



## Two groups of epigeic arthropods differ in colonising of piedmont quarries: the necessity of multi-taxa and life-history traits approaches in the monitoring studies

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**Abstract:** It is increasingly understood that inventorying and monitoring biodiversity requires a multi-taxa approach and that comparing simple indices, such as species richness, should be accompanied by deeper analyses of species community composition and by comparisons of species life-history traits among taxa and habitats. Here, we document that two ecologically rather similar groups of epigeic predators, ground-dwelling spiders (Araneae) and ground beetles (Coleoptera: Carabidae), differ in patterns of stone quarry colonization. Such post-industrial barrens as abandoned quarries are increasingly appreciated as potential refuges for species that are becoming rare in modern landscapes. We compared species richness, community composition and species life-history traits of two epigeic invertebrates groups, in quarries and adjoining seminatural biotopes in a submountain region with granulite and limestone bedrock in SW Czech Republic. For both groups, quarries were species-poorer than seminatural sites, herbaceous biotopes were richer than scrubby and rocky biotopes, and no significant effects on species richness were revealed for substrate. Assemblages colonising quarries differed from those outside of quarries. They contained numerous regionally rarer species of rocks and scree in the case of spiders, but generalists of open landscapes prevailed among ground beetles. A survey limited to ground beetles, as well as to species richness analyses, would fail to detect a conservation potential of the quarries. Hence, a multi-taxa approach should be preferred, and species richness analyses should be assembled by insights onto community composition and species life-history traits in monitoring studies.

**Abbreviations:** ANOVA – Analysis of Variance, CCA – Canonical Correspondence Analysis, DCA – Detrended Correspondence Analysis.

**Nomenclature:** Hurka (1996) for ground beetles, Buchar and Ruzicka (2002) for spiders.

### Introduction

Inventorying of biodiversity and monitoring its changes represent indispensable tools in conservation. Because the diversity of separate taxonomic groups is often distributed incongruently in space (e.g., Lawton et al. 1998, Niemela and Baur 1998, Ricketts et al. 2002, Vessby et al. 2002, Lovell et al. 2007), outcomes of monitoring studies depend critically on selection of those taxonomic groups which can give us the most applicable and powerful conclusions for conservation. Despite this, many inventories and monitoring studies still rely on a single taxon, finding the justification by the umbrella species concept (Simberloff 1998, Fleishman et al. 2000). In addition, in a few cases of extraordinarily known taxa, such as birds, butterflies or vascular plants, the concept of a higher-taxa umbrella has been evoked (Kremen 1992, Thomas et al. 2004, Bried et al. 2007). For the majority of cases and taxa however, a novel multi-species umbrella ap-

proach has been proposed (Lambeck 1997, Roberge and Angelstam 2004) and seems to be gradually prevailing, and the monitored groups are preferentially selected from different ecological guilds (e.g., Batáry et al. 2007, Spitzer et al. 2008).

Budgetary constraints will always press for monitoring project based on a limited selection of taxonomic groups. In the real world, taxa to be targeted are often selected not according to their ecological functions, and hence expected indicator value, but according to practical consideration – there must be available easily reproducible monitoring methods, sufficient coverage by expert taxonomists, and some background biological knowledge (Pearson 1994, Dufrene and Legendre 1997). It is sometimes suggested that selection of monitored taxa should include groups that respond to their environments differently in order to allow reliable conservation policy inference (Kremen et al. 1993, McGeoch 1998). On the other hand, it is rarely considered that ecologically similar taxa (belonging to a single 'guild') might differ in

their responses to their environments, and hence conservation actions.

Besides suitable taxa selection, methods of evaluation and results are crucial. Too many monitoring projects conclude by comparing changes in species richness. This approach has only limited value and is increasingly supplemented by comparing threatened species richness (e.g., Balmer and Erhardt 2000, Kadlec et al. 2008) or such indices as specialists : generalists ratio (Batáry et al. 2007, Rainio and Niemela 2003, Devictor et al. 2008). But with accelerating loss of even formerly common species from European landscapes, it is desirable that projects of biodiversity monitoring target common species as well. Ordination analyses, on the other hand, allow tracking not only numbers of species, but also changes in species identities (Clarke 1993, Lepš and Šmilauer 2003). Comparisons of species life-history traits seem to promise a suitable addition, as they, aside from observing changes in species numbers, allow inferring which environmental processes have been responsible for the observed changes in species composition (Kremen et al. 1993, Owens 1999). These approaches are particularly suitable for regions with good background biodiversity knowledge, such as parts of Europe, where basic life history information is available for many taxonomic groups.

Human-disturbed sites such as abandoned quarries are increasingly appreciated by ecologists as potential refuges for species that are becoming rare in wider, commonly exploited landscapes (Schulz and Wiegand 2000, Benes et al. 2003, Rosenzweig 2003, Samways 2007). Such sites typically harbour diverse mosaics of rather extreme abiotic conditions (Wheater and Cullen 1997, Novak and Konvicka 2006) which had existed in pre-modern landscapes at sites such as exposed river sediments, landslides and overgrazed commons (Thomas 1993, Andersen and Hanssen 2005, Bates et al. 2007). The future of quarries, dumps, sand-pits and brownfields, however, is often uncertain, due to strong pressures for technical reclamation (Prach and Pysek 2001, Hodacova and Prach 2003). Therefore, the monitoring of the anthropogenic sites and their importance for common landscape biodiversity is particularly important.

This study compares patterns of quarried habitats colonisation and of adjacent seminatural habitat communities of two groups of predatory epigeic arthropods – ground beetles (Coleoptera: Carabidae) and ground-dwelling spiders (Araneae). Both groups are often used as indicator taxa (Marc et al. 1999, Rainio and Niemela 2003). In addition to species richness patterns, we analyze the species composition of communities colonising quarried habitats, and the life-history traits of constituting species. The spiders were analysed in detail in a previous study, in which we found that quarries tend to be colonised by regionally rare species of considerable conservation interest, probably because they contain regionally rare extreme habitats (Tropek and Konvicka 2008). Here, we argue that colonisation by ground beetles, as an ecologically rather similar group, differs in a few crucial pat-

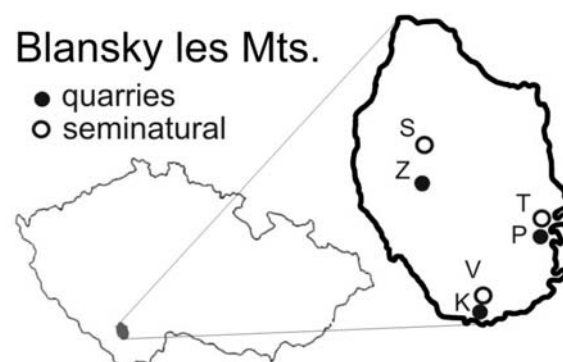
terns which highlight the necessity of a multi-taxa approach in monitoring studies.

## Material and methods

### Study area and sampling design

The study was carried out in a relatively cold region containing both basic (limestone) and acidic (granulite) bedrock, at the piedmont of the Blansky les Mts. (SW Czech Republic; Fig. 1), a low-mountain area reaching its maximum at Klet Mt., 1084 m a.s.l. The landscape consists of beech and spruce forests, fields, pastures and a scarce built-up area of small villages. The climate is cold to moderately warm, annual temperatures ranging from 4.7 to 7 °C and precipitation being 560-720 mm.

We sampled the invertebrates at six sites, three quarries paired with three adjoining seminatural ones (Table 1). Three distinct biotopes were sampled in each quarry: rocks, herbaceous stage and scrub, assuming that succession in the quarries would eventually lead either to herbaceous or scrubby conditions (Wheater and Cullen 1997, Wiegand and Felinks 2001). Only herbaceous and scrub biotopes were sampled at seminatural sites, as no rocky walls due to intensive rock harvest for local construction activity in the past recently exist there, but isolated stones and/or small flat outcrops are still present. A line of four pitfall traps (spaced every 10 meters) was set in each of the biotopes from May to September 2006, and the traps were emptied every three weeks, i.e., five times each during the study period. The minimum distance between lines/biotopes within a site was 50 metres. To obtain a comparable number of the samples of the site character, we used eight instead of four traps, set in two independent lines, for the herbaceous biotopes outside of the quarries. Special hanging desk traps (consisting of a desk, which formed an artificial horizontal surface, and a can inserted in the centre of the desk, Ruzicka 2000) were used on the rocks, whereas plastic cups were used elsewhere. The traps of both types had



**Figure 1.** Position of the Blansky les Mts. and individual sites. Site names abbreviations – V, Vysny; K, Vysenske kopce; P, Plesovice; T, Trisov; Z, Zrcadlova hut; S, Na Strazi.

**Table 1.** Sites of pitfall trapping in quarries and adjoined seminatural xeric sites in the Blansky les Mts. In analyses, each quarry was paired with following seminatural xeric site.

Site	Character, description	Substrate	Coordinates	Altitude	Area
Vysny	quarry, excavation terminated in 1993	limestone	48°49'57"N, 14°17'49"E	570 m	5 ha
Vysenske kopce	seminatural, former pasture	limestone	48°49'22"N, 14°17'52"E	570 m	5 ha
Plesovice	quarry, operating	granulite	48°52'18"N, 14°20'58"E	520 m	21 ha
Trisov	seminatural, a warm sheltered plateau	granulite	48°52'57"N, 14°21'03"E	520 m	1 ha
Zrcadlova hut	quarry, terminated in 2000	granulite	48°53'07"N, 14°13'55"E	650 m	12 ha
Na Strazi	seminatural, former pasture	granulite	48°55'49"N, 14°13'43"E	570 m	3 ha

an identical upper diameter and depth (9 cm and 15 cm, respectively) and contained a solution of 5% formaldehyde. They were treated as identical in the analyses.

### Analyses

We performed all analyses separately for ground beetles and spiders, using PAST 1.81 (Hammer et al. 2001) for rarefaction curves, Statistica 6.0 (StatSoft 2001) for univariate methods and CANOCO for Windows 4.5 (ter Braak and Šmilauer 2002) for multivariate ordinations.

Sample rarefaction curves (Mao tau) (Gotteli and Colwell 2001) were constructed to compare species richness between quarries and seminatural sites (character), limestone and granulite (substrate) and herbaceous, scrubby and rocky biotopes (biotope). Standard deviation values were used to compare differences in their shapes.

Species composition was analysed using CCA, a constrained unimodal ordination technique relating the composition of samples to external predictors. DCA was used to assess gradient lengths and thus to select between unimodal and linear methods (Lepš and Šmilauer 2003). The Monte Carlo permutation tests (with 999 runs) were used to test for non-random patterns in the ordinations. The permutations were performed so that they reflected the temporal and spatial distribution of catches: the lines of traps were permuted as line transects and the emptying visits as a time series. We used log-transformed species data to level off great differences in catch sizes among individual species in the samples, and applied the CANOCO downweighting of rare species option to minimise the possible effects of species caught in very small numbers. Because empty rows in the data matrices (zero catches) precluded using more complex permutation designs, we added a miniscule value (0.0001) to each data matrix cell.

### Life-history traits

Traits of individual species belong to both groups – as summarised for Czech spiders by Buchar and Ruzicka (2002) and for Czech ground beetles by Hurka (1996) (humidity and light requirements) and Hurka et al. (1996) (habitat quality) – were used to compare samples from different conditions. We considered (i) habitat quality, a ranked variable based on

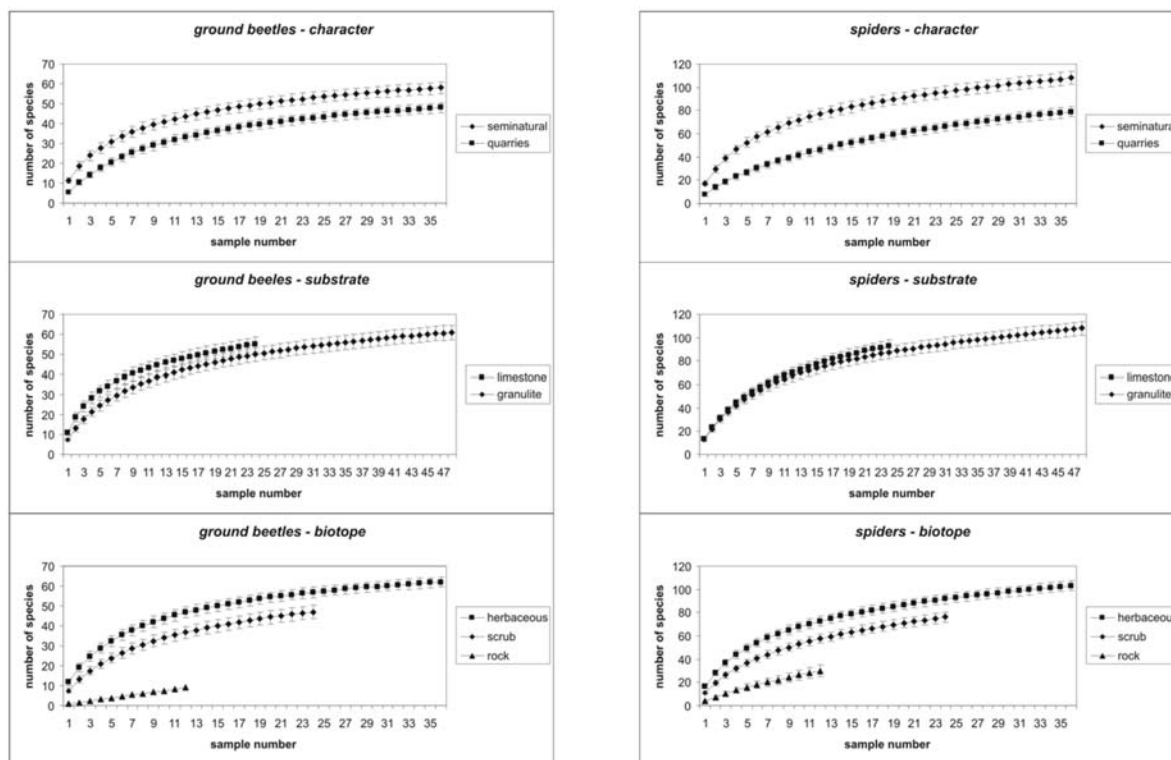
categorisation by Buchar (1983) distinguishing relic ('species restricted to natural, undisturbed habitats'), adaptable ('able to colonise both undisturbed and moderately disturbed habitats'), and eurytopic species ('colonising even heavily anthropically disturbed sites') (details in Tropek and Konvicka 2008); (ii) humidity requirement, a ranked variable with five states (very dry, dry, semi-humid, humid, very humid); (iii) light requirement, ranked with five states (dark, shaded, partly shaded, semi-open, open); (iv) distribution extent, a numeric variable expressed as the number of occupied grid squares in the Czech distribution atlases (spiders: Buchar and Ruzicka 2002, ground beetles: Skoupy 2004). Because Skoupy (2004) does not include two genera of large-bodied beetles, *Cicindela* and *Carabus*, we replaced the missing information for captured species by means computed for all remaining ground beetles (i.e., strengthening the null hypothesis of no pattern).

For each of the above life-history traits, we first substituted the numeric values of the traits for each captured individual. We thus obtained means of the respective trait per trap (weighted average values). For the next step, we compared the traps with respect to character (quarry vs. seminatural sites) using one-way ANOVA. The non-parametric Kruskal-Wallis ANOVA was used to compare the traps according to substrate (granulite vs. limestone) and biotope (herbaceous, scrubby and rocky biotopes). The non-parametric test was selected because of the non-optimal design (no rocky biotopes at seminatural sites).

### Results

The total catches consisted of 3029 individuals of 132 spider species and 2937 individuals of 71 ground beetle species.

As shown by the rarefaction curves (Fig. 2), a higher richness of both groups of epigeic arthropods occurred in seminatural sites, this difference was more distinct for spiders. The two groups did not differ in the numbers of species in different substrates. In both ground beetles and spiders, herbaceous biotope contained the highest species richness, curves for scrubby biotopes had a similar shape but contained significantly less species, whereas rocky walls were the poorest. A majority of the curves approached asymptotic pla-



**Figure 2.** Sample rarefaction curves for pitfall catches of ground beetles and spiders. *Character* compares quarry and seminatural sites, *biotope* compares rocky, herbaceous and scrubby biotopes, and *substrate* compares granulite and limestone. The bars are standard deviation values.

teaux, except for the curves from the rocky biotope, which was probably caused by the low number of caught species.

In ordinations (Fig. 3), quarries differed from seminatural sites in species compositions of both groups (ground beetles:  $F = 9.09$ ,  $p = 0.001$ ; spiders:  $F = 8.16$ ,  $p = 0.001$ ). In ground beetles (Fig. 3a), the group associated with quarries consisted almost exclusively of species tolerating repeated mechanical disturbance, as many of the species occur, e.g., on regularly ploughed arable fields (*Bembidion quadrimaculatum*, *Bembidion lampros*, *Harpalus affinis*, *Pterostichus melanarius*, *Calathus erratus*, *Calathus melanocephalus*, *Poecilus cupreus*, *Poecilus versicolor*). The group appeared rather homogeneous internally, displaying low scatter along the second ordination axis. The species associated with seminatural sites formed a rather wide second-axis gradient, from species with lower humidity requirements of closed-sward grasslands in negative values of the second ordination axis (e.g., *Amara equestris*, *Amara montivaga*) to species with higher humidity requirements of shady, wooded habitats (*Abax parallelepipedus*, *Pterostichus burmeisteri*).

The homogeneous group of spiders associated with quarries (Fig. 3b) contained several species of early-successional rocks (*Drassyllus pusillus*, *Hahnina nava*, *Meioneta rurestris*, *Oedothorax apicatus*, *Phrurolithus festivus*) or xeric grasslands (*Talavera petrensis*, *Xerolycosa nemoralis*). The group associated with seminatural sites appeared more heterogeneous, containing species of woodland (*Coelotes terrestris*,

*Histoipona torpida*, *Haplodrassus silvestris*, *Pardosa lugubris*) and dry grassland (*Xysticus robustus*, *Zodariion germanicum*, *Alopecosa trabalis*, *Zelotes electus*, *Trachyzelotes pedestris*).

The comparison of life-history traits (Table 2) revealed, with regard to character, that quarries were inhabited by spiders with limited distribution extent and by spiders requiring more open habitats, whereas no such pattern applied for ground beetles. Regarding biotope, catches of ground beetles from herbaceous biotopes contained species of higher quality habitats than catches from scrub and rock, with no such pattern for catches of spiders. Scrubby biotopes hosted both ground beetles and spiders preferring higher humidity. Herbaceous and rocky biotopes (for both groups) hosted species demanding more light. Catches of spiders but not of ground beetles differed in terms of distribution extent: rocky biotopes hosted rarer spiders than scrubby and herbaceous biotopes. Regarding *substrate*, limestone catches contained both ground beetles and spiders with limited distribution extent.

## Discussion

Our study revealed several similarities in occupancy patterns of quarries and adjoining seminatural habitats by ground beetles and spiders. For both groups, species richness was higher in the seminatural habitats than in the quarries, herbaceous biotopes were species-richer than scrubby and rocky biotopes. Assemblages inhabiting the quarries were

**Table 2.** Comparisons of life-history traits of catches of ground beetles and spiders originating from quarries and at adjoining seminatural sites in the Blansky les Mts. Weighted averages per trap and individual were compared using ANOVA for *character* (quarries vs. seminatural sites), and by Kruskal-Wallis ANOVA for *substrate* (granulite vs. limestone) and *biotope* (rocky, herbaceous and scrubby). See ‘Material and methods’ for life-history traits description.

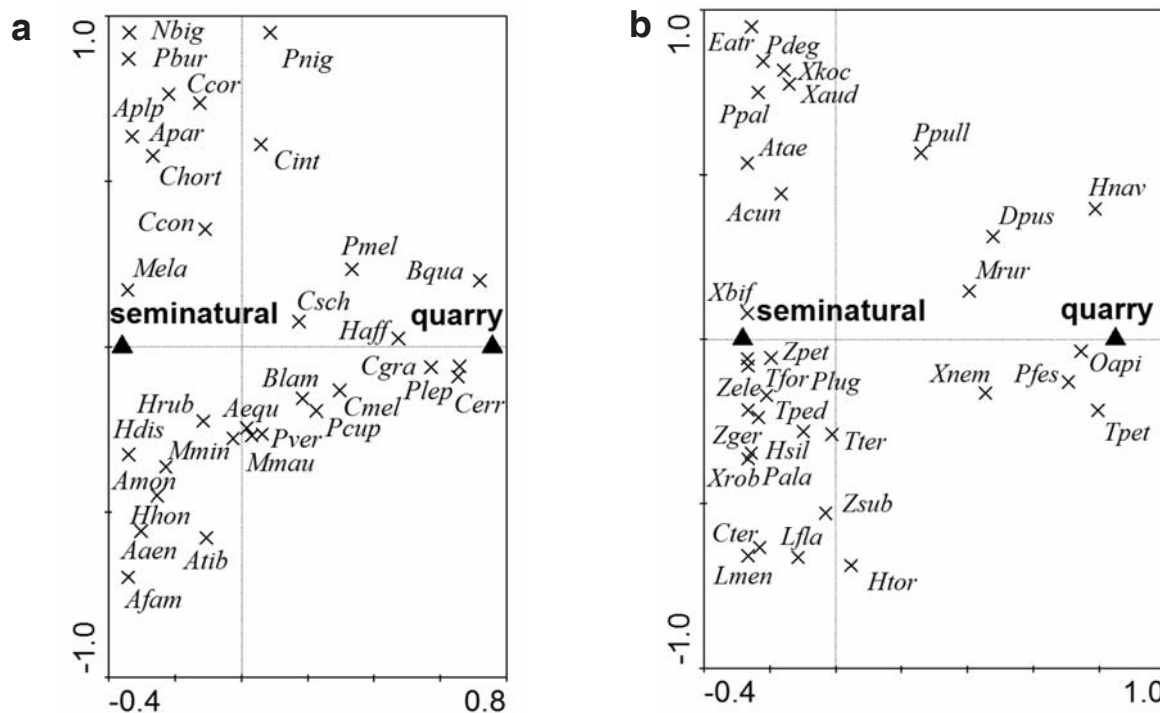
Traits compared	Ground beetles				Spiders			
	ANOVA	df	F	p	Direction	F	p	Direction
<i>character</i>								
Habitat quality	1	0.72	ns	-	1.69	ns	-	
Humidity requirement	1	0.02	ns	-	0.01	ns	-	
Light requirement	1	2.39	ns	-	26.61	**	q > sn	
Distribution extent	1	0.03	ns	-	42.93	**	sn > q	
<i>substrate</i>								
Habitat quality	1	1.02	ns	-	0.24	ns	-	
Humidity requirement	1	3.09	ns	-	0.66	ns	-	
Light requirement	1	1.40	ns	-	1.53	ns	-	
Distribution extent	1	8.64	**	g > l	9.13	*	g > l	
<i>biotope</i>								
Habitat quality	2	28.06	**	(sc = r) < h	0.19	ns	-	
Humidity requirement	2	16.97	**	sc > (h = r)	8.06	*	sc > (h = r)	
Light requirement	2	43.29	**	sc < (h = r)	27.84	**	sc < (h = r)	
Distribution extent	2	3.57	ns	-	12.04	*	(sc = h) > r	

Abbreviations in column “direction” – Character: q, quarry; sn, seminatural. – Biotope: h, herbaceous; r, rocky; sc, scrubby. – Substrate: g, granulite; l, limestone. ns: not significant; \*, p < 0.05; \*\*, p < 0.01.

formed by significantly different sets of species than those inhabiting the seminatural habitats. The substrate had no effect on species richness of both groups, but limestone sites hosted spiders and ground beetles demanding habitats of higher quality (according to Buchar 1983). Importantly, the quarries tended to be occupied by regionally rarer spiders (Tropek and Konvicka 2008), but no such pattern applied to

ground beetles. A survey limited to ground beetles only, as well as a survey limited to species richness, would therefore fail to detect the conservation potential of the quarries.

The differences in life-history traits between the two groups were not dramatic: none of the life-history patterns disclosed for one group went in an opposing direction for the other group. Still, the few differences between ground bee-



**Figure 3.** Ordination diagram of CCA analysis, comparing ground beetles and spiders catches in quarries and adjoining seminatural habitats of the Blansky les Mts. (a) Ground beetles: 1st axis % var. expl. = 2.6, F = 9.09, p = 0.001. (b) Spiders: 1st axis % var. expl. = 2.2, F = 8.16, p = 0.001. Only species having the highest fit (more than three per cent) to the ordination model are shown. See Appendix, for species names.

tles and spiders warrant interpretation, considering that our survey targeted two groups of remarkably similar ecology, both being composed of ground-dwelling predators. Among the recent studies using multi-taxa approach for comparing the conservation value of habitats, disparities seem to be frequent among groups exhibiting different life-history traits. Examples include comparisons between generalist and specialist beetles (Batáry et al. 2007), diurnal butterflies and nocturnal moths (Ricketts et al. 2002, Cremene et al. 2005, Baur et al. 2006), and vertebrates, invertebrates and plants (e.g., Kati et al. 2004, Roth et al. 2008).

The fact that the quarries tended to be colonised by regionally rare spiders but not by regionally rare ground beetles is probably due to differences in the composition of species pools providing colonists for these early-successional sites (cf. Brandle et al. 2003, Broring and Wiegler 2005, Novak and Konvicka 2006). Czech spider fauna contains a considerable number of specialists of open rocks and scree, many of them with restricted distribution and of conservation interest (Ruzicka 2000, Buchar and Ruzicka 2002). Rocky habitats are rare in the wide environs of study sites, but spiders as a group are efficient colonisers, profiting from the ability of ballooning (Wheater et al. 2000, Edwards and Thornton 2001, Weyman et al. 2002). On the other hand, practically all ground beetles inhabiting the quarries were common generalists, occurring at such inhospitable habitats as arable fields. Because they depend on ground-running or on active, distance-limited flight (cf. Small et al. 2006, Gutierrez et al. 2004) or form fully-winged adults just occasionally (Hurka 1996, Kotze and O'Hara 2003), ground beetles are poorer dispersers than spiders. Typical habitats of the rare representatives of Czech ground beetles that exploit early-successional conditions include exposed riverine sediments and gravel and sand beds. These species usually disperse along water courses (Andersen 2000, Andersen and Hanssen 2005, Bates et al. 2007). Because none of our quarries adjoined a river, they were still not accessible for such colonists.

#### Conclusions for conservation and monitoring

The previous finding that quarries tended to be colonised by regionally rare species of spiders (Tropék and Konvicka 2008) did not apply to ground beetles. This observation supports the claims that assessment of conservation value of natural localities, and planning of their future uses, should be based on multiple groups. This multi-taxa or 'shopping basket' approach (Niemela and Baur 1998, Sauberer et al. 2004) may be particularly important for heavily human-exploited, early-successional or dynamic environments, such as various kinds of post-industrial barrens, where taxon-specific peculiarities in dispersal and colonisation ability affect the composition of local communities.

Another message of this study is the necessity to consider species identities, and life-history traits, in conservation surveys and monitoring. Too often, monitoring projects conclude by comparing species richness or such indices as diversities or specialists: generalists ratios. In our case, the sites

did not differ in species richness at all. Considering that data collection and species identification consume the largest shares of monitoring costs, it is unwise to stop and only compare richness, and it is highly desirable to invest into deeper, species-level analyses.

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- Appendix. Key to species abbreviations.**
- Ground beetles (Figure 3a). Aaen – *Amara aenea* (De Geer, 1774); Aequ – *Amara equestris* (Duftschmid, 1812); Amon – *Amara montivaga* Sturm, 1825; Apar – *Abax parallelus* (Duftschmid, 1812); Aplp – *Abax parallelepipedus* (Piller & Mitterpacher, 1783); Atib – *Amara tibialis* (Paykull, 1798); Blam – *Bembidion lampros* (Herbst, 1784); Bqua – *Bembidion quadrimaculatum* (Linnaeus, 1761); Ccon – *Carabus convexus* Fabricius, 1775; Ccor – *Carabus coriaceus* Linnaeus, 1758; Cerr – *Calathus erratius* (C. R. Sahlberg, 1827); Cgra – *Carabus granulatus* Linnaeus, 1758; Chor – *Carabus hortensis* Linnaeus, 1758; Cmel – *Calathus melanocephalus* (Linnaeus, 1758); Csch – *Carabus scheidleri* Panzer, 1799; Haff – *Harpalus affinis* (Schrank, 1781); Hdis – *Harpalus distinguendus* (Duftschmid, 1812); Hhon – *Harpalus honestus* (Duftschmid, 1812); Hrub – *Harpalus rubripes* (Duftschmid, 1812); Mela – *Molops elatus* (Fabricius, 1801); Mmau – *Microlestes maurus* (Sturm, 1827); Mmin – *Microlestes minutulus* (Goeze, 1777); Nbig – *Notiophilus biguttatus* (Fabricius, 1799); Pbur – *Pterostichus burmeisteri* Heer 1841; Pcup – *Poecilus cupreus* (Linnaeus, 1758); Plep – *Poecilus lepidus* (Leske, 1785); Pmel – *Pterostichus melanarius* (Illiger, 1798); Pver – *Poecilus versicolor* (Sturm, 1824).
- Spiders (Figure 3b). Acun – *Alopecosa cuneata* (Clerck, 1757); Atae – *Alopecosa taeniata* (C. L. Koch, 1835); Cter – *Coelotes terrestris* (Wider, 1834); Dpus – *Drassyllus pusillus* (C. L. Koch, 1833); Eatr – *Erigone atra* Blackwall, 1833; Hnav – *Hahnina nava* (Blackwall, 1841); Hsil – *Haplodrassus signifer* (C. L. Koch, 1839); Htorp – *Histopona torpida* (C. L. Koch, 1834); Lfla – *Lepthyphantes flavipes* (Blackwall, 1854); Lmen – *Lepthyphantes mengei* Kulczynski, 1887; Mrur – *Meioneta rurestris* (C. L. Koch, 1836); Oapi – *Oedothorax apicatus* (Blackwall, 1850); Pala – *Pardosa alacris* (C. L. Koch, 1833); Pdeg – *Pachygnatha degeeri* Sundevall, 1830; Pfes – *Phrurolithus festivus* (C. L. Koch, 1835); Plug – *Pardosa lugubris* (Walckenaer, 1802); Ppal – *Pardosa palustris* (Linnaeus, 1758); Ppul – *Pardosa pullata* (Clerck, 1757); Tfor – *Thanatus formicinus* (Clerck, 1757); Tped – *Trachyzelotes pedestris* (C. L. Koch, 1837); Tpet – *Talavera petrensis* (C. L. Koch, 1837); Tter – *Trochosa terricola* Thorell, 1856; Xaud – *Xysticus audax* (Schrank, 1803); Xbif – *Xysticus bifasciatus* C. L. Koch, 1837; Xkoc – *Xysticus kochi* Thorell, 1872; Xnem – *Xerolycosa nemoralis* (Westring, 1861); Xrob – *Xysticus robustus* (Hahn, 1832); Zele – *Zelotes electus* (C. L. Koch, 1839); Zger – *Zodarion germanicum* (C. L. Koch, 1837); Zpet – *Zelotes petrensis* (C. L. Koch, 1839); Zsub – *Zelotes subterraneus* (C. L. Koch, 1833).

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