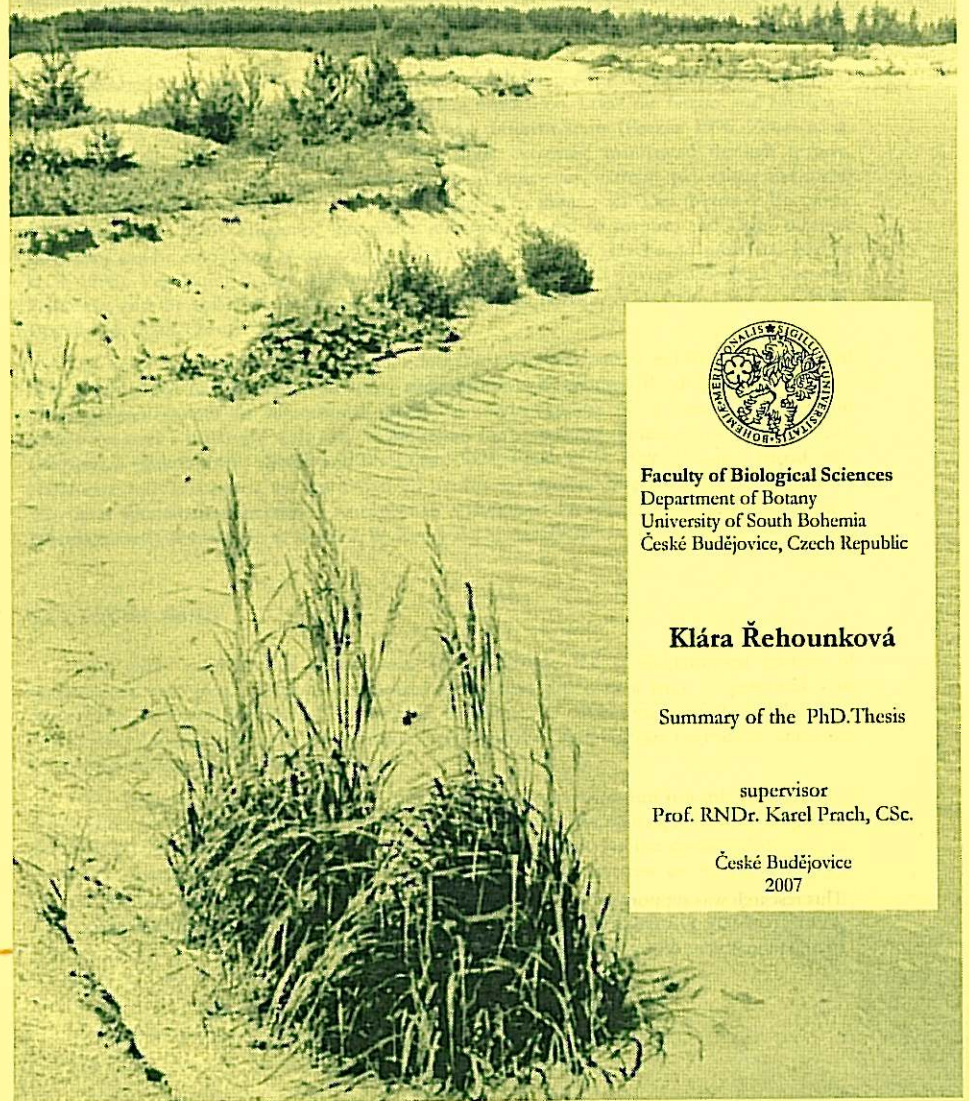


**Variability of spontaneous
vegetation succession in disused
gravel-sand pits: importance
of environmental factors
and surrounding vegetation**



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Summary of the PhD.Thesis

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Introduction

Primary succession is defined as species turnover on barren substrates where severe disturbances have removed most biological activity (Walker & del Moral 2003). Disused pits, where sand and gravel were extracted down to a depth of several metres, provide all of these conditions and represent suitable sites for research on succession, as processes of primary succession hardly ever can be observed elsewhere in the European cultural landscape, except for mining sites (Glenn-Lewin et al. 1992). Despite the fact that such sites are quite frequent in various landscapes, detailed or long-term studies on spontaneous vegetation succession in disused gravel-sand pits are very rare (Borgegård 1990) in contrast to other sites disturbed by extraction, including stone quarries (Ursic et al. 1997, Cullen et al. 1998, Novák & Prach 2003) or dumps and wastes (e.g., Skousen et al. 1994, Kirmer & Mahn 2001, Wiegleb & Felinks 2001, Kovář et al. 2004).

Distinguishing which environmental factors most influence the development of vegetation in disturbed sites is crucial for successful ecosystem restoration. Local site factors and landscape factors act as selective filters of species possessing different traits (Bazzaz 1996, Zobel et al. 1998). Physical and chemical deficiencies or habitat extremes, manifested through texture, stability, temperature, water retention, severe nutrient deficiency, extreme pH values and metal toxicity, are common handicaps of many sites disturbed by mining activities (Marrs & Bradshaw 1993, Bradshaw 2000). However, low water retention, related to texture, and slight nutrient deficiency can be considered as the only limiting abiotic factors of gravel-sand substrates (Lubke et al. 1996). Vegetation change is related to local species pool and governed by both dispersal limitation, and the ability of species to establish and persist (Bakker et al. 1996, Díaz et al. 1998, Pywell et al. 2003, Ozinga et al. 2005).

Spontaneous succession often provides desirable target ecosystems and has a large potential as a suitable tool for restoration of many sites disturbed by mining (Prach 2007). Besides its potential contribution to successional theory, an understanding of spontaneous vegetation succession over a landscape scale may be important for promoting natural recovery of degraded ecosystems (Luken 1990, Klötzli and Grootjans 2001, Prach et al. 2006). Using a broad-scale experience with succession, we can tentatively predict the rate and direction of succession if we rely upon spontaneous succession or expect to manipulate the spontaneous development in a disturbed site (Glenn-Lewin et al. 1992, Walker & del Moral 2003).

Aims of the thesis

The main aims of this thesis were: (1) to analyze the spatial-temporal pattern of spontaneous vegetation succession in disused gravel-sand pits over a large geographical scale throughout the Czech Republic, (2) to quantify the effects of environmental factors influencing the course of succession, and (3) to evaluate the potential of spontaneous vegetation succession in restoration programs for particular pits.

The following main questions were asked: (1) Does succession run towards (semi-)natural vegetation within a reasonable time? (2) Is succession divergent or convergent inside and among the pits? (3) Are local site or landscape factors more important for the course of succession? (4) Which species traits are correlated with the colonization success of particular species?

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Contents

The thesis is composed of five original studies:

1.

Vegetation succession over broad geographical scales: which factors determine the patterns?

Prach K. & Řehouňková K. 2006. *Preslia* 78: 469-480.

We reviewed 37 studies on vegetation succession in which the succession started on bare ground, was followed in at least six sites, and where these sites were spatially separated over at least 10 km². The effect of environmental factors, which were explored in at least five studies, on the course of succession was assessed, based on the proportion of significant and non-significant results. Surrounding vegetation, macroclimate, soil moisture, amount of nitrogen and soil texture appeared to have the highest influence on the course of succession. Less influential were the size of a disturbed site, pH, organic matter and phosphorus content. Surrounding vegetation exhibited a significant effect in all cases where this was considered. These results imply that succession cannot be studied without the landscape context. The large-scale approach to succession has the potential to contribute substantially to both the theory of succession and practical applications, especially in restoration ecology.

2.

Spontaneous vegetation succession in disused gravel-sand pits: Role of local site and landscape factors

Řehouňková K. & Prach K. 2006. *Journal of Vegetation Science* 17: 583-590.

The following main questions were asked: (i) What is the variability of succession over a large geographical area? (ii) What is the relative importance of a) local site factors and b) landscape factors in determining spontaneous vegetation succession? The study was conducted in various regions of the Czech Republic, Central Europe. The regions represent two categories characterized by agrarian lowlands with a relatively warm and dry climate, and predominant woodland uplands with a relatively cold and wet climate. Gravel-sand pits (36) ranged in age from 1 to 75 years since abandonment. Three types of sites were distinguished: dry, wet, and hydric in shallow flooded sites. Together 224 vegetation relevés were recorded with species cover (%) visually estimated using the space-for-time substitution approach. Local site factors, such as water table and soil characteristics, and landscape characteristics, namely climatic parameters, presence of nearby (semi-)natural plant communities and main landcover categories in the broader surroundings, were evaluated. Ordination analyses showed that water table was the most important local site factor influencing the course of spontaneous vegetation succession. Succession was further significantly influenced by soil texture, pH, macroclimate, the presence of some nearby (semi-)natural communities and some land cover categories in the broader surroundings. Spontaneous vegetation succession led to the formation of either shrubby grassland, deciduous woodland, alder and willow carrs, and tall sedge or reed and cattail beds in later stages depending predominantly on the site moisture conditions. Although the water table was the most influential on the course of vegetation succession, the landscape factors together explained more vegetation variability (44%) than local site factors (23%).

3.

Spontaneous vegetation succession in gravel-sand pits: a potential for restoration

Řehounková K. & Prach K. 2007. Restoration Ecology, in press.

Vegetation variability, the participation of target and undesirable species and the role of local species pool were studied in the course of spontaneous succession in disused gravel-sand pits. The study was conducted in various regions of the Czech Republic, Central Europe. The regions represented either agrarian lowlands with a relatively warm and dry climate, or mostly woodland uplands with a relatively cold and wet climate. The gravel-sand pits (36) comprised stages of different age from 1 to 75 years since abandonment. Three types of environments were distinguished: dry, wet, and hydric in shallow flooded sites. Altogether, 224 vegetation samples were recorded with species cover (%) visually estimated. Species affinity to different vegetation types was assessed in each sample based on the species cover. Local site factors, such as water table and soil characteristics, and landscape characteristics, namely climatic parameters, presence of nearby (semi-)natural plant communities and main land cover categories in the broader surroundings, were evaluated as well as the participation of target (grassland, woodland, and wetland) and undesirable (ruderal, alien) species. Ordination analyses showed that vegetation succession led to target grassland, wetland, or woodland vegetation depending on local site factors and the presence of (semi-)natural vegetation in the surroundings (local species pool). Restoration of target vegetation in disused gravel-sand pits by processes of spontaneous succession can be possible and successful in about 20 yr, especially if (semi-)natural vegetation exists in the surroundings. The invasion of the alien tree *Robinia pseudacacia* must be taken into consideration within the dry sites in lowlands.

4.

Life-history traits and habitat preferences of species in relation to their colonization success in disused gravel-sand pits

Řehounková K. & Prach K. [manuscript]

We used plant life-history traits and habitat preferences by species to find which of the characteristics predict establishment of species in different successional stages inside the disused gravel-sand pits. Data were collected in 36 abandoned gravel-sand pits in various regions of the Czech Republic. Seral stages in the gravel-sand pits ranged in age from 1-75 years. Together 224 phytosociological relevés were recorded in 5 m x 5 m plots in representative parts of all available seral stages. Complete lists of species occurring in (semi-)natural habitats were surveyed up to the distance of 100 m from each relevé. Colonization success of each species was expressed by an index between 0-1 which was obtained as the ratio: the number of relevés with species present/the number of relevés with the species occurrence in the surroundings. Data were elaborated by the ordination analysis and the regression tree analysis. Results showed that certain traits were linked with colonization success in three main stages of vegetation succession: young, middle, and late. Generally, the most successful colonizers of disused gravel-sand pits were hydrophytes with ability to vegetative reproduction. At the beginning of succession, the most important role played anemochorous, stress tolerant species, possessing light diaspores, being typical for nitrogen poor and acid habitats. Later, the importance increased of sciophilous and nitrophilous species of mesic habitats, with heavier diaspores, mostly phanerophytes or geophytes, often with ability to vegetative reproduction and higher demands for pH. Probability of species occurring in the surroundings to colonize gravel-sand pits is decreasing in succession:

young stages - 41%, middle stages - 30%, late stages - 15%. Plant functional traits were recognized as powerful tools to predict colonization success of plants available in the local species pool. It may help in prediction of vegetation succession in various human-disturbed sites and thus be used in various restoration programmes.

5.

Spontaneous vegetation succession and the effect of abiotic factors in a disused gravel-sand pit

Řehounková K. & Prach K. [manuscript]

Variability of vegetation development and the relative importance of abiotic factors influencing spontaneous vegetation succession were studied in a disused gravel-sand pit in the eastern part of the Czech Republic (central Moravia). The study site was 2 ha and gravel and sand extraction was stopped in 1982. Four types of sites habitats were distinguished: mesic, wet, shallow flooded and aquatic. Vegetation relevés were recorded in 34 permanent plots (4 m x 1m). Semiquantitative cover of all vascular species and bryophytes was estimated by the seven point Braun-Blanquet scale. The vegetation samples were repeated between 1997 and 2005, that is 1, 2, 3, 4, 5 and 8 years since the extraction was stopped. Abiotic factors, such as water table and soil physical and chemical characteristics, were evaluated. Ordination analysis showed that, after eight years, vegetation development led to the formation either of mesic grassland with scattered shrubs, *Salix* carrs accompanied by *Phragmites australis*, *Typha latifolia* and *P. australis* or macrophyte vegetation in pools depending predominantly on site moisture conditions. Water table was the factor most influencing spontaneous vegetation development. Vegetation succession was further significantly influenced by other abiotic factors, namely soil texture and pH. The vegetation development and changes in abiotic factors, though observed for only the first 8 years of succession, showed similar trends as those resulting from a broad-scaled and multi-site study of gravel-sand pits throughout the Czech Republic.

Conclusions

The review of 37 studies on vegetation succession over a broader geographical scale, started on bare ground in various disturbed sites over the globe, showed that environmental factors have a significant influence on vegetation development. Besides time, i.e. successional age, landscape factors, namely surrounding vegetation and macroclimate, and some local site factors, i.e. soil moisture, amount of nitrogen and soil texture, had the highest influence on the course of succession. Organic content, pH, phosphorus content and size of a disturbed site are local site factors, which have significant effects only in some cases. Surrounding vegetation exhibited a significant effect in all cases whenever this was considered. The results imply that spontaneous succession in various types of disturbed sites, including mining sites such as gravel-sand pits, cannot be studied without a broader landscape context (Chapter I).

At the country scale, spontaneous vegetation succession in gravel-sand pits led to the formation of either shrubby grassland in dry sites in lowlands, deciduous woodland in dry upland sites, alder and willow carrs in wet sites, regardless of region, and tall sedge or reed and cattail beds in shallow flooded sites disregarding the region (Chapter II and III). Except for some dry sites in lowlands, where the alien species *Robinia pseudacacia* may expand, succession proceeds towards (semi-)natural vegetation within approximately 20 years (Chapter III). Site moisture was the most influential factor on the course of succession. The vegetation pattern was further significantly influenced by the following studied factors: pH and the proportions of silt and gravel among local site factors, and altitude, mean annual temperature, mean annual precipitation, presence of some vegetation types up to 100 m from a sampling site, and predominant land cover up to 1 km from a pit. Although the water table was the most influential on the course of vegetation succession, the landscape factors together explained more vegetation variability (44%) than local site factors (23%) (Chapter II).

Restoration of target vegetation, i.e. grassland, woodland or wetland, in the studied disused gravel-sand pits by processes of spontaneous vegetation succession can be successfully achieved in about 20 years. This means that no technical restoration is needed. The presence of (semi-)natural vegetation in the close surroundings facilitates this process; thus it is important to preserve at least some remnants of the vegetation during mining and postmining operations. However, the invasion of alien species, such as black locust (*Robinia pseudacacia*), in dry lowland sites in this study, must be taken into consideration. Such species should be eradicated in the vicinity of a pit before the onset of succession (Chapter III).

Plant functional types can be a powerful tool in predicting colonization success of species occurring in the surrounding (semi-)natural vegetation into disused gravel-sand pits. This may help in the prediction of spontaneous vegetation. It was documented that different traits were linked with colonization success in three main stages of vegetation succession: young, middle, and late. Generally, the most successful colonizers of disused gravel-sand pits were hydrophytes with the ability to vegetatively reproduce, while the least successful were annual weeds and ruderals. Moreover, species typical of natural vegetation are largely successful, mostly in the late stages. The anemochorous, stress tolerant species, with light diaspores typical for nitrogen poor and acid habitats, played the most important role at the beginning of succession. Later, the importance of sciophylous, nitrophilous species of mesic habitats with heavier diaspores, increased. These species are mostly phanerophytes or geophytes, often with the ability to reproduce vegetatively and higher demands on pH. The probability to colonize gravel-sand pits by species from the surroundings decreases during succession: young stages (41% of species appeared in a pit), middle stages (30%), late stages (15%) (Chapter IV).

Vegetation development and changes in abiotic factors, though observed on permanent plots for only the first 8 years of succession in only one extensive pit, showed similar trends as those resulting from a broad-scaled and multi-site study of gravel-sand pits throughout the Czech Republic using the space-for-time substitution approach. Spontaneous vegetation succession proceeded relatively quickly towards (semi-)natural vegetation shortly after abandonment of the restored gravel-sand pit, i.e. to grasslands with scattered shrubs in mesic habitats, *willow* carrs accompanied by *Phragmites australis* in wet habitats, *Typha latifolia* and *P. australis* in shallow water habitats or macrophyte vegetation in pools over the eight years. Site moisture was the most influential abiotic factor on the course of succession, but succession was further significantly influenced by other abiotic factors, such as texture and pH (Chapter V).

It can be concluded that in many restoration projects potentially scheduled for disused gravel-sand pits, we can completely rely upon spontaneous vegetation succession. Moreover, the disturbed sites provide a challenge for conservation biology, providing valuable biotopes, such as wetlands or open sand grasslands. On the other hand, the negative effects of intensive gravel and sand mining cannot be neglected, such as the destruction of valuable habitats or the presence of monotonous coniferous monocultures resulting from traditional technical reclamation of the pits.

Curriculum vitae

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