ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LX 17 Number 3, 2012

GROUND BEETLES (CARABIDAE) ON QUARRY TERRACES IN THE VICINITY OF BRNO (CZECH REPUBLIC)

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Received: February 16, 2012

Abstract

NOVOTNÁ, L., ŠŤASTNÁ, P.: *Ground beetles (Carabidae) on quarry terraces in the vicinity of Brno (Czech Republic).* Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 3, pp. 147–154

The occurrence of ground beetles (Carabidae, Coleoptera) was monitored in the exhausted limestone quarry of massif Hády near Brno using formaldehyde pitfall traps with a monthly interval of collection. Research was conducted from April to October in 2009 and 2010. The obtained material was investigated on some synecological characteristics and species affiliation to bioindication groups. In total for both years, 462 specimens of 43 species were captured. Most species were found in habitats with vegetation cover in the immediate vicinity of cultivated agricultural land – 441 specimens of 39 species. In the quarry itself only a minimal amount of ground beetles was found – 21 specimens of 11 species. Decrease in the abundance of ground beetles towards the center of the quarry was demonstrated. Next, significant species of *Brachinus crepitans*, *Brachinus explodens* and *Cicindela sylvicola* (endangered species pursuant to Decree 395/1992 Coll.) and species listed in the Red List were reported – near threatened *Ophonus sabulicola* and vulnerable *Cylindera germanica* (also endangered species pursuant to Decree 395/1992 Coll).

Carabidae, limestone quarry, spontaneous succession, massif Hády

Intensity of human activities impact on nature increases, resulting in a decline of sites not affect by humans in our urbanized landscape. This fact is reflected particularly in biodiversity loss and reduction of species abundance associated with traditional farming methods. At first glance, this negative trend on condition and appearance of the landscape is caused by mining and quarrying. If, however, exhausted quarries are left to spontaneous succession, they can become very interesting in terms of biodiversity. In this respect limestone quarries have a great potential due to their bedrock which allows creation of valuable habitats with low, xerothermofilous grassland communities, which are among the richest and most threatened habitats in Europe (Jefferson, 1984). In early developmental stages, post-mining areas become a potential refuge for species sensitive to high content of nutrients, nitrogen and phosphorus or species able to survive in an environment of absolute lack of nutrients. Exhausted and closed quarries can function as a substitute habitat for some vanishing species of plants and animals and serve to rescue them (Sádlo & Tichý, 2002).

A rich variety of species and a high protection potential of mining areas are confirmed in work of many authors, e.g. Beneš *et al.* (2003), Tichý (2004), Tropek (2007), Tropek *et al.* (2008, 2010), Hula & Šťastná (2010a).

In terms of the occurrence of ground beetles, post-mining areas and other xerothermic habitats have been explored only marginally and data are very scarce. The largest survey of these sites here was made by Tropek *et al.* (2008, 2010) who compared technical reclamation and spontaneous succession in limestone quarries of Český Kras using several groups of organisms, including ground beetles. Sigmund & Waitzbauer (2007) and Hula & Šťastná (2010b) focused on mapping of ground beetles in a limestone quarry.

How the ground beetles colonize the quarry and how their generic representation and abundance changes from the edge of the quarry to its center has not yet been examined. This very question was an impulse to implement this research.

MATERIAL AND METHODS

The survey was conducted in a limestone quarry Lesní lom located approximately 1 km from the northern edge of the city district of Brno-Líšeň (49°13'24.662"N, 16°41'41.494"E). The site is located at an altitude of 360 m above sea level. At the time of research, the quarry had been closed and no mining or reclamation activities had taken place here for 8 years.

To capture Carabidae we used pitfall traps with liquid fixation fluid – 4% formaldehyde with a detergent as a wetting agent. These pitfall traps were placed at five plots, one line was buried at the edge of the quarry, four other lines were placed directly on the terraces inside the quarry. Each line contained three pitfall traps at 10 m distance. The traps were covered with a stone roof. Within survey was no trap destroyed.

Samples were collected at monthly intervals between 2009 and 2010 in the growing season. In 2009, pitfall traps were buried in April and the material was collected five times – on 18 May, 27 May, 26 June, 4 September, and 6 October. In 2010, traps were again resumed in early April and collections were carried out six times – on 28 April, 1 June, 25 June, 30 July, 6 September, and 6 October. The collected material was partly determined on-site, permanent fixation was performed using 70% alcohol.

The beetles were sorted according to the individual systematic groups, specific identification which followed according to the monograph by Hůrka (1996). The nomenclature is according to Audisio & Taglianti (2010).

Values of dominance and Shannon-Wiener index of species diversity were calculated for the material. According to Tischler (1965), species were classified into five domination groups: eudominant species (more than 10% representation one species specimens of the total number of specimens in a given habitat), dominant (5–10%), subdominant (2–5%), recedent (1–2%), and species subrecedent with less than 1% representation.

Pursuant to Hůrka *et al.* (1996), species were classified into three indication groups (R, A, E) according to their ecological valency and dependence on the habitat. Species in the R group are stenotopic species with the narrowest ecological valency, mostly rare and endangered species of native, intact ecosystems. Group A is characterized by adaptable species occurring in habitats close to natural state. The last bioindication group E includes eurytopic species that have no special demands on the quality of the environment (species of unstable and changing habitats, habitats strongly influenced by human activities).

Description of plots (Fig. 3)

A terraced quarry pit is characterized by its high steep walls that prevent full light and most of the bottom is thus overshadowed throughout the day. Microclimate is very typical here with a lack of moisture and high temperatures.

Plot 1

The first plot is located on the edge of the quarry close to cultivated agricultural land. It is a narrow grassy strip forming a transition boundary between an adjacent field and the mentioned quarry. Pitfall traps were placed in a loamy soil. It is surrounded by continuous grassland, separate shrubs of roses (*Rosa* sp.), dogwood (*Cornus* sp.), pine trees (*Pinus sylvestris*), and birch (*Betula pendula*).

Plots 2–5

Plots 2 to 5 are very similar, located directly on the quarry terraces. These are bare areas with minimal vegetation cover. Plot 2 is the area on the first etage of the quarry, Plot 3 is on the second etage, Plot 4 is on the third etage, and Plot 5 is on the fourth quarry etage. Pitfall traps were buried into continuous limestone rubble. Vegetation is very sparse without any continuous herbaceous cover, consisting of separate pine trees (*Pinus sylvestris*), birch (*Betula pendula*) and clusters of *Epilobium dodonaei*.

RESULTS AND DISCUSSION

In the area of the Hády Lesní lom the total number of 462 specimens of Carabidae belonging to 43 species was trapped in both years of this observation. In 2009 it was 281 individuals belonging to 34 species and in 2010 it was 181 individuals belonging to 30 species. In comparison with other sites this is a very low amount, for example, Kielhorn *et al.* (1999), Horáková *et al.* (2005) during their two-year research found several thousands of specimens of Carabidae. But it is necessary to point out that their sites were characterized by absolutely different habitat conditions. The most abundant species in both years were *Pseudoophonus rufipes* – 67 specimens in 2009 and 45 in 2010, *Anchomenus dorsalis* – 44 specimens in 2009 and 30 in 2010. Other abundant species in 2009 were *Abax parallelepipedus* (29 individuals), *Harpalus rubripes* (25 individuals), and *Harpalus subcylindricus* (23 individuals). In 2010, the only other significantly abundant species was *Pseudoophonus griseus* (26 individuals).

The vast majority of specimens were in both years caught at the Plot 1 (441 specimens out of 462). According to Hůrka (1996), all trapped species belong to indication groups A (adaptable) and E (eurytopic). The ratio of representation of these bioindication groups was very balanced, one species only (*Ophonus sabulicola*) belonged to the group R (relict). In both years there was a relatively high index of species diversity on Plot 1 – 2.58 in 2009 and 2.48 in 2010. The eudominant species included *Anchomenus dorsalis* and *Pseudoophonus rufipes*.

I: *Species presence and abundance of Carabidae at individual Plots*

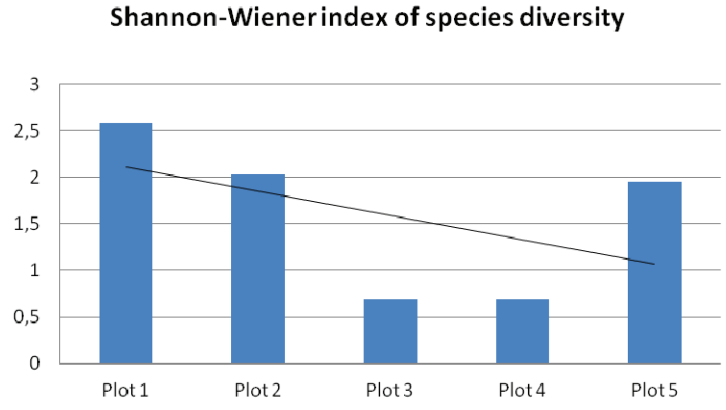
	Year 2009					Year 2010				
Species	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Abax ovalis (Duftschmid, 1812)	1	0	0	0	0	1	0	0	0	0
Abax parallelepipedus (Piller & Mitterpacher, 1783)	29	0	0	0	0	4	0	0	0	0
Abax parallelus (Duftschmid, 1812)	0	0	0	0	0	2	2	0	0	0
Amara aenea (De Geer, 1774)	1	0	0	0	0	0	0	0	0	0
Amara bifrons (Gyllenhal, 1810)	1	0	0	0	0	0	0	0	0	0
Amara curta Dejean, 1828	3	0	0	0	0	0	0	0	0	0
Amara equestris (Duftschmid, 1812)	0	1	0	0	0	0	0	0	0	0
Amara similata (Gyllenhal, 1810)	1	0	0	0	0	0	0	0	0	0
Anchomenus dorsalis (Pontoppidan, 1763)	44	0	0	0	0	30	0	0	0	0
Brachinus crepitans (Linne, 1758)	3	0	0	0	0	0	0	0	0	0
Brachinus explodens Duftschmid, 1812	2	0	0	0	0	1	0	0	0	0
Calathus ambiguus (Paykull, 1790)	1	0	0	0	0	0	0	0	0	0
Calathus fuscipes (Goeze, 1777)	2	0	0	0	0	1	0	0	0	0
Callistus lunatus (Fabricius, 1775)	11	0	0	0	0	1	0	0	0	0
Carabus granulatus Linne, 1758	1	0	0	0	0	1	0	0	0	0
Carabus intricatus Linne, 1761	0	0	0	0	0	0	0	0	0	1
Cicindela sylvicola Dejean in Latreille & Dejean, 1822	0	0	0	0	1	0	0	0	0	0
Clivina fossor (Linne, 1758)	0	0	0	0	0	1	0	0	0	0
Cylindera germanica (Linne, 1758)	0	0	0	0	1	0	1	0	0	0
Harpalus affinis (Schrank, 1781)	12	0	0	0	1	5	1	1	1	0
Harpalus anxius (Duftschmid, 1812)	7	0	0	0	0	0	0	0	0	0
Harpalus caspius Schauberger, 1928	0	0	0	0	0	2	0	0	0	0
Harpalus distinguendus (Duftschmid, 1812)	5	0	0	0	0	3	0	0	0	0
Harpalus rubripes (Duftschmid, 1812)	25	0	0	0	1	7	2	0	0	0
Harpalus rufipalpis Sturm, 1818	0	0	0	0	0	1	0	0	0	0
Harpalus serripes (Quensel in Schonherr, 1806)	1	0	0	0	0	0	0	0	0	0
Harpalus subcylindricus Dejean, 1829	23	0	0	0	0	8	0	0	0	0
Leistus ferrugineus (Linne, 1758)	5	0	0	0	0	3	0	0	0	0
Licinus depressus (Paykull, 1790)	1	0	0	0	0	0	0	0	0	0
Molops elatus (Fabricius, 1801)	1	0	0	0	0	8	0	0	0	0
Molops piceus (Panzer, 1793)	2	0	0	0	0	2	1	0	0	0
Ophonus azureus (Fabricius, 1775)	1	0	0	0	0	0	0	0	0	0
Ophonus puncticeps Stephens, 1828	0	0	0	0	0	1	0	0	0	0
Ophonus rupicola (Sturm, 1818)	1	1	0	0	0	3	0	0	0	0
Ophonus sabulicola (Panzer, 1796)	0	0	0	0	0	1	0	0	0	0
Panagaeus bipustulatus (Fabricius, 1775)	0	0	0	0	0	1	0	0	0	0
Poecilus cupreus (Linne, 1758)	3	0	0	0	0	6	1	1	0	1
Pseudoophonus griseus (Panzer, 1796)	9	0	0	0	0	26	0	0	0	0
Pseudoophonus rufipes (De Geer, 1774)	66	0	0	1	0	44	0	0	0	1
Pterostichus melanarius (Illiger, 1798)	0	0	0	0	0	1	0	0	0	0
Pterostichus oblongopunctatus (Fabricius, 1787)	7	0	0	0	0	2	0	0	0	0
Trechus quadristriatus (Schrank, 1781)	1	0	0	0	0	1	0	0	0	0
Zabrus tenebrioides (Goeze, 1777)	4	0	0	0	0	0	0	0	0	0
Number of Specimens	274	2	0	1	4	167	8	2	1	3
Number of Species	31	2	0	1	4	28	6	2	1	3

Conversely, a total of 25 species were subrecedent (Tab. II), this overwhelming preponderance of subrecedent species points to the heavily disturbed and artificial biocenosis.

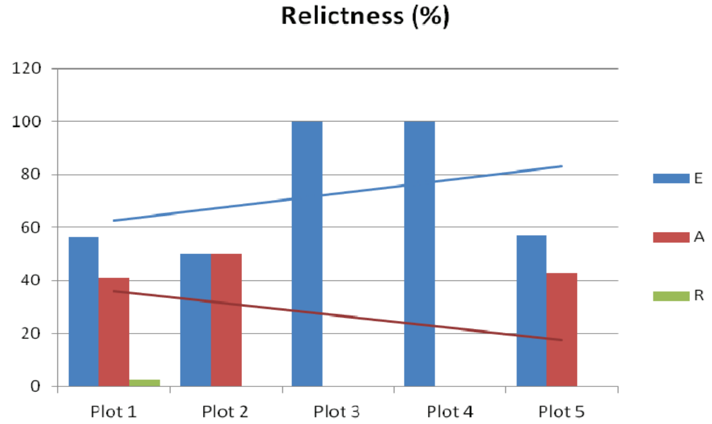
II: *Species affiliation to bioindication groups by Hůrka et al. (1996), species classification according to their dominance by Tischler (1965): orange – eudominant, blue – dominant, green – subdominant, violet – recedent, pink – subrecedent*

		Dominance (%)				
Species	**Relictness**	**1**	**2**	**3**	**4**	**5**
Abax ovalis (Duftschmid, 1812)	A	0.5				
Abax parallelepipedus (Piller & Mitterpacher, 1783)	A	7.5				
Abax parallelus (Duftschmid, 1812)	A	0.5	20			
Amara aenea (De Geer, 1774)	E	0.2				
Amara bifrons (Gyllenhal, 1810)	E	0.2				
Amara curta Dejean, 1828	A	0.7				
Amara equestris (Duftschmid, 1812)	A		10			
Amara similata (Gyllenhal, 1810)	E	0.2				
Anchomenus dorsalis (Pontoppidan, 1763)	E	16.8				
Brachinus crepitans (Linné, 1758)	E	0.7				
Brachinus explodens Duftschmid, 1812	E	0.7				
Calathus ambiguus (Paykull, 1790)	A	0.2				
Calathus fuscipes (Goeze, 1777)	E	0.7				
Callistus lunatus (Fabricius, 1775)	A	2.7				
Carabus granulatus Linné, 1758	E	0.5				
Carabus intricatus Linné, 1761	A					14.3
Cicindela sylvicola Dejean in Latreille & Dejean, 1822	A					14.3
Clivina fossor (Linné, 1758)	E	0.2				
Cylindera germanica (Linné, 1758)	A		10			14.3
Harpalus affinis (Schrank, 1781)	E	3.9	10	50	50	14.3
Harpalus anxius (Duftschmid, 1812)	A	1.6				
Harpalus caspius Schauberger, 1928	A	0.5				
Harpalus distinguendus (Duftschmid, 1812)	E	1.8				
Harpalus rubripes (Duftschmid, 1812)	E	7.3	20			14.3
Harpalus rufipalpis Sturm, 1818	A	0.2				
Harpalus serripes (Quensel in Schonherr, 1806)	A	0.2				
Harpalus subcylindricus Dejean, 1829	A	7.0				
Leistus ferrugineus (Linné, 1758)	E	1.8				
Licinus depressus (Paykull, 1790)	A	0.2				
Molops elatus (Fabricius, 1801)	A	2.0				
Molops piceus (Panzer, 1793)	A	0.9	10			
Ophonus azureus (Fabricius, 1775)	E	0.2				
Ophonus puncticeps Stephens, 1828	E	0.2				
Ophonus rupicola (Sturm, 1818)	E	0.9	10			
Ophonus sabulicola (Panzer, 1796)	R	0.2				
Panagaeus bipustulatus (Fabricius, 1775)	A	0.2				
Poecilus cupreus (Linné, 1758)	E	2.0	10	50		14.3
Pseudoophonus griseus (Panzer, 1796)	E	7.9				
Pseudoophonus rufipes (De Geer, 1774)	E	24.9			50	14.3
Pterostichus melanarius (Illiger, 1798)	E	0.2				
Pterostichus oblongopunctatus (Fabricius, 1787)	A	2.0				
Trechus quadristriatus (Schrank, 1781)	E	0.5				
Zabrus tenebrioides (Goeze, 1777)	E	0.9				

The Carabid beetles were almost absent at the quarry terraces. Of the total, only 21 specimens (11 species) were found in the 12 ground traps on all 4 etages.



1: *Change in species diversity towards the center of the quarry*



2: *Relictness change towards the center of the quarry*

In the second plot there were 10 Carabidae belonging to the 8 species trapped – *Abax parallelus, Amara equestris, Cylindera germanica, Harpalus affinis, Harpalus rubripes, Molops piceus, Ophonus rupicola, Poecilus cupreus*. In the third area there were only 2 pieces recorded – *Harpalus affinis* and *Poecilus cupreus* both belonging to the indication group E. The fourth plot (third quarry terrace) was again not inhabited by Carabid beetles, only two specimens were found there – eurytopic *Pseudoophonus rufipes* and *Harpalus affinis*. In the last examined terrace the abundance was slightly higher. In total 7 specimens belonging to 7 species were trapped here. Due to their low abundance, all species were evaluated as eudominant. Numbers of species at individual sites are summarized in Tab. I. Species dominance and affiliation to bioindication groups are shown in Tab. II.

The graph of species diversity index (Fig. 1) demonstrates the significantly decreasing trend of Carabidae away from Plot 1 to Plot 5. Higher species diversity was reported at the Plot 5.

In both years, eurytopic species representation slightly predominated over adaptable species. Towards quarry center, representation percentage of eurytopic species increased while the number of adaptable species declined (Fig. 2).

Clearly more abundant occurrence of Carabidae was recorded at Plot 1. Only three ground traps were placed there, but the number of trapped specimens was 20 times higher. These were in particular eurytopic and adaptable species, mostly typical field species that are not dependent on specific environmental conditions. Increased occurrence of Carabidae may be caused by a close proximity of a cultivated field and easy access to the site. Similar results were also obtained by Tropek *et al.* (2010) who also recorded a much lower number of specimens of Carabid beetles in unreclaimed quarry compared with reclaimed quarry. The work also confirms the results by Hula & Šťastná (2010b) who conducted a similar research in preceding years. In their work, Carabidae were also very rare at quarry terraces.

Although at Plot 1 a relatively high number of specimens was recorded, only one species was relict (*Ophonus sabulicola* (Panzer, 1796)). From the bioindicative perspective of captured species, this site is very strongly anthropogenically influenced. Also some more significant species were recorded here, such as *Brachinus crepitans* (Linné, 1758), *Brachinus explodens* Duftschmid, 1812 (protected as endangered species by law under Decree No. 395/1992 Coll.), and *Ophonus sabulicola* (Panzer, 1796) (near threatened under the Red List (Veselý

3: *Location of pitfall traps (source: www.mapy.cz)*

et al., 2005)), however, it was only three species out of 39 species found at Plot 1 for two years. Another remarkable species such as *Callistus lunatus*, *Licinus depressus* and *Panagaeus bipustulatus* were found. In the Czech Republic are these species very sporadic and are typical of old quarries. In their research in field communities, Šťastná & Bezděk (2002) do not mention any significant species out of the 41 captured (33 923 specimens).

On the quarry terraces (Plots 2–5) significant species of *Cicindela sylvicola* Dejean in Latreille & Dejean, 1822 (protected as an endangered species pursuant to Decree 395/1992 Coll.) and *Cylindera germanica* (Linné, 1758) (vulnerable species according to the Red list (Veselý *et al.*, 2005) and protected as an endangered species pursuant to Decree 395/1992 Coll.) were also found.

SUMMARY

Research was conducted in 2009 and 2010, always in the growing season from April to October. Pitfall traps with preservative solution were selected as the method for beetles capturing. These pitfall traps were placed in lines of three on the terraces of the quarry. Collection and subsequent determination of the material were performed at monthly intervals.

Within two years of research, 462 specimens of Carabidae belonging to 43 species were reported. A dominating center of Carabidae abundance was detected at the quarry edge which is covered by continuous vegetation. Reduced abundance of Carabidae was observed towards the center of the quarry. Of the total, 7 specimens belonging to 7 species only were trapped here. It could be summarized that Carabidae do not actually live in the quarry itself. It is possible that this is due almost missing vegetation, extreme microclimatic conditions or a lack of nutrition. Similarly, high incidence of Carabid beetles at the edge of the quarry may be caused by close proximity of the field, which is also suggested by the trapped species that are mostly eurytopic and typically preferring field habitats. On the edge of the quarry there were captured some important species, including *Brachinus crepitans*, *Brachinus explodens* (endangered species listed in Decree 395/1992 Coll.), and *Ophonus sabulicola* (a near threatened species included in the Red List). On the terraces of the quarry there were also reported species of *Cylindera germanica* (vulnerable species under the Red List and protected as an endangered species pursuant to Decree 395/1992 Coll.) and *Cicindela sylvicola* (protected as an endangered species pursuantto Decree 395/1992 Coll.).

Acknowledgment

This study was supported by project of IGA MENDELU No. IP17/2012 and IGA MENDELU No. TP04/2012. We thank especially to Vladimír Hula, Zuzana Vítková, Jaroslav Šafář for their help in the field and laboratory and Luboš Purchart for help with determination. The authors thank to Zdeněk Laštůvka for his notes to the manuscript.

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