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Ecological Engineering xxx (2006) xxx–xxx

ECOLOGICAL ENGINEERING

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Proximity of valuable habitats affects succession patterns in abandoned quarries[☆]

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Received 28 October 2004; received in revised form 6 May 2005; accepted 7 June 2005

Abstract

The study tested the hypothesis that the composition of vegetation formed during primary succession in basalt quarries is affected by the distance to, and area of, conservation-valuable biotopes of surrounding xerophilous grasslands. The successional vegetation was recorded in 270 relevés collected in 34 quarries in the area of Ceske Stredohori Hills, Czech Republic. We used detrended correspondence analysis to visualise the relationship between successional vegetation, ages of individual sites, and distances to the closest xerophilous grasslands. Subsequent regression analyses of fidelities of individual reléves to the grassland alliances *Festucion valesiacae* and *Allyso-Festucion pallentis* corroborated the view that the probability of development of valuable habitats within the quarries decreased with distance to the closest grassland sites, and increased with their area. It also increased with successional age, but this effect was suppressed if quarry identity was considered as covariable in the regressions. Our results show that the valuable biotopes would eventually develop in quarries situated less than 100 m from adjoining xerophilous grasslands. We advocate that quarry operators pay attention to conservation management of biotopes that surround excavation sites, because maintaining valuable vegetation in the vicinity will eventually reduce costs of post-excavation restoration.

Keywords: Basalt quarry; Primary succession; Restoration; Species pool; Xerophilous grasslands

1. Introduction

Most of the xerophilous grasslands in Western and Central Europe are products of traditional non-intensive land use, including light grazing, small-scale hay cutting, occasional burning, and scrub removal for fuel purposes (Thomas, 1993; Bignal and McCracken,

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[☆] *Nomenclature:* Kubat (2002) for taxa and Oberdorfer (1992) for syntaxa.

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doi:10.1016/j.ecoleng.2005.06.008

1996; Wilmanns, 1997; Poschlod and WallisDeVries, 2002). As intensive agriculture coupled with abandonment of less productive lands has replaced the traditional land use during the last decades, a considerable diversity of specialised plants and animals whose survival depends on now-outdated management practices face extinction threats (Hillier et al., 1990; Van Swaay, 2002).

One approach to battle this development is creation of protected areas (reserves) that are actively managed by mimicking traditional land use (e.g., Bobbink and Willems, 1993; Pärtel et al., 1998; Dolek and Geyer, 2002). However, since only small fragments of once extensive xerophilous grasslands remain in many regions, the approach will ultimately reach the limits of available space. Therefore, it is increasingly argued that areas of protected lands should be augmented by restoration of unproductive and even degraded lands for conservation of biodiversity (e.g., Young, 2000; Benes et al., 2003). Particularly promising in this respect are various types of post-industrial barrens, such as quarries, sand and gravel pits, mining dump heaps or old factory yards (e.g., Davis, 1982; Cullen et al., 1998; Novák and Prach, 2003). They typically contain thin topsoil, which slows down forest growth and maintains the sites in arrested successional stages. Spontaneous colonisation of post-industrial barrens by species of conservation interest has been reported for many organisms, including plants (Wheater and Cullen, 1997; Prach and Pysek, 2001), butterflies (Benes et al., 2003), beetles (Brandle et al., 2000), spiders (Bell et al., 2001), and birds (Bejcek and Tyrner, 1980), whereas the supply of traditionally managed habitats transferable into reserves is steadily shrinking, the extent of restorable barrens increases, as abandoning of once-exploited sites is an inherent feature of an industrial economy (Schulz and Wiegleb, 2000). Hence, conservation use of localities exploited by industry offers a cheap and socially acceptable opportunity to augment the already small and fragmented areas of high quality biotopes in many regions (cf. Rosenzweig, 2003).

Quarries rank highly among such localities because they represent large and prominent landscape features and occupy larger areas than reserves in many regions. They may host valuable assemblages of both plants and animals (e.g., Usher, 1979; Jefferson, 1984). Recently, restoration of abandoned quarries via spontaneous succession has been proposed as a cheap alternative to expensive technical reclamation (Benes et al., 2003; Novák and Prach, 2003; Prach, 2003). However, the conditions channelling successional development in disused quarries towards specific vegetation are little known. In particular, there is minimum information to what extent the vegetation surrounding quarry sites influences the course of succession.

We studied the role of surrounding vegetation on the course of successional development in abandoned quarries within an ancient volcanic region of the Czech Republic. In this region, the biotopes most valuable from the conservation point of view are semi-natural xerophilous grasslands, protected by the EU Habitat Directive (Appendix A classification: Rupicolous pannonic grasslands and semi-natural dry grassland and shrubland facies on calcareous substrates). We tested the hypothesis that the distance to adjoining xerophilous grasslands and the proportion of the grasslands in quarry surroundings affects the vegetation of successional sites within the quarries. We used an ordination technique to describe the changes in plant species composition during succession in relation to the age following site abandonment, and the distance and extent of xeric grasslands in the quarry vicinity. Then, we use regression techniques to assess the effect of surrounding grasslands upon the composition of vegetation of successional sites.

2. Methods

2.1. Study area

The study was conducted within a 500 km^2 area situated in the Ceske Stredohori Hills, located in the north-western part of the Czech Republic, Central Europe, latitude 50°34′–50°48′N, longitude 13°41′–14°32′E (Fig. 1). The altitude ranges from 180 to 420 m, the climate is mild with a low snow cover in winter, the mean annual temperatures range between 7.5 and 9 °C, and the annual precipitation ranges between 500 and 600 mm (Kubat, 1970).

The landscape is a mosaic of deciduous forests, fields, hay meadows, human settlements, and xerophilous grasslands. The forests, dominated by mesophilous oak-hornbeam and thermophilous oak woodlands, cover 30% of the landscape, whereas xerophilous grasslands (less than 5% of the landscape)

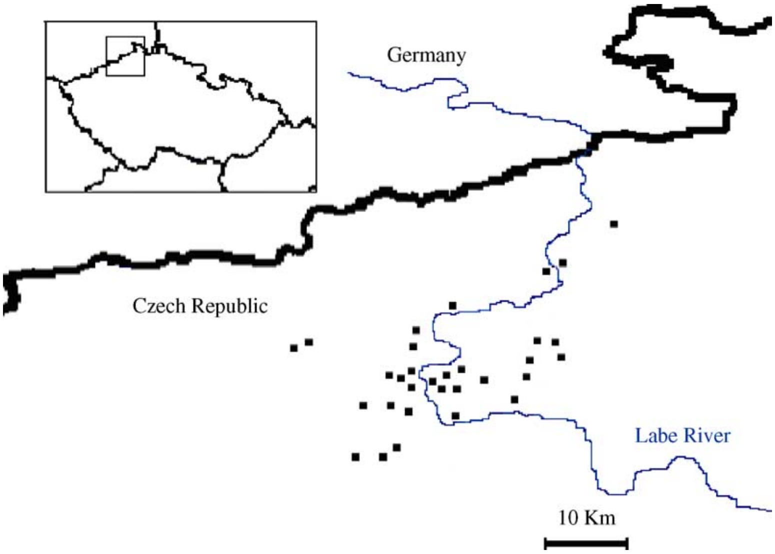

Fig. 1. Map of the study area showing its position in the Czech Republic and locations of the studied quarries.

are found either at steep and dry slopes unsuitable for forest growth or at sites of former pastures.

2.2. Vegetation of xerophilous grasslands

Two types of semi-natural xerophilous grasslands occur in the area, closed-sward ones occurring on well-developed soils and open-sward ones occurring on rocky substrates. Central European phytosociologists classify them as *Festucion valesiacae* and *Allyso-Festucion pallentis* alliances, respectively (Oberdorfer, 1992). A quantification of variation within these two alliances (Chytry and Tichy, 2003) showed that both are well-delimited, with 97.7 and 48.3% of species, respectively, being confined to them or rare in other alliances.

The *Festucion valesiacae* alliance consists of species-rich formations dominated by thin-bladed tussock forming grasses, such as *Festuca valesiaca*, *Stipa* spp. and *Carex humilis*, accompanied by perennial herbs, such as *Potentilla arenaria*, *Eryngium campestre* and *Thymus pannonicus*, and spring ephemerals, such as *Arenaria serpyllifolia* or *Acinos arvensis*. Many of the species exhibit continental range types, reaching from Russian steppes to Central Europe. The formation is considered to be a relic from early post-glacial period, preserved owing to centuries-long grazing of domestic animals.

The *Alysso-Festucion* alliance is found on steep sun-exposed rocks and scree. The dominant grass is *Festuca pallens*, accompanied by hemicryptophytes, such as *Artemisia campestris*, *Aurinia saxatilis*, *Centaurea stoebe* and *Seseli osseum*, and by succulents including *Sedum album* and *Jovibarba globifera* (for details, see Chytry et al., 2001; Chytry and Tichy, 2003).

Industrial quarrying of basalt was initiated in the 1920s and culminated in the 1980s in the region. There are now 34 quarries in total, 9 of which are still active. Owing to the diverse landscape, none of the quarries is situated further than 4 km from a xerophilous grassland.

2.3. Data collecting

We sampled spontaneously re-vegetated sites in all 34 quarries present in the study region. In still operating quarries, freshly abandoned sites (1 year after excavation) were sampled. Within each quarry, we sampled vegetation by recording 5 m × 5 m phytosociological relevés of representative successional stages, using the seven-degree Braun-Blanquet scale (Braun-Blanquet, 1964) to estimate covers of all species of higher plants present. The collected data consisted of 270 relevés (mean per quarry = 8, S.D. = 6.5, median = 5), containing 393 species of higher plants (mean per relevé = 21, S.D. = 6.9, median = 20).

We used historical maps and information from quarry operators for dating successional age of the sampled sites. The age since cessation of quarrying ranged from 1 to 78 years. Because exact dating was not always possible, we used the following ordinal scale: (1) <3 years; (2) 4–10 years; (3) 11–25 years; (4) 26–40 years; (5) >40 years.

We located xerophilous grasslands surrounding the quarries by surveying the vicinity of each quarry with aerial photographs and detailed (1:5000) topographic maps. The percentage proportion of the biotope in concentric circles around each relevé (up to 30, 31–100, 100–300 and more than 300 m from the relevé) was then recorded using the maps.

2.4. Statistical analyses

To visualise the effect of distance to xerophilous grasslands on succession within the quarries, we used detrended correspondence analysis (DCA). DCA is an indirect ordination method that ordinates the positions of samples according to their species composition. Ages of individual relevés, and the distance of the relevés to the closest patches of xeric grasslands, were superimposed onto the ordination as supplementary environmental variables. We used CANOCO v. 4 (ter Braak and Smilauer, 1998), option “detrending by segments”.

We used fidelity of individual relevés (herein sample fidelity, Φ_R) towards the pre-defined vegetation alliances *Festucion valesiacae* and *Alysso-Festucion pallentis*, as a measure of similarity between the successional sites and the semi-natural grasslands. The analysis was based on species fidelities Φ_S or coefficients of association between individual species and the two above alliances. Fidelities of individual species of Czech flora towards all vegetation alliances were tabulated by Chytry and Tichy (2003) using empirical data stored in the Czech National Phytosociological Database, an immense source containing 54,310 reléves collected by 332 authors between 1922 and 2002 (Chytry and Rafajova, 2003).

The computing algorithm for species fidelity is,

$$\Phi_S = \frac{N \cdot n_P - n \cdot N_P}{\sqrt{n \cdot N_P \cdot (N-n)(N-N_P)}}$$

where N is the number of relevés in the database, N_P the number of reléves in the particular vegetation unit P, n the number of occurrences of the species in the database, and n_P is the number of occurrences of the species in P (Sokal and Rohlf, 1995; Chytry et al., 2002). The values of species fidelities range from −1 to 1, Chytry and Tichy (2003) consider species with $\Phi_S > 0.18$ as diagnostic for individual alliances.

Based on the species fidelities, we computed sample fidelities Φ_R for each of our reléves. We used the Φs of individual species towards the alliances *Festucion valesiacae* and *Alysso-Festucion pallentis*, as given by Chytry and Tichy (2003), entering middle values for species with a a fidelity towards both alliances. The computation was,

$$\Phi_R = \sum_{i,j} (\Phi_S \cdot N_S)$$

i.e., sum of fidelities of all species present in the sample weighted by their percentual abundances N_S. For species not considered diagnostic for either of the two alliances, Φ_S were set to zero.

We then regressed the sample fidelities against the distance to surrounding xerophilous grasslands and (arcsine transformed) percentual areas of the grasslands. The method was generalised linear modelling with assumed Poisson distribution of the response variable and log link (S-plus, 1999–2000). Then, we tested single-term relationships, and finally constructed a multiple-regression model based on forward stepwise selection procedure from all variables and their interactions. We then repeated the analysis with forcing quarry identity as a categorial covariable onto the null model. This allowed controlling for pseudo-replication effect of multiple samples taken from one quarry, and for effects of such site-specific patterns as differences in altitude or climate.

3. Results

The course of succession in the quarries is visualised in Fig. 2. In early stages (<4 years), there is little difference among the samples, which is evident from the short gradient on the horizontal axis, and all the early samples exhibit a strong fit of widespread annual weeds (e.g., *Arenaria serpyllifolia*, *Conyza canadensis*, and *Tripleurospermum inodorum*). With increasing age, the samples diverge according to their distance to the xerophilous grasslands. Those in closest distances

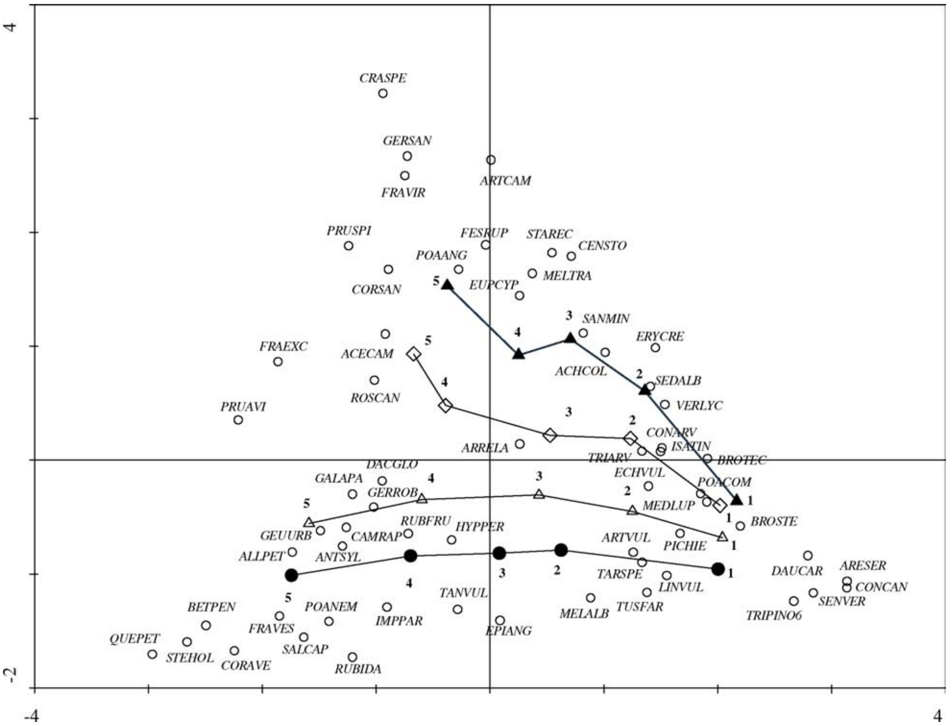

Fig. 2. Detrended correspondence analysis ordination diagram showing positions of species in samples collected from successional sites in basalt quarries. Successional age and distance to the closest xerophilous grassland were entered to the ordination as supplementary environmental variables. First and second canonical axes are shown. *Eigenvalues:* 1st axis, 0.67; 2nd axis, 0.49; sum of all eigenvalues, 2.71. The successional trajectories were created by connecting centroids of samples in particular successional age and distance class. The bold numbers accompanying the symbols delimit successional age: (1) <3 years; (2) 4–10 years; (3) 11–25 years; (4) 26–40 years; (5) >40 years. The symbols indicate the distances to the closest xerophilous grasslands: (▲) <30 m; (◇) 30–100 m; (△) 150–300 m, (●) >300 m. See Appendix A for abbreviations of species names.

exhibit the strongest fit of characteristic steppe grasses and forbs (e.g., *Artemisia campestris*, *Festuca rupicola*, *Melica transsilvanica*, *Potentilla incana*, and *Stachys recta*). This applies even to the latest successional stages. Here, however, the above species become accompanied by mesophilous herbs (e.g., *Fragaria viridis*), grasses (e.g., *Poa angustifolia*), and shrubs (e.g., *Prunus spinosa*, *Crataegus* sp.). Sites situated further from the xerophilous grasslands (with threshold at ca. 100 m) are dominated by tall mesophilous grasses (e.g., *Arrhenatherum elatius*) in middle-successional stage and by mesophilous scrub (i.e., *Fraxinus excelsior*, *Betula pendula*, and grass *Brachypodium sylvaticum*) in the latest stages.

The values of sample fidelities were distinctly right-skewed, ranging from $\Phi_R = 0.0$ to 33.0 with mean = 3.0 and median = 2.0. Single-term regressions (Table 1) corroborated the role of distance to the nearest xerophilous grassland and of the area of the surrounding grasslands on the course of succession. Sample fidelities increased with increasing area of surrounding grasslands, which was the best predictor in terms of decrease of model deviance, and decreased with grassland distance. They also increased with successional age. When the (highly significant) effect of quarry entered the regressions as a covariable, the area and distance retained their effects, while the effect of successional age dissipated. This was expected, as individual quarries differed in ages.

The multiple regressions pointed to the independent effects of area and distance on the composition of suc-

Table 1
Single-term regressions of fidelities of vegetation samples recorded at successional sites within basalt quarries against distance to nearest xerophilous grasslands, and areas of the xerophilous grasslands surrounding the sites

Model	Regressions without covariable						Regressions containing covariable					
		d.f.	Deviance[a]	qAIC[b]	*F*	*p*		d.f.	Deviance	qAIC	*F*	*p*
Null		269		1526.4								
Quarry							(–)	33, 236	55.3	814.4	9.6	***
Distance	↓	1, 268	51.2	763.9	158.4	***	↓	34, 235	7.0	683.7	44.2	***
Area	↑	1, 268	55.7	683.9	304.4	***	↑	34, 235	13.6	548.1	109.1	***
Age	↑	1, 268	6.6	1444.6	16.0	***		34, 235	0.01	813.4	3.2	NS

Generalised linear models with assumed Poisson distribution of response variable. The darts (↓ and ↑) show directions of the relationships. Values of F and p are related to null model ($y \sim +1$) in regressions without covariable, and to model containing quarry as a categorical covariable in regressions with covariable.

*** $p < 0.0001$.

[a] Percentage deviance explained by the fitted model.

[b] Quasi-Akaike information criterion, weighting explained deviance by model complexity; the lower the value, the better and more parsimonious is model fit.

Table 2
Multiple-regression models of association of vegetation successional sites within basalt quarries to distance and area of adjoining xerophilous grasslands

Model	d.f.	Deviance	AIC	*F*	*p*
Quarry identity not in the model[a]					
+Area – distance + age + (distance × age) + (area × age)	5, 264	73.5	431.1	1117.5	***
Quarry identity as a covariable[b]					
+Area – distance + (area × distance)	3, 233[*]	18.2	506.1	42.4	***

Generalised linear models with assumed Poisson's distribution of response variable.

*** $p < 0.0001$.

[a] Deviance values and significance test computed against null model.

[b] Deviance and significance computed against a model containing covariable.

cessional vegetation (Table 2). In addition, there were significant non-additive interactions between explanatory variables. In the model without covariable, the decrease of sample fidelities with increasing distance to xerophilous grassland was steeper in older quarries (distance × age in Table 2). Also, sample fidelities grew with area of surrounding grasslands rather monotonously at young sites, whereas at old sites, they remained close to zero until a cutting value of some 40% of grasslands, and then, steeply increased (interaction area × age in Table 2).

Controlling for quarry identity (by inclusion of covariable "quarry") pointed to a significant interaction between area and distance. If the grasslands were found within low distances, the fidelities grew linearly with grassland area, whereas in large distances (above ca. 100 m) they remained low irrespective of grassland area (Fig. 3).

4. Discussion

4.1. Ecological interpretation

The course of succession in basalt quarries towards conservation-desirable xerophilous grasslands is strongly affected by the distance to the nearest grassland and the proportional share of the grasslands in quarry environs. Therefore, the successional assemblages are not randomly drawn from the vegetation of the wider study area, but depend on the species pool within a close distance. This was expected, as the probability that an organism arrives at a site during succession is related to size and distance of source populations (Willson, 1993), and the dispersal ability, quality, and abundance of its propagules (Hansson, 1991; With and Crist, 1995; Stryskstra et al., 1996; Hillebrand and Blenckner, 2002). However, the role of proximity of

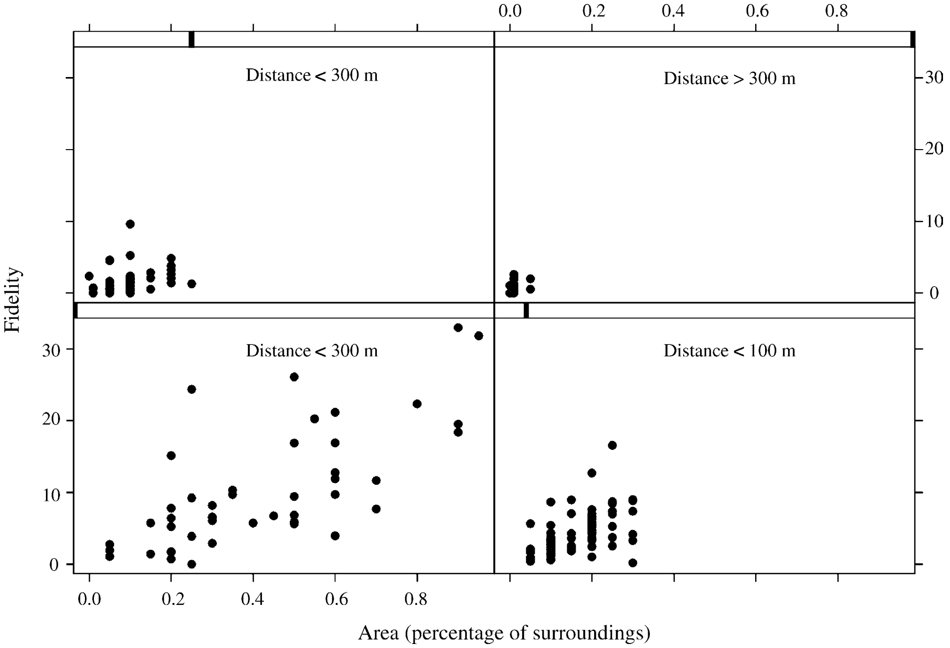

Fig. 3. Trellis diagram showing the interaction effect of area of surrounding xerophilous grasslands and distance to the grasslands on fidelity of successional vegetation to vegetation formations of xerophilous grasslands (i.e., interaction area × distance from Table 2).

sources on the course of succession remains sparsely documented. A majority of studies that focused on the role of surrounding species pool on the successional development deal with secondary succession at such sites as abandoned fields (Foster et al., 2004) or newly planted woods (Butaye et al., 2002; Dupré et al., 2002). Studies focusing on primary succession are scarce, and studies dealing with industry-created primary succession sites are practically non-existent (but see Kirmer and Mahn, 2001; Campbell et al., 2003). By selecting quarries as a model system, we demonstrated the role of surrounding species pool on the course of primary succession, using a relatively large sample of sites situated on identical substrate and within an identical climatic region. The use of sample fidelities, as measures of association between successional sites and surrounding semi-natural vegetation, facilitated simple and unequivocal testing of our hypotheses.

The arrival of some species before others determines the course of succession through shifts in competitive abilities (Lawton, 1987; Grace, 1987; Tilman, 1994). In the studied area, the time of arrival and rate of establishment of plants characteristic for xerophilous grasslands determines whether a site will develop towards a biotope of high conservation value or towards a mesophilous scrub (Novák and Prach, 2003). Whereas the extreme environmental conditions of barren basalt rock prevent establishment of woody species in early stages of succession, in later stages, the presence or absence of relatively competitive grasses determines whether woody plants would take over or not (Connel and Slayter, 1977). Apparently, propagules of grassland species arrive earlier, and in larger amounts, if there are large grasslands in the surroundings.

A closer look into the plants recorded in the quarries that exhibited high fidelities to xerophilous grasslands allows distinguishing two distinct groups. One consisted of poor competitors that thrive at disturbed and/or rocky surfaces with minimum soil (e.g., *Erysimum crepidifolium*, *Sedum album*, *Trifolium arvense*). The other group included plants forming closed turf at sites with fully developed soils (e.g., *Festuca valesiaca*, *Koeleria macrantha*, *Stipa pennata*). Some representatives of the former group occurred even in quarries situated further from xerophilous grasslands, but were rare at older successional stages. In contrast, plants of the latter group occurred only at older stages that adjoined large tracts of xerophilous grasslands (personal observation). The dichotomy is easily interpretable, as species of the former groups are good dispersers that can colonise the quarries even from relatively distant sources, but cannot withstand competition with later-arriving mesophilous species. The latter group, on the other hand, consists of poorer dispersers but better competitors (Ellenberg, 1979; Grime, 1979).

Naturally, some woody cover would ultimately develop in all the studied quarries, except perhaps on steep rocks and screes (Ursic et al., 1997; Novák and Prach, 2003). This seemingly conflicts with the increase of fidelity with age observed in our analyses. The paradox is explicable by the limited range of quarry ages available in study area; none of the quarries was older than 80 years, whereas primary succession into woodlands may take centuries (Elias and Dias, 2004; Nishi and Tsuyuzaki, 2004). It is also notable that old quarries tended to be surrounded by larger xerophilous grasslands than young ones (grassland area and age were marginally significantly correlated, Spearman's $r = 0.12$, $t_{268} = 1.93$, $p = 0.054$), perhaps, because it was easier for the past operators to begin excavations in grasslands and rocks than elsewhere.

Finally, it should be noted that the entire landscape surrounding the quarries had passed a substantial transformation during the last half-century due to decline of pasture land and the increase of forests (Barta, 1999; Sadlo and Pokorny, 2003). This will likely influence the course of future succession in some of the quarries studied. The average quarry abandoned some 50 years ago was surrounded by more xeric grasslands than an average quarry abandoned in the present. It can be expected that in recently closed quarries, spontaneous development of “mature” xerophilous grasslands (corresponding to the upper part of the ordination diagram in Fig. 2) will become increasingly rarer, unless a purposeful management changes the course. Instead, a majority of recent quarries may spontaneously develop more mesophilous vegetation.

4.2. Applied implications

Our findings may result into the paradoxical advice to locate new quarries next to biologically valuable sites or taken to the extreme, directly within reserves. This would be absurd if we do not call for sacrificing valuable biotopes to quarrying, and insist that new excavations should be located at lands with minimum conservation value, such as plantation forests or intensively farmed land. However, if there is a choice between locating a quarry near an existing xerophilous grassland or far from it, we advise the former alternative. Provided that a quarry will be ultimately restored via spontaneous succession (Prach, 2003), it will attain higher conservation value if located closely to valuable habitats.

It is equally important that high quality biotopes should persist in quarry vicinity in order to provide colonising propagules for eventual succession after cessation of quarrying. This highlights the importance of managing the areas surrounding active quarries. It is in the best interest of quarry operators to support such activities as non-intensive grazing, hay and shrub cutting, conservation burning, or eradication of aggressive alien species at grasslands adjoining excavated sites (e.g., Sutherland and Hill, 1995). The above activities may be prohibitively expensive for conservationists, but relatively cheap if compared with the budgets of excavating companies. For them, investments into the maintenance of high-quality vegetation around quarries may ultimately cut the costs of restoration after quarry closure.

Acknowledgements

Our interest in quarry ecology has developed in fruitful discussions with J. Benes, P. Kepka, J. Sadlo, and M. Tichy. M. Chytry, K. Prach, and two anonymous referees contributed valuable suggestions to earlier versions of the manuscript. Z. Fric helped with preparing the graphs, and M. Sweney improved our English. Funding was provided by the Czech Department of Education (6,007,665,801).

Appendix A. Abbreviations of plant names appearing in Fig. 2

ACECAM	*Acer campestre*
ARESER	*Arenaria serpyllifolia*
ACHCOL	*Achillea collina*
ALLPET	*Alliaria petiolata*

ANTSYL	*Anthriscus sylvestris*
ARRELA	*Arrhenatherum elatius*
ARTCAM	*Artemisia campestris*
ARTVUL	*Artemisia vulgaris*
BETPEN	*Betula pendula*
BROSTE	*Bromus sterilis*
BROTEC	*Bromus tectorum*
CAMRAP	*Campanula rapunculoides*
CRASPE	*Crataegus* sp.
CENSTO	*Centaurea stoebe*
CORSAN	*Cornus sanguinea*
CONARV	*Convolvulus arvensis*
CORAVE	*Corylus avellana*
CONCAN	*Conyza canadensis*
DACGLO	*Dactylis glomerata*
DAUCAR	*Daucus carota*
ERYCRE	*Erysimum crepidifolium*
EPIANG	*Epilobium angustifolium*
EUPCYP	*Euphorbia cyparissias*
FRAVIR	*Fragaria viridis*
FRAVES	*Fraxinus excelsior*
FESRUP	*Festuca rupicola*
GERSAN	*Geranium sanguineum*
GERROB	*Geranium robertianum*
GEUURB	*Geum urbanum*
GALAPA	*Galium aparine*
HYPPER	*Hypericum perforatum*
ISATIN	*Isatis tinctoria*
IMPPAR	*Impatiens parviflora*
LACSER	*Lactuca serriola*
LINVUL	*Linaria vulgaris*
MELTRA	*Melica transsilvanica*
MELALB	*Melilotus albus*
MEDLUP	*Medicago lupulina*
POAANG	*Poa angustifolia*
POACOM	*Poa compresa*
POANEM	*Poa nemoralis*
PICHIE	*Picris hieracioides*
PRUAVI	*Prunus avium*
PRUSPI	*Prunus spinosa*
ROSCAN	*Rosa canina*
RUBFRU	*Rubus fruticosus*
RUBIDA	*Rubus idaeus*
QUEPET	*Qeurcus petrea*
SALCAP	*Salix caprea*
SANMIN	*Sanguisorba minor*
SEDALB	*Sedum album*
STAREC	*Stachys recta*
TANVUL	*Tanacetum vulgare*
TARSPE	*Taraxacum* sp.
TRIARV	*Trifolium arvense*
TRIINO	*Tripleurospermum inodorum*
TUSFAR	*Tussilago farfara*
VERLYC	*Verbascum lychnitis*

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