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SPECIES DIVERSITY OF CARABIDAE (COLEOPTERA) IN DIFFERENT SUCCESSION STAGES OF A LIMESTONE QUARRY HÁDY (BRNO, CZECH REPUBLIC)

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Abstract

HULA, V., ŠŤASTNÁ, P.: *Species diversity of Carabidae (Coleoptera) in different succession stages of a limestone quarry Hády (Brno, Czech republic).* Acta univ. agric. et silvic. Mendel. Brun., 2010, LVIII, No. 4, pp. 57–64

Carabid beetle samples were obtained from pitfall traps at an abandoned quarry of a limestone massif Hády near Brno. The samples were collected each month between April and September in years 2007–2008. A total of 61 species were registered and represented by 2619 individuals. Similarity of individual areas was evaluated by using the Cluster analysis – the most significant similarity was found in reclaimed sites (99.87%) and control sites (90.52%). The difference in similarity between two observed years came out distinctively (F = 2.906; P = 0.0010). Three species (*Cylindera germanica, Licinus cassideus* and *Aptinus bombarda*) from the Red List of Invertebrate Animals of the Czech Republic and one species (*Cylindera germanica*) affected by the Order 395/1992 Sb. as amended by Decree 175/2006 Sb. were detected among the observed species. The reclaimed land and surrounding field areas left to natural succession were dominated by species of open habitats.

Carabidae, massif Hády, reclamation, limestone quarry, CCA

Nature of South Moravia is under a strong pressure from human activities; on the one hand, intensive exploitation (agriculture, mining, settlement, recreation), and on the other hand, complete absence of some traditional landscape shaping by some human activities (grazing, mowing, burning between ad.). From the perspective of nature conservation, it is obvious that we will be forced increasingly to think of the protection of previously marginalized habitats such as edges of the roads, quarries, or so-called brownfields.

Monitoring of various organisms of anthropogenic habitats is one of the very popular topics recently. It has turned out that these habitats are often very valuable. For example, in various (mainly limestone) quarries there are refugia for a wide range of thermophilic organisms – such as butterflies (Beneš et al., 2003), small mammals (Rathke & Bröring, 2005), Orthoptera (Wagner et al., 2005) or spiders (Tropek, 2007; Tropek & Konvička, 2008) – to be found. Of course, the species spectrum of organisms occupying the quarries is influenced by a variety of factors, such as the type of reclamation, the age of the quarry, geological substrate and habitats in the immediate vicinity. If we focus on Carabidae, this area appears as rather unexplored, and there are just a few data concerning similar grounds available. At present, about the best-known paper is by Tropek et al. (2008) who found that Carabidae respond positively to the reclamation of the quarry while the spiders, on the contrary, respond negatively. Further they showed that the most important species of spiders inhabit unreclaimed quarries or habitats in the immediate vicinity where ground beetles are significantly slower with their colonization. Their study was supported by later work (Tropek et al., 2010) where is it strongly demonstrated that carabids responses positively (from point of view of species richness and conservation value) on reclamation in contrary of other groups of invertebrates (orthopte-

roids, true bugs, leafhoppers, butterflies and moths, spiders, centipedes, millipedes, woodlice and harvestmens) and plants.

Carabidae are very often used as a bioindication group (Rainio & Niemelä, 2003; Farkač, 1994; Nenadál, 1993). Their advantage is a wide base of specialists, well-developed methodology for the collection and determination, a rich core of collections and literature and finally, a large number of species with different ecological requirements (over 500 species in the Czech Republic). The presented paper evaluates differences between species and quantitative representation of Carabidae of the limestone quarry at different succession and recultivation levels. It also assesses the suitability of Carabidae as a bioindicator group for very dry, anthropogenic habitats.

MATERIAL AND METHODS

In our study we examined epigeic fauna of Carabidae (Coleoptera) of the quarries at limestone massif Hády near Brno (Lesní lom – 49°13'24.662"N, 16°41'41.494"E). The samples from pitfall traps were collected at 8 habitats: 4 lines on quarry terraces without reclamation (two plots with spontaneous succession and two without vegetation), 2 lines on reclaimed areas and 2 lines in control areas in the vicinity.

For each area a line of three pitfall traps was installed. The pitfall traps were situated with 5 m distances. The samples were collected once a month from the beginning of April to the end of September 2007 and 2008. The beetles were fixed in 4% solution of formaldehyde with addition of adhesive. Later, the material was transferred into 70% solution of ethanol as a final fixation.

The beetles were sorted according to the individual systematic groups, specific identification which followed according to the monograph by Hůrka (1996). Nomenclature according Audisio & Taglianti (2009). Hůrka et al. (1996) divided the Carabid beetles into three groups (R, A and E) according to their ecological potence. The E group comprises eurytopic species showing no special requirements as for their environments. Such species inhabit anthropogenous landscape. The species of the A group comprise taxa inhabiting more or less natural habitats. The R group comprises taxa with the narrowest ecological potence, rare or endangered species accompanying natural, little influenced habitats.

For the processing of basic analysis, software package CANOCO (Ter Braak & Šmilauer, 1998) and software package Statistica 8.0 were used. We used CCA analyses for comparison of particular years. For evaluation of similarity among plots we used correlation tables. A Cluster analysis was done after standardisation of dataset by Statistica 8.0 tool.

Characteristics of the plots

Quarries, as well as natural rock outcrops, are characterized by the lack of moisture, humus and consequently the low coherence of herb cover. At the time of our research, the observed quarry was already without any mining or reclamation works for 7 years mining ceased in 1997, recultivation in 2000. This etage limestone quarry was founded for the purpose of extracting the cement raw materials.

Localities marked as RECLAMATION

Plot 1

This is a reclaimed area. Reclamation was carried out through a put up of tailings and consequential topsoil overlap. The entire area has been sown with grasses and herbs seed mixtures, with significant thrive of ruderal species (*Dactylis glomerata*, *Artemisia vulgaris*, *Melilotus* spp., *Astragalus glycyphyllos*) only. At the same time, the area was planted with young limes. However, most of them died due to a drought. The area is mowed annually. The entire area has been covered with an artificially created layer of organic detritus.

Plot 2

Reclamation area; the line stretches from black locust (*Robinia pseudacacia*) grove across the terrace. The line began in the coherent fescue underbrush (*Festuca* sp.) and terminated in uncovered soil with a vegetation of *Artemisia vulgaris* and *Rubus* sp. The entire area has been covered with an artificially created layer of organic detritus.

Localities marked as SPONTANEOUS PROCESS

Plot 3

Significantly sloping surface with incoherent vegetation of hazels (*Corylus avellana*) left to spontaneous succession. Vegetation in the undergrowth plain and incoherent consisting of some herbs and bramble (*Rubus* sp.). Backing consists of unsolid rubble with just a minimum content of soil. This area is located on the first quarry etage from above.

Plot 4

This area is located on the second terrace at the foot of the wall of the 1st terrace. It consisted of loose debris with a minimum amount of vegetation (only individual plants *Epilobium dodonaei*) partially covered with leaves casting from the nearby brushwood of *Salix caprea*. The pitfall traps were placed in a very loose weathered rock substrate.

Localities marked as WITHOUT VEGETATION

Plot 5

This area is located on the second terrace and the pitfall traps were placed in a coherent crushed limestone. The vegetation consisted of individual pine trees (*Pinus sylvestris*), birch (*Betula pendula*) and individual *Epilobium dodonaei* plants.

Plot 6

The Line of pitfall traps was placed on the first quarry terrace. The conditions were very similar to the previous location.

Localities marked as CONTROL BIOTOPE

Plot 7

This area was selected as a hypothetical reference – what would the area look like if there were no quarry. It was the thick black locust brushwood with an undergrowth of black elderberry (*Sambucus nigra*). In the summer, aspect nitrophytes and sciophytes (*Urtica dioica*, *Chelidonium majus*, *Elytrigia repens*, *Dactylis glomerata*) dominated.

Plot 8

The second reference plots. It was a bosque between abandoned fields. The pitfall traps were placed on the border between the bosque and xerothermic grass vegetation. The bosque consisted of sloe (*Prunus spinosa*), roses (*Rosa* sp.) and other species of shrubs.

RESULTS AND DISCUSSION

A total of 61 species of Carabid beetles were registered in the quarry represented by 2619 individuals (1981 individuals in 2007, 638 individuals in 2008). The most numerous in both years were: *Brachinus crepitans* – 1131 (2007), 38 (2008); *Pseudoophonus rufipes* 581 (2007), 184 (2008); *Abax parallelepipedus* 34 (2007), 91 (2008); *Harpalus rubripes* – 24 (2007), 15 (2008). From these values it is obvious how large was a difference between the years pursued. This difference is also confirmed by the CCA analysis (Ter Braak & Šmilauer, 1998) for the difference in years – the difference was highly significant (F = 2.906; P = 0.0010). Also Rainio & Niemelä (2003) encounter this trend (different numbers of trapped Carabid beetles in different years) in their work and point out that not every year the bioindication properties of the beetles can be used. The quantity of species is found high in comparison with, for example, agrocenoses (Skuhravý, 1959; Šťastná & Bezděk, 2001, 2002) or protected areas (Šustek, 1983, 1984).

Hůrka et al. (1996) distinguish three groups within Carabidae in relation to the ecological potence and habitat preference of the individual species. These characteristics are considered to be very precise and are often used. In our case, however, there was a situation which is not often being documented. On the most arid terraces of limestone quarries Carabidae thrive scarcely. The species spectrum in quarry was dominated by species of the group E. This group involves species occurring in a wide scale of habitats including secondary anthropogenous landscape and expansive taxa. Although the difference with the types of species of the group A was high (Tab. I). However, when taking into account the quantity of caught individuals this ratio clearly shows the benefit of the eurytopic ones. From the R-group species there were found exclusively on reclaimed plots and on control plots. According to Tropek et al. (2008, 2010), this situation is common for Carabid beetles.

The dominance evaluation followed according to Tischler (1965) discerning eudominant species (more than 10% representation), dominant (5–10% representation), subdominant (2–5% representation), recedent (1–2% representation) and subrecedent (less than 1% representation). The individual dominance classes representation in the observed plots is presented in Tab. II. For the following evaluation it is necessary to access the areas a little differently. Unfortunately, it has become clear that some parts of the quarries are not occupied by Carabid beetles. Such status has not been recorded neither by Tropek et al. (2008), nor other authors.

If we analyze the individual observed habitats we can see the different situations especially in the areas directly in the quarry (areas SPONTANEOUS PROCESS and WITHOUT VEGETATION). During the two years there was extremely low number of Carabid beetles in the area SPONTANEOUS PROCESS, three species of 4 individuals in total plus all species of the category of adaptable species (*Harpalus caspius roubali*, *Stomis pumicatus* and *Carabus ullrichii*). *Harpalus caspius roubali* is a macropterous species inhabiting arid habitats which it is capable to colonize relatively easy. In contrast, two other species found here (*S. pumicatus* and *C. ullrichii*) were the brachypterous ones where *S. pumicatus* pre-

I: *Bioindication values of Carabid beetles of all particular localities for both observation years*

	Year	Number of species	%			Number of specimens	%		
			A	R	E		A	R	E
Reclamation	2007	28	42.86	3.57	53.58	1244	2.01	0.32	97.67
Spontaneous process	2007	2	100	0	0	3	100	0	0
Without vegetation	2007	6	16.67	0	83.33	8	25	0	75
Control biotope	2007	20	50	5	45	726	17.49	3.58	78.93
Reclamation	2008	35	34.28	2.86	62.86	154	34.42	0.65	64.93
Spontaneous process	2008	1	100	0	0	1	100	0	0
Without vegetation	2008	8	50	0	50	27	51.85	0	48.15
Control biotope	2008	27	51.85	3.71	44.44	456	35.53	1.1	63.37

II: *The dominance evaluation followed according to Tischler (1965): orange – eudominant, blue – dominant, green – subdominant, yellow – recedent, grey – subrecedent*

Species	Reclamation	Spontaneous process	Without vegetation	Control biotope
Abax ovalis (Duftschmid, 1812)				0.42
Abax parallelepipedus (Piller & Mitterpacher, 1783)	0.43		33.33	9.13
Abax parallelus (Duftschmid, 1812)	0.14			0.51
Acupalpus meridianus (Linnaeus, 1761)			3.03	0.08
Amara aenea (De Geer, 1774)	0.07			
Amara aulica (Panzer, 1797)	0.57			
Amara consularis (Duftschmid, 1812)	0.07			
Amara convexior Stephens, 1828	0.14			
Amara curta Dejean, 1828	0.07			
Amara equestris (Duftschmid, 1812)	0.07		3.03	
Amara ovata (Fabricius, 1792)	0.14			0.08
Amara similata (Gyllenhal, 1810)	0.07			
Anchomenus dorsalis (Pontoppidan, 1763)	0.57		3.03	0.42
Aptinus bombarda (Illiger, 1800)				2.62
Badister bullatus (Schrank, 1798)	0.14			
Bembidion guttula (Fabricius, 1792)				0.08
Bembidion lampros (Herbst, 1784)	0.43			
Brachinus crepitans (Linnaeus, 1758)	83.37			0.08
Calathus fuscipes (Goeze, 1777)	1.43			0.68
Calathus melanocephalus (Linnaeus, 1758)				0.08
Callistus lunatus (Fabricius, 1775)	0.07			0.08
Carabus cancellatus Illiger, 1798	0.21		3.03	
Carabus glabratus Paykull, 1790	0.07			
Carabus granulatus Linnaeus, 1758	0.07			0.17
Carabus hortensis Linnaeus, 1758				0.76
Carabus intricatus Linnaeus, 1761	0.07			0.25
Carabus linnei Panzer, 1810				0.08
Carabus nemoralis O. F. Müller, 1764	0.07		3.03	2.96
Carabus ullrichii Germar, 1824	0.29	25		9.21
Carabus violaceus Linnaeus, 1758	0.43			0.42
Cicindela campestris Linnaeus, 1758	1.14			
Cicindela sylvicola Dejean in Latreille et Dejean, 1822	0.07			
Cylindera germanica (Linnaeus, 1758)	1.86			0.08
Elaphropus quadrisignatus (Duftschmid, 1812)			3.03	
Harpalus affinis (Schrank, 1781)	0.43			
Harpalus atratus Latreille, 1804				0.25
Harpalus caspius roubali Schauberger, 1928		25		0.08
Harpalus distiguendus (Duftschmid, 1812)				0.08
Harpalus honestus (Duftschmid, 1812)	0.43			
Harpalus luteicornis (Duftschmid, 1812)	0.07			
Harpalus modestus Dejean, 1829	0.07			
Harpalus rubripes (Duftschmid, 1812)	1.21		6.06	0.51
Harpalus rufipalpis Sturm, 1818	0.07			
Harpalus serripes (Quensel in Schönherr, 1806)	0.07			
Harpalus subcylindricus Dejean, 1829	0.07			
Harpalus tardus (Panzer, 1797)	0.29			
Leistus ferrugineus (Linnaeus, 1758)				0.08

Species	Reclamation	Spontaneous process	Without vegetation	Control biotope
Licinus cassideus (Fabricius, 1792)	0.29			
Licinus depressus (Paykull, 1790)	0.07			
Microlestes maurus (Sturm, 1827)	0.07			0.17
Ophonus azureus (Fabricius, 1775)	0.29			
Ophonus nitidulus Mannerheim, 1825				0.17
Ophonus puncticeps Stephens, 1828	0.14			
Ophonus rufibarbis (Fabricius, 1792)				0.08
Ophonus rupicola (Sturm, 1818)	0.14			
Poecilus cupreus (Linnaeus, 1758)	0.79		9.09	0.25
Pseudoophonus griseus (Panzer, 1797)	0.14		15.15	9.47
Semiophonus signaticornis (Duftschmid, 1812)	0.14			
Pseudoophonus rufipes (De Geer, 1774)	3.07		18.18	60.52
Stomis pumicatus (Panzer, 1796)		50		
Zabrus tenebrioides (Goeze, 1777)	0.07			0.08

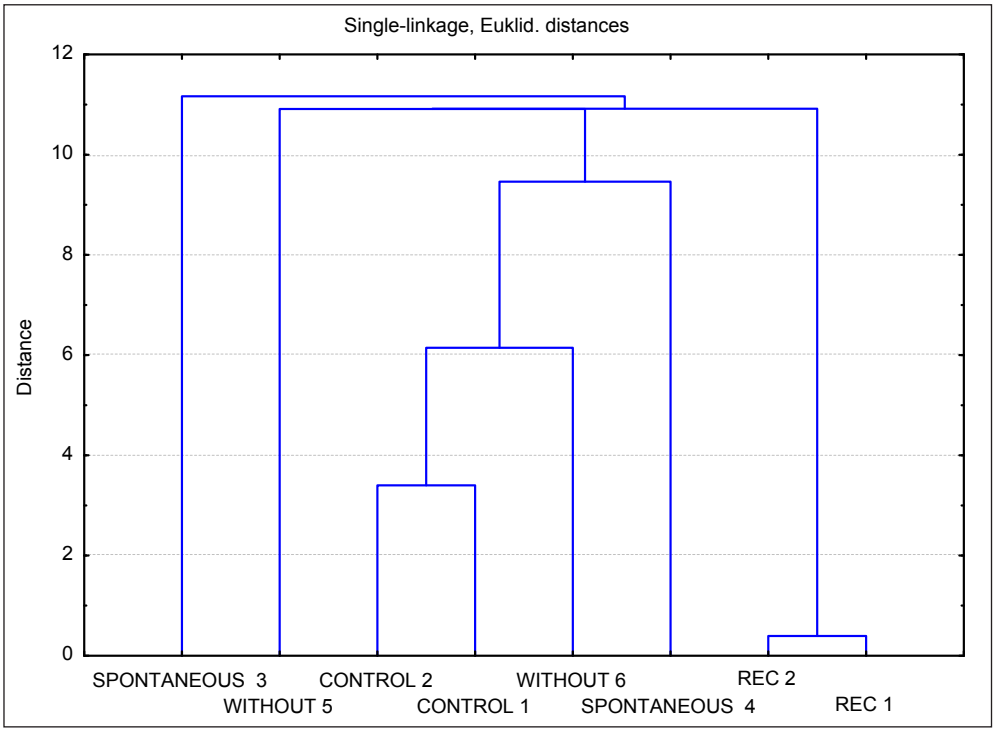
III: *Correlation table of all plots for both years (2007-2008): SPONT – spontaneous process, CONTROL – control biotope, WITHOUT – without vegetation, REC – reclamation*

	Marked correlations are p < .05000; N = 62							
PLOT	**Rec 1**	**Rec 2**	**Spont 3**	**Spont 4**	**Without 5**	**Without 6**	**Control 1**	**Control 2**
Rec 1	1.0000	0.9987	–0.0267	–0.0145	–0.0240	–0.0192	–0.0091	0.0060
Rec 2	0.9987	1.0000	–0.0264	–0.0196	–0.0268	–0.0165	0.0032	0.0228
Spont 3	–0.0267	–0.0264	1.0000	–0.0221	–0.0390	–0.0492	–0.0474	–0.0312
Spont 4	–0.0145	–0.0196	–0.0221	1.0000	–0.0289	–0.0364	0.2661	0.0849
Without 5	–0.0240	–0.0268	–0.0390	–0.0289	1.0000	0.0242	–0.0617	–0.0336
Without 6	–0.0192	–0.0165	–0.0492	–0.0364	0.0242	1.0000	0.6905	0.5235
Control 1	–0.0091	0.0032	–0.0474	0.2661	–0.0617	0.6905	1.0000	0.9052
Control 2	0.0060	0.0228	–0.0312	0.0849	–0.0336	0.5235	0.9052	1.0000

fer wet habitats and its finding on this habitat is peculiar. However, all these species are considered as abundant in the Czech Republic (according to Hůrka, 1996). Likewise, the situation in plots WITHOUT VEGETATION was very similar. Slightly larger number of species and individuals of Carabid beetles was trapped here (9 species with 36 individuals), however the data from this locality also suffer with low numbers of trapped beetles. The eudominant species here are *Abax parallelepipedus* and euryvalent *Pseudoophonus griseus* and *P. rufipes*. The low numbers of collected beetles distorted the dominance results – even species represented by just a single specimen are automatically presented as a subdominant species.

Localities marked as CONTROL BIOTOPE and RECLAMATION are quite comparable in the respect of Carabid beetles collected (RECLAMATION 1398 individuals, CONTROL BIOTOPE 1182 individuals). Also the dominance data are more comparable in these two localities. In the RECLAMATION area we found 47 species, in the CONTROL BIOTOPE area we found 32 species. During both pursued years euryvalent species dominated here (in the respect of both species and individuals numbers; see Tab. I). The most abundant species in RECLAMATION was an euryvalent *Brachinus crepitans* (1169 totally in both years) and in CONTROL BITOPE it was *Pseudoophonus rufipes* (765 totally in both years).

By means of the Cluster analysis and correlation tabs (Statistica 8.0) we found that the chosen techniqually recultivated areas were nearly the same regarding the species composition (99.87%), just as control areas (90.52%). Correlation of the other observed areas is evidenced by Tab. III. It is possible to track an interesting trend that the areas near the edge of the quarry (SPONTANEOUS PROCESS – plot 4 and WITHOUT VEGETATION – plot 6) which are simultaneously only with minimum of vegetation, are similar to CONTROL BIOTOPE (plot 7 and 8 – see Fig. 1 and Tab. III). The other observed areas have the absolutely unique consist of biota Carabid beetles and their similarity is not significant. It is evidently that single non-recultivated areas have the absolutely unique consist of biota Carabid beetles. For next research, this finding should be impeached and we can't rely on findings of the only line of the pitfall traps in one quarry.



1: *Cluster analysis of similarity of all localities for both sampling years (2007–2008): SPONTANEOUS – spontaneous process, CONTROL – control biotope, WITHOUT – without vegetation, REC – reclamation*

The presence of some relict species (sensu Hůrka et al., 1996) is remarkable. The following species were found: *Aptinus bombarda*, *Licinus cassideus* and *Harpalus modestus*. According to Veselý et al. (2005) one species of the endagered cathegory (*Licinus cassideus*) and one of the vulnerable cathegory (*Cylindera germanica*) were detected. At the same time *C. germanica* is a species protected by the Order 395/1992 Sb. One species was nearly endangered (*Harpalus modestus*). Despite small amount of carabids found, this result is very positive because for example on field crops, there is not found such species often (Šťastná & Bezděk, 2001, 2002).

Our finding is fully in agreement with Tropek et al. (2010); more important species of ground beetles colonise especially recultivated biotopes and they nearly can't be found in this non-recultivated quarry. Obviously, Carabid beetles colonise quarries in different ways according to the structure of habitants and therefore every single habitat differs – it is necessary to impeach this in next application of Carabidae as a bioindicators. In addition, in extreme conditions they react unlike the other organisms (Tropek et al., 2010) and in these biotopes is application of the Carabidae as a bioindicators controversial.

SOUHRN

Diverzita střevlíkovitých (Carabidae) na různých sukcesních stadiích vápencového lomu Hády (Brno, Česká republika)

Odběry do zemních pastí byly prováděny od dubna do září v letech 2007 a 2008 a pasti byly vybírány v měsíčním intervalu. Pro jednotlivé habitaty byly zpracovány třídy dominance – využití dalších ekologických charakteristik by bylo zatíženo velkou chybou vzhledem k malému množství střevlíků odchycených přímo v lomu (dohromady 40 ks za oba roky).

Na terasách Lesního lomu na masivu Hádů bylo odloveno celkem 2619 jedinců střevlíků náležejících k 61 druhům za oba sledované roky. I přes relativně malé množství odchycených jedinců se jedná o velké množství druhů, například v polních kulturách jsou počty druhů výrazně nižší. Nejvíce jedinců bylo odchyceno na rekultivovaných plochách (*Brachinus crepitans* 1169 ks) a na přirozených biotopech v okolí lomu (*Pseudoophonus rufipes* 765 ks). Byl zjištěn signifikantní (F = 2,906; P = 0,0010) rozdíl mezi sledovanými lety. Největší druhové spektrum bylo zjištěno na rekultivovaných plochách, ale jednalo se většinou druhy s malým počtem odchycených jedinců. Kromě adaptabilních a eurytopních druhů zde byly zjištěny i druhy reliktní. Obdobná situace byla i na kontrolních biotopech, kde

byly zastoupeny rovněž všechny bioindikační skupiny. Na ostatních plochách nebyly zjištěny žádné reliktní druhy a početní a druhové zastoupení bylo jen velmi nízké.
Co se týče podobnosti lokalit, byla vysoce signifikantní podobnost rekultivovaných ploch (99,87 %) a kontrolních biotopů (90,52 %). Dále byla zjištěna pozitivní korelace mezi plochami bez vegetace na předposlední lomové terase, která se dle druhového spektra velmi podobala kontrolním plochám (52,35 %, respektive 69,05 %). Z ostatních ploch byla zjištěna podobnost pouze v případě plochy na suti mezi druhou a první lomovou terasou s kontrolní plochou v akátovém hájku (26,61 %). Ostatní nerekultivované plochy byly velmi diverzifikované a nebyla zjištěna signifikantní podobnost jejich fauny střevlíků mezi sebou.
Celkově bylo zjištěno i několik velmi významných druhů, z nichž nejcennější jsou ohrožený *Licinus cassideus* a zranitelný svižník *Cylindera germanica*. Je zajímavé, že druhu *C. germanica*, který je zároveň chráněn vyhláškou č. 395/1992 Sb., ve znění vyhl. č. 175/2006 Sb., vyhovují podmínky zemědělské rekultivace, která pravděpodobně nahrazuje úhory, které tento druh přirozeně obývá. Z výše uvedeného je patrné, že fauna nerekultivovaných ploch (ponechaných přirozené sukcesi) je sice chudá a nepříliš významná, ale je velmi diverzifikovaná. Potvrdili jsme zjištění dalších autorů, kteří popisují střevlíky jako jediné z běžně sledovaných epigeických organismů, kteří pozitivně reagují na rekultivace vápencových lomů.

Carabidae, Hády, rekultivace, vápencový lom, CCA

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