expect that the sites O1and O2 will develop into an open steppe subclimax. Whereas the O3..6 sites are supposed to develop into a ruderal steppe-forest community.

The succession on the initial stage seems to be markedly influenced by the older stage, as the I1 site (i.e. closer to the older stage sites) is resembling the community of spiders as well as the vegetation-structure of the O1+2 group more than the I2 site which is far from the older stage.

According to the 'Intermediate Disturbance Hypothesis' (HUSTON 1979), maximum diversity is reached during the middle stages. In agreement with this hypothesis, PRACH (1987) found that maximum plant diversity was reached in about 10-15 years, which is identical to HEJKAL's (1985) findings for carabids. The latter also observed that maximum number of individuals was obtained from 6-year-old stage, while maximum species from 2-year-old stage, and both were lowest on 20-years old stage. VOGEL & DUNGER (1991) recorded maximum species richness of carabids and staphylinids around 3-4 years after rehabilitation. This is probably due to rehabilitation activities that hastened the succession. The diversity indexes as well as eveness in this study were found to be declining in order I1+2, O1+2 and O3..6. The results fit to the hypothesis, with the exception of the O1+2 group that is difficult to classify.

When comparing the vegetation-structure and the composition of spiders of the dump in Novaky with dumps in other regions, it should be stressed that the area undergoing succession in Novaky is markedly smaller than dumps in e.g. north-west Bohemia, or north Moravia. Therefore, the composition of species on the dump in Novaky is more influenced by surroundings. However, there are certain similarities /or differencies recognized.

Vegetation-structure is governed by climatic factors and each geographic region is therefore different e.g. vegetation of dumps in NW Bohemia (PRACH 1987). For example, in NW Bohemia *Calamagrostis epigejos* occurs after 10 years of succession together with *Arrhenatherum elatius* (L.). In this study *Calamagrostis epigejos* was recorded abundantly from the initial stage, while *Arrhenatherum elatius* was completely absent. However, in the age of 22 years the vegetation on dumps in both regions reach similar composition. As PRACH (1988) concludes this stage will probably last for a long time and may be considered an arrested successional stage (subclimax).

On the whole, composition of spiders is similar to those of mine dumps (of identical age) in north Moravia (MAJKUS 1988) or in Germany (BROEN & MORITZ 1965, MADER 1985). There are a few exceptions such as *Xerolycosa nemoralis* and *Zodarion germanicum* which are replaced in this dump by the thermophilous species *Xerolycosa miniata* and *Zodarion rubidum*. This suggests that despite the difference in the area and climatic conditions, the succession of spiders on mine dumps has a comparable trend.

It should not be overlooked that the succession of spiders is more efficiently described when bearing in mind species biology. For example, cover of mosses and lichens which accumulate water offer favourable conditions for hygrophilous species such as *Cicurina cicur*. Sites O1 and O2, on the other hand, are preferred by the jumping spider *Talavera thorelli* that lives on dead grass stems of *Calamagrostis epigejos*. The ant-eating spider *Zodarion rubidum* lives together with the ants *Myrmica sabuleti* Mein. and *Tetramorium caespitum* L.. These ants build their nests under bare ground or with a sparse grass cover, and therefore occurred more frequently on the initial stage sites.

It is difficult to state whether any of the succession models (CONNELL & SLATYER 1977) applied to the spider succession, since no interspecific interactions have been studied. However, from the dominance on the particular stages, it is concluded that two models - „facilitation“ and „tolerance“ - can be recognized. The latter may apply to *Xerolycosa miniata*, whereas „facilitation“ may apply to *Xysticus kochi*. „Inhibition“ was only determined for vegetation-structure, in case of *Calamagrostis epigejos* (see above). Inevitably, more detailed study of species interactions within succession of spiders is required.

**Acknowledgment:** I want to thank Prof. J.BUCHAR and Mgr. J.SVATOŇ for the assistance given in identifying spiders and advice during study. My thanks are also due to Dr M.STRAKOVÁ for identification of plants and Ing. J.LUTTMERDING for providing an information about the mining dump. At last but not least, I am very grateful to Dr. V.RŮŽIČKA and Dr. J.LEPŠ for comments on the manuscript, and Prof. J.D.MAJER also for some alterations to the English.

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Zeitschrift/Journal: Arachnologische Mitteilungen

Jahr/Year: 1997

Band/Volume: 14

Autor(en)/Author(s): Pekár Stanislav

Artikel/Article: Changes in epigeic spider community in primary succession on a brown-coal dump 40-50