Ecological restoration in the Czech Republic

Editors

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Front cover photograph:
— Šumava foothills near Želnava. (Z. Patzelt)

Back cover photographs:
— Raking hay in Javorůvky NR, Bílé Karpaty PLA. (J.W. Jongepier)
— Disturbing sites with *Gentianella lutescens*, Pod Hribovňou NR, Bílé Karpaty PLA. (I. Jongepierová)
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Foreword

František Pelc

Despite strong efforts and partly positive results in the field of nature conservation, we have recently witnessed continuing deterioration of the natural environment and decrease in biodiversity on a global as well as a national scale. It is therefore no wonder that rather lively discussions have been going on between conservationists, biologists and other interested parties on ways of securing the protection of the most valuable natural environment, usually concentrated in small fragments, in total covering a few percent of our country's area. Sometimes this problem has unfortunately been centred around two rivalling visions: the approach of 'conservation' management (by some considered obsolete), based on non-intervention and preference of natural processes, on the one hand, and 'active' management (often considered modern), based on systematic intervention by man.

The dispute about what is more correct has led to endless discussions. I am convinced that most protected areas need some kind of active management. However, there will always be a wide range of options depending on what we want to protect – from preferring absolute protection of natural processes to very specific management simulating e.g. abandoned farming methods or preserving selected sites or protected species. Both approaches must be part of an integral concept of modern conservation and restoration of our natural heritage. They are mutually complementary and no antipodes. It is important to make clear what to protect and how to achieve this, taking into consideration the natural potential and historical context of a given area. Based on this, a long-term, sustainable strategic decision can be adopted, which must however not unpredictably be changed in the short term.

In general it would be desirable to respect the fact that man cannot steer everything in the natural environment, and protected areas are no exception. He does not have sufficient knowledge or means. After all, it is just a small step from here to the misused noosphere concept by Russian philosopher Vernadský. On the other hand, man has influenced the environment and environmental processes in such a way that many natural phenomena cannot be protected or rehabilitated anymore without his intervention.

The present publication is a representative display of restoration management case studies realised in various environments such as forests, wetlands, grasslands as well as specific sites damaged or created by mining or other activities. It should also contribute to the so desirable integration of views by scientists, conservationists, foresters, farmers, fishermen and other interested parties, and their application. As such it should become the starting point of a more effective use of scientific knowledge to preserve our nature and protect our landscape better.

Although the case studies mainly deal with so-called active management, I hope their overall impression will contribute to creating a state in which the management of protected areas and natural habitats will not be divided into 'conservational' and 'active', but rather be judged as good or bad.

František Pelc, Director
Nature Conservation Agency of the Czech Republic

Introduction

The Czech Republic, a country in central Europe, used to consist of a fine-scale mosaic of natural, semi-natural and anthropogenous ecosystems. However, this mosaic has been substantially disturbed in the second half of the 20th century under the communist regime. Many ecosystems were disturbed, degraded or destroyed.

The traditional nature conservation approach in the Czech Republic was, similarly to other countries, strictly protecting well-preserved ecosystems. Only in the past three decades, more active approaches utilising methods of ecological restoration have been adopted. These are applied to both existing ecosystems, such as meadows, and newly developing ones, for example sites disturbed by mining or developed on former arable land. Recently, also some attempts have been made to restore complete landscapes.

It is a highly positive trend that near-natural ways of restoration are gradually being accepted, not only in nature conservation but also by some decision-makers, mining companies, and increasingly by the public. Another favourable development is the collaboration of academics with practical restorationists, NGOs, and state authorities in various restoration projects.

However, the potential of near-natural restoration is not yet adequately exploited in the Czech Republic. Various heavily disturbed sites have been, and still are, technically reclaimed, i.e. restored by means of technical measures, with little regard to natural processes and denying the potential of modern ecological restoration methods. This is especially true for forest management and reclamation on heavily disturbed sites.

Restoration, and especially reclamation, activities are not always aimed at restoring ecologically desirable ecosystems, but often at gaining financial profit by private firms. In the latter case such activities lack a scientific background, are expensive and often meaningless. Besides financial profit, the reasons for this are ecological ignorance and lack of education. It is therefore necessary to make people aware of the fact that near-natural ecosystems usually provide much better ecosystem services to humans than uniform, technically reclaimed land.

In this publication we discuss the possibilities of ecological restoration and present selected case studies concerning woodlands, grasslands, wetlands, mining sites, military training areas, and landscapes as a whole. In this, we have attempted to illustrate Czech restoration activities as broadly as possible, although the authors' willingness and ability to submit contributions has also played a role. The compilation offers the participants of the 8th European Conference on Ecological Restoration held in České Budějovice, September 9–14, 2012 a representative overview of ecological restoration efforts in the Czech Republic.

We also hope it will contribute to a further development of restoration ecology as a branch of science and of practical ecological restoration in the country.

The editors

Nomenclature, abbreviations and explanatory notes

Nomenclature of plant species follows Kubát et al. (2002), names of non-forest plant communities are according to the recent vegetation compendium of the Czech Republic (Chytrý 2007, 2011; online version available at: http://www.sci.muni.cz/botany/vegsci/vegetace.php?lang=en), names of woodland and shrubland communities follow Chytrý et al. (2010).

Butterfly and moth species names follow the national checklist (Laštůvka & Liška 2005), names of most other invertebrates as well as vertebrate species follow the national red lists (Farkač et al. 2005, Plesník et al. 2003).

- **NP** – National Park
- **PLA** – Protected Landscape Area
- **NR** – Nature Reserve (including the categories National Nature Reserve, Nature Reserve, National Nature Monument, and Nature Monument)
- **SCI** – Sites of Community Importance under Natura 2000
- **SPA** – Special Protection Area in agreement with the Birds Directive
- **Landscape management programmes**: several subsidy schemes financed by the Ministry of the Environment (Landscape Management Programme, River System Revitalisation Programme, etc.)

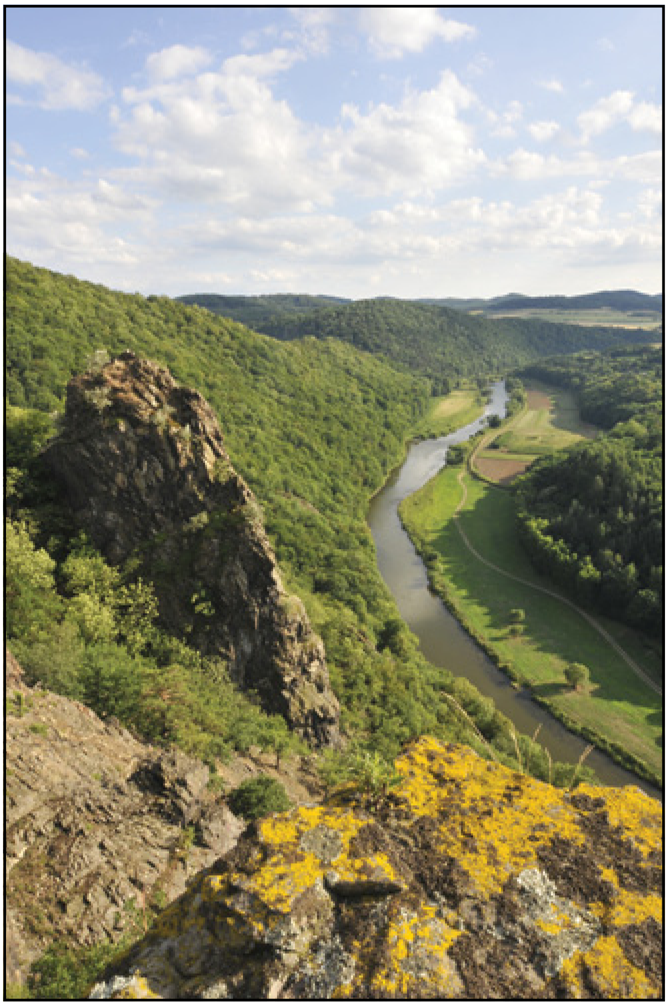

Fig. 1. Křivoklátsko PLA. (Z. Patzelt)

Fig. 2. České středohoří PLA. (Z. Patzelt)

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Restoration ecology and ecological restoration in the Czech Republic

Karel Prach, Pavel Pešout & Ivana Jongepierová

In the Czech Republic, restoration ecology was introduced as a science in the middle 1990s (Prach 1995), however various restoration and reclamation activities, including conservation management, have a longer tradition.

The first local restoration attempts concerned the reclamation of mining sites and had been realised already in the first half of the 20th century. Large-scale reclamation activities started in the two largest coal mining districts in the 1960s. For a long time these were based on technical approaches only, although spontaneous succession was demonstrated to be a very convenient and cheap way of spoil heap restoration already in the early 1980s (Prach 1982). The current state of mining site restoration is evident from the 'Mining and post-industrial sites' section.

The first ideas about active management of nature reserves appeared already in the 1950s, but were not put into practice at that time (Petříček 1999). In the 1980s, conservation management was mostly carried out by volunteers, predominantly in nature reserves with species-rich meadows, where regular cutting was necessary to sustain the species richness.

After the collapse of the communist regime in 1989 the position of nature conservation changed radically, when the Ministry of the Environment was established, led at that time by ministers well-educated in the natural sciences. Following this, the modern Act on Nature and Landscape Protection was adopted in 1991. In 1994 the Landscape Management Programme was set up, from which not only conservation management but also restoration activities (Petříček 1999, Petříček & Míchal 1999), mainly in nature reserves, have been financed to this day (€6–8 million/yr).

Today, the restoration of secondary grasslands is advanced in the country, but financial support from the Ministry of the Environment has recently decreased. A certain compensation for this reduction is offered by Agri-environmental schemes launched in 2004, but these are – due to their uniformity and inflexibility – considered very problematic in terms of preserving and restoring grassland biodiversity. However, currently attempts are being made to turn them into a more environmentally-friendly instrument.

In the past decade, modern methods of grassland recreation, such as sowing regional seed mixtures, have been applied (Jongepierová 2008). More information on grassland restoration and recreation is given in the 'Grasslands' section.

In the 1990s, a special River System Revitalisation Programme was launched by the Ministry of the Environment, which also included pond restoration and construction, partly aimed at increasing water retention in our landscape. However, the finances were often

Fig. 1. Spontaneous succession in the Moravia river valley: Vlčí hrdlo near Bzenec, alluvial meadows recovering since 2008. (J.W. Jongepier)

Fig. 2. Restored stream at Domašín near Vlašim, Central Bohemia (2009–2011). Restoration included the creation of several ponds and tree plantings. (P. Mudra)

inappropriately invested into technical projects which benefited nature only marginally (Simon et al. 1998). Recently, river corridor restoration has shifted very slowly into a more ecological direction. The only unambiguous progress made in the case of rivers over the past two decades is the great improvement of their water quality, also a kind of restoration. Examples of restoration of watercourses and other wetlands are presented in the 'Wetlands' section.

Serious problems persist in the restoration of forests ('Forests' section), especially in terms of restoring near-natural species composition. Most forests in the country have been converted to monospecific, mostly Norway Spruce (*Picea abies*) and Scots Pine (*Pinus sylvestris*) plantations, resulting in soil degradation, acidification, decreased water retention, and an overall decrease in species diversity (Fanta 2007). The emphasis on timber production, still advocated by the majority of our foresters, means that the use of natural regeneration and other near-natural measures are not easily accepted.

The need for restoration of complete landscapes is very urgent in the Czech Republic. In the second part of the 20th century, nearly all water courses were channelised, the area of arable land expanded, huge amounts of pesticides and fertilisers polluted the water, the soil was degraded, and landscape connectivity was disrupted. Since some parts of the country have suffered heavily, restoration of the landscape structure and functions (at least in part) is highly desirable. Some examples of landscape restoration are given in the 'Landscapes' section of this publication.

Extensive military training areas can be considered a special type of landscape. The Czech Republic, with a border dividing NATO Germany and Warsaw Pact Czechoslovakia during the communist regime, had many such areas. In spite of all the negative aspects, military training areas have mostly retained some landscape structures from the mid-20th century with a low to zero eutrophication level (Kopecký & Vojta 2009). Repeated disturbances have also preserved a mosaic of different successional stages here. Therefore, military training areas are very valuable from the viewpoint of nature conservation, and restoration activities substituting military activities are desirable in some parts (see more in the 'Abandoned military areas' section). These areas could be partially left to spontaneous processes to create new 'wilderness', accompanied by re-introduction of large herbivores and predators (rewilding).

In a way, each restoration has to do with ecological succession. Restoration measures attempt to substitute, mimic, accelerate, slow down, modify, return, or at least interfere with spontaneous succession (Prach et al. 2007). The Czech Republic can boast a long tradition of research into this process at various human-disturbed sites.

Already in the 1970s and the early 1980s, a multidisciplinary study of spontaneous succession on abandoned arable land was initiated by M. Rejmánek (Osbornová et al. 1990). Later, attention was also directed to various industrial sites, such as spoil heaps after coal mining (Prach 1987), sedimentary basins (Kovář 2004), sand pits (Řehounková & Prach 2006), stone quarries (Novák & Prach 2003), and extracted peatlands (Bastl et al. 2009).

Several case studies presented in this volume show how the knowledge acquired from these studies can successfully be applied in ecological restoration.

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Forests

Deciduous forest, Podyjí NP. (Z. Patzelt)

Introduction

Tomáš Vrška

Historical changes in forest conditions

The Czech Republic has 2,657,379 ha of forest covering 33.8% of our country. On the European scale, this slightly above-average cover does not have a corresponding level of forest quality, as for forest stand health, tree species composition, spatial structure, or related biodiversity. A total of 67% of our woodland consists of predominantly coniferous stands (i.e. with more than 75% of conifer species). The current proportion of coniferous tree species (74%) is more than twice that of conifers (35%) in natural stands, according to reconstruction (Anonymus 2011b).

Forest management has a rich history. It began in the Neolithic age in the lowest and therefore warmest regions approximately 4,000–5,000 years ago. These beginnings were not purposeful forms of management, but only they just indicate man's influence on forests. As society developed, this impact spread to higher elevations. Medieval colonisation of highlands had a strong impact on forests. Pressure on forest use grew as the technology for cutting and processing large diameter trees developed, and forests were intensively used for grazing, burning charcoal, litter raking, etc. The bad state of the forests and a looming energy collapse (coal was not yet a standard source of energy) led to issuing the so-called Theresian patents (in 1754 and 1756), which meant a fundamental change in the society's view of forests in the 18th century. Forest uses diminishing yields and degrading the production potential were restricted (e.g. litter raking, grazing, etc.), and forest management regulations were introduced, including the first forest management plans.

Planning played a major role in the change of forest conditions. Thanks to the application of procedures adopted from the German forestry school, open and untended stands were restored according to a plan, primarily by the planting of Norway Spruce (*Picea abies*) and Scots Pine (*Pinus sylvestris*). These long-term, targeted efforts not only provided the expected results in gradually increasing production (growth increment) and instantly raising timber supplies in forests, but also led to the creation of standardised, production-focused forestry. Thus forestry entered the 19th century as an established form of human activity. It also conditioned the current state of our forests. In that time the production advantages of using spruce and pine were unquestioned, although repeated regeneration of coniferous monocultures soon began to show its drawbacks: soil podzolisation and corresponding decrease in potential soil production, a significant decline in forest stability due to biotic and abiotic factors, and of course a decrease in forest stand biodiversity. Due to these changes many forest species are currently declining rapidly and are endangered, some have even gone extinct (Farkač et al. 2005).

Forest restoration rehabilitating functional ecosystems

In the second half of the 20th century conditions worsened, and the acid rain catastrophe which struck the Czech Sudeten Range clearly indicated that the state of the forests needed improvement. Research aimed at restoration of the pollution-stricken forests started in the former Czechoslovakia in the 1960s. From today's point of view

Fig. 1. Beech forest, Bílé Karpaty PLA. (B. Jagoš)

Fig. 2. Montane spruce forest after bark beetle outbreak, Šumava PLA. (Z. Patzelt)

the application of its findings were the first tangible results of forest restoration management and restoration ecology in a broader sense. The main issue here was the reinstatement of basic forest functions. Restoration of the production potential was to be the icing on the cake and was, in the earliest stages, not a goal considered to be attainable in the near future. A good example is the restoration of forests in the Jestřebí Mountains in the Trutnov region (Tesař et al. 2011).

In protected areas the acid rain catastrophe in mountain forests was another reason for the first extensive forest restoration. The Krkonoše National Park, in existence since 1963, was one of the most affected areas, where 8,000 ha of forest were destroyed. In 1992–2001 the most extensive and costly action aimed at restoring forest functions and natural forest conditions ever taken in the Czech Republic was carried out here. Thanks to financial support of the Dutch FACE Foundation 5,200 ha of forest were restored (i.e. natural species composition and spatial differentiation of stands, leading to development of natural conditions). FACE invested USD 19.5 million into this project (Anonymus 1998). Forest restoration management projects were also started up in other protected areas, such as the Jizera Mts. and the Eagle Mts.

Purpose and aims of forest restoration management

The planning and implementation of restoration management in forests affected by air pollution (either in protected areas or outside of them) was automatically perceived as unquestionable and to be undertaken without delay. In the earliest stages, however, the aims of restoration management on the general level were not dealt with. A major change in the competency of state nature conservation authorities codified in the Act on Nature and Landscape Protection enabled a rapid start to take measures in forests in protected areas (Anonymus 2011a). It then became necessary to answer basic questions about the purpose and aims of restoration management.

Generally, forest restoration management can be broken down into three approaches, each with different aims relating to different functions of the forests to be restored:

1. Forest restoration to rehabilitate a functional ecosystem without emphasising production functions. This is exemplified by the situation in the Jestřebí Mts. (see above), where part of the strategy is also the restoration of the previously stable production potential. These cases of restoration management are not limited to protected areas.
2. Conversion to a near-natural forest, subsequently leaving the forest to spontaneous development. This is, in contrast, almost always applicable to forests in protected areas and with specific aims. Nonetheless, of the three approaches, this one has been least applied. A special variant of this approach is "zero management", i.e. spontaneous regeneration of forest where strong disturbances have taken place either in large areas or affecting basic forest functions (such as wind damage followed by bark beetle infestations, or fires). The ecosystem is in its initial development phase, but its restoration is left to the spontaneous effects of natural forces. Here man is merely an observer of the phenomena taking place.
3. Restoration of forests to a certain state (even if conditioned by man) allowing endangered species to survive and requiring long-term, more-or-less active management, i.e. restoration management with protection of biological diversity as the priority. This approach is currently mostly applied to forests in protected areas, but this does not always have to be the case. Even the Forest Act defines a category of 'Special-purpose forests', with 'Forests necessary for preserving biodiversity' as a subcategory.

Forest restoration aimed at leaving the forest to spontaneous development

If Approach 1 represents the restoration of mountain ecosystems, then Approach 2 typically includes introduction of missing tree species important for development dynamics, and spatial management of forest stands, which are then left to develop spontaneously. In 1992–2012, missing or underrepresented fir was most often introduced, or in some cases supported, in stands dominated by beech in forest reserves. This is a very good illustration of forests having been influenced by man in various ways (selective cutting, occasional grazing, occasional removal of decomposing wood, or formerly managed beech stands on fir–beech sites surrounded by spruce monocultures), which have been designated protected areas with the aim of remediating their state and then leaving them to spontaneous development (Vrška et al. 2002). Fir is either actively introduced to stands by underplanting the beech storey or to small areas affected by disturbance. At other sites where part of the original population has remained, natural regeneration of fir is supported, either by passive protection from wildlife browsing, or actively by increment thinning in the beech storey.

Nature conservation authorities and forestry organisations are more or less in agreement on these procedures, however there is certainly less agreement on the question of what state forests should be left in for spontaneous development. There is of course no single answer to this question. In the field of forest restoration management it is however an issue which has yet to be assessed comprehensively, both within and outside of the Czech Republic.

Forest restoration management for biodiversity protection

The youngest, yet very important, approach to forest restoration management is Approach 3, which was developed in nature conservation at the end of the 20th century in the Czech Republic. The preservation, restoration, and subsequent stabilisation of forest biodiversity, especially when endangered species are involved, mostly concerns low-altitude forests, i.e. forests located under the beech wood belt. In contrast to forests at mid-level altitudes, these forests are not characterised by a dramatic change in tree species composition, but by long-term intensive forest management comprising of coppice systems with short rotation periods to produce fuel wood, agroforestry, pasturing in forests, pruning of branches to create hollows in tree trunks, etc.

Man's intensive and long-lasting influence including a wide variety of forest management techniques has allowed for the survival of species dependent on sunnier and warmer microhabitats. In the 1950s coppicing was strongly limited in order to increase forest productivity and the cultivation of species of higher quality. It is now only used for black locust control, primarily in South Moravia. Oak and hornbeam coppice forests have been converted using whole-area soil preparation after which they were reforested with pine. At sites adjacent to stands where oak is managed, no change in species composition has taken place, but for example standard large-scale oak shelterwood systems, although not posing problems in terms of production and maintaining the production potential of the site, do not create sufficient conditions for the survival of critically endangered insect species.

Therefore, restoration management forms focusing on protecting biodiversity have met with varied reactions. Currently this issue is dealt with by means of experiments with forest grazing (in the Bohemian Karst PLA and Podyjí NP) and to a somewhat greater extent with restoring coppice systems (at Křtiny Training Forest Enterprise of Mendel University Brno and in Podyjí NP).

From the perspective of biodiversity there is also a clear incongruity between active management using old management techniques and leaving forests to spontaneous development. This is caused inter alia by the fact that, logically, we do not have 'traditional' forest reserves at lower elevations, in contrast to mid-altitude and mountain regions (e.g. Žofín and Boubín Virgin Forests). Therefore, we do not yet have knowledge about the disturbance dynamics of forests below the beech vegetation zone. At the same time, forests influenced by man secondarily left to spontaneous development have not yet had sufficient time for disturbance patterns to develop fully: zero management principles have been used here for not more than a few decades.

In contrast to lower altitudes, the restoration of biodiversity at middle and high altitudes is linked to forests which we consider natural (Miko & Hošek 2009) and where there is no fundamental conflict between zero management or minimal maintenance management and biodiversity. Here, biodiversity is linked to decomposing wood and to the natural species composition of forests.

Future issues

Of the total forest area of the Czech Republic, 28.4% is located in protected areas (Anonymus 2011a). One of the main issues for the future is clarifying the aims of restoration management, especially in protected areas, a process which is taking place alongside the gradual renewal of management plans for each area. These plans can lead to further decisions about the management methods to be used.

Forests left to spontaneous development form a specific subgroup. They currently make up 0.95% of the forest area, and consensus has yet to be reached on their total target area (for example, in 2011, a

Fig. 3. Forest along Klaper stream, Podyjí NP. (Z. Patzelt)

Fig. 4. Underplanting of *Abies alba* in spruce forests on slopes of Mt. Velký Blaník, Blaník PLA. (P. Kostečka)

proposal of 4% was not accepted by the coordinating committee of National Forest Programme II). The question in what state we want to leave restoration management forests for future spontaneous development still needs a comprehensive study.

A more serious issue is that of selecting a method of permanent forest management in protected areas and outside them – especially in special-purpose forests for the preservation of biodiversity. As opposed to forests intentionally left to spontaneous development, which will never make up more than a few percent of the forest area, the forest area in protected areas with permanent management will exceed 20%. Their specific management, especially in low-altitude areas, is linked with the adoption of earlier management forms (e.g. coppice systems), as well as with compensation for loss of profit for non-state forest owners due to nature conservation measures. In state-owned forests, a clear policy should be adopted for registering the profit loss by entities operating in them as well as for disputable subsequent state-to-state payments (Nature Conservation Agency of the Czech Republic). Considering assumed future limits on financial resources for special-purpose forest management, today most attention should be focused on selecting important biodiversity protection areas, which will be given funding priority to preserve specific forms of management.

Fig. 5. Forest severely damaged by air pollution, Špindlerova bouda, Giant Mountains (Krkonoše) NP. (Z. Patzelt)

Four case studies in forest restoration management present examples of both spontaneous processes (through zero management) as well as the results of long-term active approaches in forest restoration. These examples come from mountain forests and low-altitude forests. The study of mountain forest restoration in the Jizera Mts. presents the results of 20 years of restoring mountain ecosystems damaged by air pollution in a protected landscape area. On the other hand, the study from the Šumava Mts. gives an example of spontaneous regeneration of a mountain forest after large-scale disturbance in the Core Zone of Šumava NP. A rare, and therefore important, example of spontaneous forest development after fire comes from Bohemian Switzerland (České Švýcarsko) NP. Forest restoration management in the Podyjí NP is presented as a case of gradual conversion of forests earlier dominated by pine to mixed deciduous forests with a rich spatial structure in order to protect the biodiversity of low-altitude forests.

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Active restoration and management of forest habitats

Lukáš Čížek

With more than a third of its area covered by forests, the Czech Republic is among the European countries with a high forest cover, and woodland organisms constitute a substantial portion of its biodiversity. Czech forest cover increased from ~25% to 33.7% between 1790 and 2010, and the standing timber stock per unit area nearly doubled between 1930 and 2010. More than half of the forests is owned by the state and run by state-owned companies. Over a quarter is part of conservation areas. Some forest reserves belong to the oldest on the continent and date back to the mid-19th century.

The above picture seems optimistic not only in comparison with the usual reports on forest destruction in the tropics, but thanks to the large share of state forests also in comparison with western Europe, where state-owned land is rather easily accessible to nature conservation. However, the picture drawn by information on the state of forest biodiversity based on facts from distribution atlases and other biological data is strongly different. Not only has forest expansion taken a dramatic toll on non-forest biodiversity, the newly created forests are also biologically inferior. This, together with a dramatic decline in old-forest biodiversity, contributes to the fact that many forest-dwelling organisms are highly endangered or locally extinct, although they were common some 50–100 years ago (Beneš et al. 2002, Farkač et al. 2005, Konvička et al. 2005). The rather peculiar fact that most forests in conservation areas are production forests managed under a uniform clear-cut system is only partly to blame for the current poor forest biodiversity.

Fig. 1. Stand of pollarded willows near Vojkovice u Brna hosting a number of endangered beetles associated with tree hollows including Hermit Beetle (*Osmoderma barnabita*). (L. Čížek)

Fig. 2. Abandonment threatens stands of pollarded willows in two ways. Neglected pollards are unable to support heavy branches and break down, or the trees are overgrown and killed by young neighbours. (L. Čížek)

Naturally, conifers would constitute ~35% of trees in the Czech forests, with Silver Fir (*Abies alba*) accounting for nearly two thirds and Norway Spruce (*Picea abies*) nearly a third of all conifers. Today, however, conifers cover ~75%, and spruce alone more than half of forested land. While silver fir cover has declined to <1%, other trees have nearly completely disappeared from the country's woodlands, including elms (*Ulmus* spp.), Crab Apple (*Malus sylvestris*), Wild Pear (*Pyrus pyraster*), and Common Juniper (*Juniperus communis*). Numerous organisms associated with these tree species have declined strongly. Nevertheless, such organisms form a rather small portion of the country's threatened woodland biodiversity. Most of the biota associated with open and semi-open woodlands, senescent trees, early successional woodland habitats, and fine mosaics of various seral stages are endangered or even extinct. Despite the strong alteration of species composition, the main problem of woodland biodiversity in the Czech Republic is formed by unification of forest spatial structure (including high canopy closure), and absence of senescent trees and insolated habitats. Attempts to reverse forest species composition to near-natural are relatively common (see case study 'Conversion of pine monocultures to mixed deciduous forests in Podyjí National Park'), but attempts to diversify the spatial and age structure of forests and actively restore habitats of endangered organisms are extremely rare.

The changes brought about by agricultural and industrial revolutions, including extreme intensification of forest management, have fallen particularly hard upon the Czech forests. In the second half of the 18th century, the Habsburg empress Maria Theresia and her son Joseph II attempted to secure supplies of strategic raw materials such as fuel and construction timber. They issued forest acts which indeed increased timber production, while on the other hand suppressing customary rights of forest use. In the second half of the 20th century, more than 99% of the Czech forests came in the hands of the communist state with its well-organised, unified, and intensive forestry. The clear-cut management system was presented to several generations of foresters as the only suitable silvicultural system. Wood pastures, tree shredding, pollarding and coppicing were regarded as detrimental to forest health and production potential, and therefore prohibited or abandoned. Forest management has become extremely unified in the whole country, and clear-cut management is widely applied even to nature reserves and other protected forests. The virtually only alternative to clear-cutting in forests of protected areas used to be absence of active management. This has led to increased canopy closure and decline of disturbance-dependent species. The vital role of disturbances in sustaining biodiversity, and thus the key role of an active approach to the management of habitats of many endangered species have yet to be fully recognised in the Czech Republic.

Wood pasture

Pasture of domesticated animals in forests has been banned from the territory of the Czech Republic for more than 250 years. With the exception of some fragments found in game reserves, grazed woodlands are thus virtually non-existent here. Serving as hunting grounds for the nobility, game reserves have often been spared from logging and fuel extraction. In the past century, they have also been partly spared from forestry intensification, increased canopy closure and related changes. The fragments of pasture woodlands in game reserves thus host a number of highly threatened organisms associated with open woodlands, old trees and dead wood. Last century, the game reserves fell into state hands, and many are still owned by the state. Today, despite their high value for biodiversity conservation, many game reserves lack any relevant protection status. Due to a recent increase in demand for revenues from state-owned forests, even the last fragments of grazed forests are in serious danger of, or are already succumbing to clear-cutting and replacement by plantation-like stands with a closed canopy.

Although giant oaks and silver firs – typical attributes of pasture woodlands – have always drawn attention, nature conservation in the Czech Republic has yet to realise the importance of wood pasture. Many formerly grazed woodlands have been designated reserves of "virgin" or "primeval" forest; whereby the presence of massive trees often served as evidence of forest "virginity". Hands-off management applied to such forest reserves has led to an inevitable biodiversity decrease due to canopy closure, substitution of the main tree species (oak, fir) by other species, and to gradual disappearance of tree veterans (e.g. Vrška et al. 2002, Vrška et al. 2006) and other valuable habitats. After it had been prohibited by law for more than two centuries, it is no wonder that wood pasture is returning painstakingly slowly. Following nearly a decade of discussions within the conservation community, wood pasture was started only recently as an experiment rather than management in Podblanicko, the Bohemian Karst near Prague, and Podyjí NP along the upper Dyje (Thaya) river.

Coppicing

The only actively coppiced woodlands today are stands of exotic, invading black locust (*Robinia pseudacacia*), which have no conservation value. Nevertheless, coppices uncut for over 50 years currently cover several thousand hectares, mostly in lowlands and foothills. Although many open woodland specialists have disappeared, the old coppices still retain continuity and are key habitats for a number of endangered organisms, including e.g. Stag Beetle (*Lucanus cervus*), Violet Click Beetle (*Limoniscus violaceus*) and Lady's-Slipper Orchid (*Cypripedium calceolus*). Rather than being restored, the old coppices are often clear-cut and replanted, even in conservation areas. In most nature reserves and national parks, on the other hand, coppices are being sacrificed to succession.

After nearly having been forgotten, coppicing was reintroduced in the Czech Republic as a hot novelty by the end of last century. Active coppicing was first restored near the town of Moravsky Krumlov in the mid-1990s. Led by economic rather than conservation reasons, it was the first and by far the largest (>100 ha) attempt to date (Utinek 2004). However, the area has now been destroyed by clear-cutting. Recently, coppicing was restored in the Bohemian Karst, Moravian Karst and Pálava PLAs, and in Podyjí NP. Active coppices are confined to small areas of mostly 1–2 ha, and coppicing has yet to be accepted as conservation management and a sometimes even economically viable, nature-friendly alternative to commercial forest management.

Pollarding

Although pollarded trees were much more common in the past, pollarding is still the most widespread traditional woodland management in the country. Pollarded willows (*Salix* sp.) are found in many areas, mostly in or near towns and villages. In extensively managed agricultural landscapes or human settlements, pollards often facilitate survival of fauna associated with veteran trees and tree hollows, including e.g. Hermit Beetle (*Osmoderma barnabita*), Red Click Beetle (*Elater ferrugineus*) and Stag Beetle (*Lucanus cervus*) (Šebek et al. 2010). Thanks to a recent increase in fuel-wood prices, pollarding is probably the most commonly restored traditional woodland management.

Conclusion

The past decade has seen efforts by a growing number of conservationists and forestry experts in introducing active conservation management in woodlands in protected areas. However, the process is

Fig. 3, 4. Lány game reserve serves as a hunting ground for Czech presidents. It is one of the last places in the Czech Republic where grazed open woodlands – key habitats to many protected organisms – still exist. Their extent, however, decreases even here as apparent from aerial photographs from 1953 (left, provided by VGHMÚř, Dobruška, © MO ČR 2009) and 2010 (right).

Fig. 5, 6. Formerly open Pannonian oak woodland on sandy deposits managed as coppice-with-standards, aerial photo from 1953, provided by VGHMÚř, Dobruška, © MO ČR 2009 (left). In half a century it has changed to closed-canopy oak woodland with a perspective of gradual replacement by pine plantations (darker patches) (right). Many Pannonian oak wood inhabitants, such as Woodland Brown (*Lopinga achine*) butterfly, are gone. Others, such as Clouded Apollo (*Parnassius mnemosyne*) and Emerald Jewel Beetle (*Eurythyrea quercus*) have so far survived. Their perspectives are however bad, despite their legal protection and the fact that the site is part of the Lower Morava (Dolní Morava) UNESCO Biosphere Reserve.

slow, mostly due to reluctance of their more conservative colleagues. On the other hand, the rapid decrease in biodiversity in conservation areas makes it inevitable to shift the emphasis from conservation of vaguely defined communities and "natural" processes to evidence-based biodiversity conservation. Although not much has been done in the field during the past decade, the attitude of the professionals concerned, including biologists, conservationists and foresters, has substantially changed. The road to restoration of traditional woodland management and active biodiversity conservation in the Czech woodlands is certainly not free of obstacles. It is, however, open.

Acknowledgements

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Conversion of pine monocultures to mixed deciduous forests in Podyjí National Park

Tomáš Vrška & Jaroslav Ponikelský

Location 	Podyjí NP, southeast Czech Republic, on the border with Austria 48°52'32" N, 15°53'25" E; altitude 375–430 m
Protection status	NP, SCI
Ecosystem types	Hercynian oak-hornbeam forests (*Carpinion*), Herb-rich beech forests (*Fagion sylvaticae*)
Restored area	Approx. 900 ha in the central part of the NP, 96 ha of which in the Pyramida experimental area
Financial support	Landscape management programmes, operational budget of the Podyjí NP Authority
Costs	Ca. €240/ha in 1992–2008

Initial conditions

Young forests used to consist mainly of coniferous monocultures (*Pinus sylvestris*, *Picea abies*). Medium-aged and older forests were more often mixed – two-layered – with conifers in the main layer (*Pinus sylvestris*, *Picea abies*, *Larix decidua*), and broad-leaved trees in the sublayer (*Quercus petraea*, *Carpinus betulus*, *Tilia cordata* etc.). Most deciduous trees developed from coppice because the mature coniferous layer was the first generation after mixed broad-leaved coppice had been converted. Deciduous forests with or without a minor admixture of conifers represented a smaller part of the area. They were mostly oak woods and mixed hornbeam–oak forests. The texture of the forests was not highly differentiated and consolidated into larger blocks; structural differentiation was limited to a maximum of two layers (main layer coniferous, sub-layer deciduous), tree species composition significantly lacked *Fagus sylvatica*, and there was no deadwood in the form of standing or lying dead logs left in situ.

Objectives

The end goal of our conversion efforts is structurally differentiated mixed deciduous forest with a finer structure and more ragged edges. In its main aspects the tree species composition should approach the potential composition.

1. The main part of these forest stands will be left to spontaneous development.
2. The stands located in the Buffer Zone of the NP will be continually managed. In these stands special attention is paid to the presence of admixed species (*Prunus avium*, *Pyrus communis*, *Sorbus* spp., etc.). Trees of the target species which have naturally died are left in situ to decompose in the forest. The fine texture of the forest will create varied, constantly changing light and temperature conditions to support viable populations of protected plant species (Decocq 2004) and animal species, especially xylophagous insects (Götmark 2007). Silvicultural management is based on selection principles, mainly the target thickness method (Diaci et al. 2006).

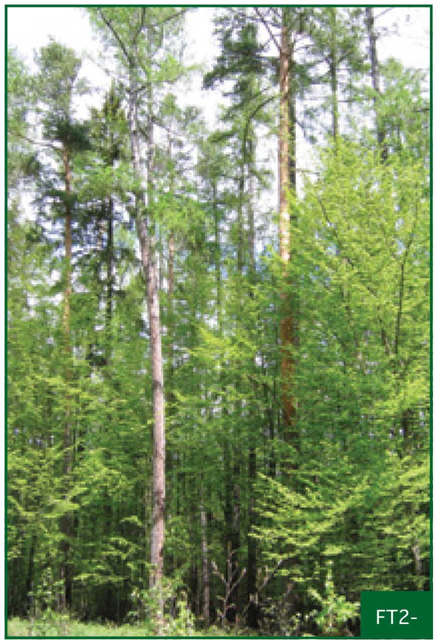
Fig. 1. Mixed woodland, Podyjí NP. The main goal of restoration management in the NP is to replace coniferous stands by broad-leaved ones. (P. Lazárek)

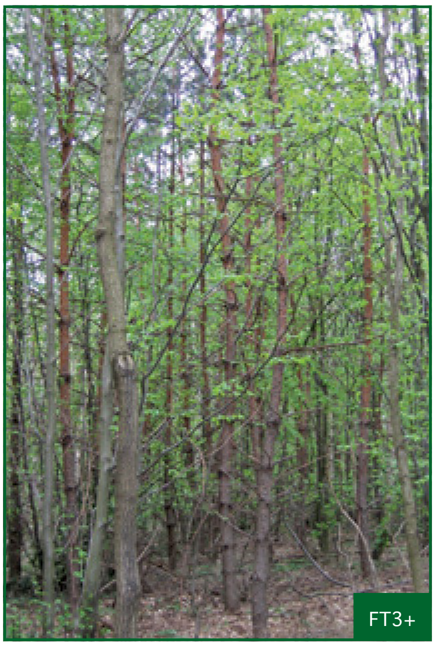
Methods

1. Classification of the initial situation in 1992 – five forest types (Fig. 2), according to:
   - **a)** current tree species composition;
   - **b)** spatial structure of the forest (degree of structural differentiation);
   - **c)** forest management methods.
2. Repeated assessment of changes (2003, 2008, planned in 2013):
   - **a)** proportions of different forest types;
   - **b)** size of textural features;
   - **c)** number of textural features;
   - **d)** tree species composition.
3. Economic evaluation of the conversion measures:
   - **a)** data from primary records (continuously archived since 1992);
   - **b)** phase calculations;
   - **c)** forest stand regeneration – from principal felling to established plantation.

Restoration measures and monitoring

1992	Cessation of conventional management of even-aged pine and spruce stands. Cessation of afforestation with pine, spruce and larch.
1992–1993	Compilation of NP management plan and classification of the initial state of the forest.
1994	Start of beech planting and active restoration management.
2003	First evaluation of changes in the forest and of the entire experimental area.
2008	Second evaluation of changes in the forest and of the entire experimental area.
2013	Third evaluation of changes in the forest and of the entire experimental area + economic and silvicultural modelling.





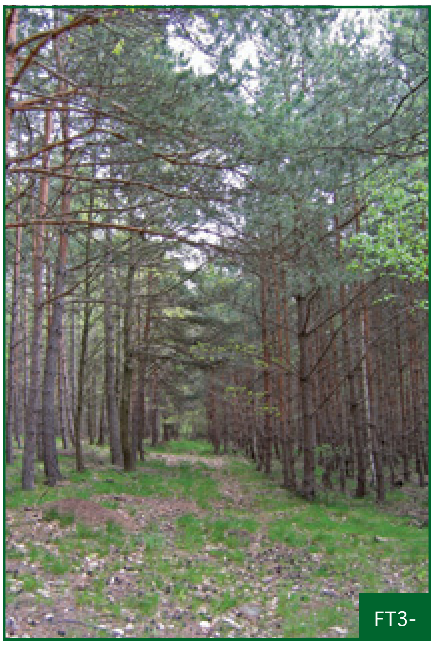


Fig. 2. Visualisation of forest types:
- FT1 target
- FT2+ advanced transitional
- FT2- initial transitional
- FT3+ predominantly coniferous
- FT3- purely coniferous

Results

Changes in the total area of forest types (FTs) are shown in Fig. 3 and changes in the spatial distribution of the FTs in Fig. 4, both for the Pyramida experimental area. The rapid decrease in FT3- area is the result of the first management measures – opening of the canopy of the pine forests planted in the 1970s and 1980s and supporting subdominant deciduous trees. These measures facilitated the conversion of FT3- to higher-quality FT3+ forest, where further canopy opening takes place and the first interventions have led to spatial differentiation of the forest. The area of FT2- and FT2+ stands has remained more or less the same during the studied period, since they are the result of the actively managed FT3+ stands, but at the same time convert to spatially and species-differentiated FT1 forest.

The development of textural differentiation of Pyramida is shown in Fig. 5. The most important result is the differentiation of compact and fully closed structurally simple forests in the SE part of the experimental area. This is where the first differentiating measures were carried out followed by the first beech plantings. The average size of the textural elements decreased from 0.81 ha (1992) to 0.48 ha (2008). The total number of structural elements increased from 177 (1992) to 197 (2008).

Changes in tree species composition in the experimental area are given in Tab. 1. The results clearly illustrate the fast change (from a silvicultural point of view) in species composition. The decrease in the percentage of conifers to 58% of the original number (1992) was achieved thanks to intensive work on scattered subdominant broadleaved trees and massive introduction of beech in various ways.

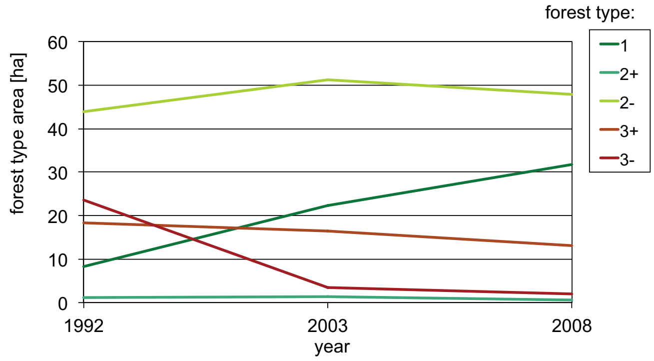


Fig. 3. Development of the total area of various forest types in the Pyramida experimental area.

Other lessons learned and future prospects

The key factor in forest restoration is a clear formulation of the long-term target and working methods for the forest managers. Using the forest type classification, practically applicable forest management guidelines can be produced by finding a balance between theory and its practical application. However, in practice the attainability of favourable results largely depends on mutual respect and good interpersonal relations.

Acknowledgements

The study was carried out with the support of project MSM 6293359101.

Fig. 4. Changes in forest type areas in the Pyramida experimental area from 1992 to 2008.

Fig. 5. Development of forest texture in the Pyramida experimental area from 1992 to 2008.

Tab. 1. Changes in tree species composition in the Pyramida experimental area as a result of the restoration methods.

Species	1992 [%]	2003 [%]	2008 [%]
Pinus sylvestris	39.0	32.2	23.7
Larix decidua	11.0	4.6	3.7
Picea abies	10.5	9.0	7.9
Σ Conifers	60.5	45.8	35.3
Quercus spp.	27.5	32.7	34.8
Carpinus betulus	8.5	13.2	16.3
Fagus sylvatica	0.5	2.5	5.4
Betula pendula	1.7	3.1	3.7
Tilia cordata	0.3	1.1	2.0
Other deciduous species	1.0	1.6	2.5
Σ Deciduous	39.5	54.2	64.7

Fig. 6. The Core Zone of the Podyjí NP is left to spontaneous development. (P. Lazárek)

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Can fire and secondary succession assist in the regeneration of forests in a national park?

Kamil Král, Jan Trochta & Tomáš Vrška

Location 	Bohemian Switzerland NP, near the NE edge of the village of Jetřichovice, northwest Czech Republic 50°51'19"–50°51'35" N, 14°24'07"–14°24'31" E; altitude 245–393 m
Protection status	NP
Ecosystem types	Predominantly acidophilous beech and beech-pine forests (mostly *Luzulo-Fagion sylvaticae*)
Restored area	13.5 ha
Financial support	Bohemian Switzerland NP Authority
Costs	€2,470 (fence construction and erosion-control measures)

Initial conditions

Most of the indigenous forests in the Bohemian Switzerland NP were in the past transformed into coniferous monocultures. Traditionally, also geographically non-indigenous trees such as White Pine (*Pinus strobus*), European Larch (*Larix decidua*), Douglas Fir (*Pseudotsuga menziesii*) and Northern Red Oak (*Quercus rubra*) were used in local forest management (Drozd et al. 2010). *Pinus strobus*, in particular, has found extremely advantageous conditions for its development here (nowadays representing 4% of trees) and is gradually occupying all suitable habitats (Patzelt 2007).

The Raven's Rock (Havraní skála) site has become widely known since June 22, 2006, when a wildfire broke out, developing into one of the largest forest fires of the Czech Republic in the past 30 years (Vonásek 2008), leaving approximately 18 hectares of burnt forest behind.

The original forest consisted mainly of *Pinus strobus* and Scots Pine (*Pinus sylvestris*) with rare occurrence of European Beech (*Fagus sylvatica*) and Sessile Oak (*Quercus petraea*). Norway Spruce (*Picea abies*) grew at the feet of the hillsides, while rocky outcrops were often occupied by Silver Birch (*Betula pendula*). The age of the forest was max. 130 years. Before the fire, management had aimed at reducing the invading *Pinus strobus*. Approximately 100 m^3 had been felled and left in situ, which was one of the factors which, besides the hot weather and minimum precipitation, contributed to the high intensity of the fire.

Subsequently, the fire-affected area was not managed according to regular forestry methods (felling and planting). Instead, the National Park Authority decided to leave it to spontaneous development (except for the clearing of a strip along a tourist trail for safety reasons). This constituted a unique opportunity to study the secondary succession following the fire and to ask the question: can the natural processes initiated by the fire be used to convert forests invaded by the alien *Pinus strobus* to forests consisting of native species?

Objectives

Currently, there are two basic forest management targets in the Bohemian Switzerland NP: (i) gradual reconstruction of the currently prevailing coniferous monocultures to achieve near-natural forests with dominant *Fagus sylvatica* and admixed *Abies alba*, *Quercus petraea* and other trees, and (ii) removal of the invading non-indigenous tree species.

The aim of the study of secondary post-fire succession is to acquire information on the interspecific competition of trees in various successional stages, the behaviour of the main invasive species (*Pinus strobus*), the rate of recovery of tree species confined to later successional phases (*Fagus sylvatica*, *Carpinus betulus*, etc.) and also on the development of the spatial structure and texture of the future forests. This raises one key question: can planned fire management become an alternative form of forest restoration in the National Park?

Methods

Most of the area (approx. 13.5 ha) was fenced to prevent damage by game and to restrict direct access to the plot by National Park visitors. This enclosure was sampled by means of a regular network (approx. 30 × 30 m) of permanent sample plots (PSPs) to monitor the course of succession. Since 2007 regeneration has been studied and measured annually in 135 square PSPs of 1.5 × 1.5 m. Each of the plots is studied in detail and all tree and shrub individuals are recorded and divided into five height classes: (i) one-year-old seedlings, (ii) up to 30 cm, (iii) 30–60 cm, (iv) 60–130 cm, (v) over 130 cm (see Fig. 2a).

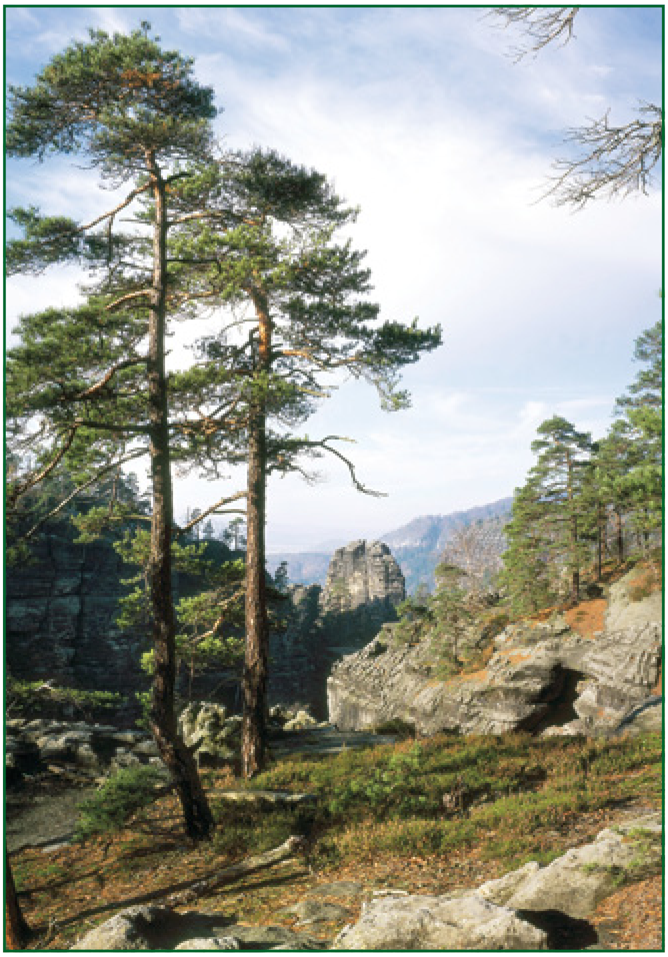

Fig. 1. Typical landscape in the Bohemian Switzerland NP. (Z. Patzelt)

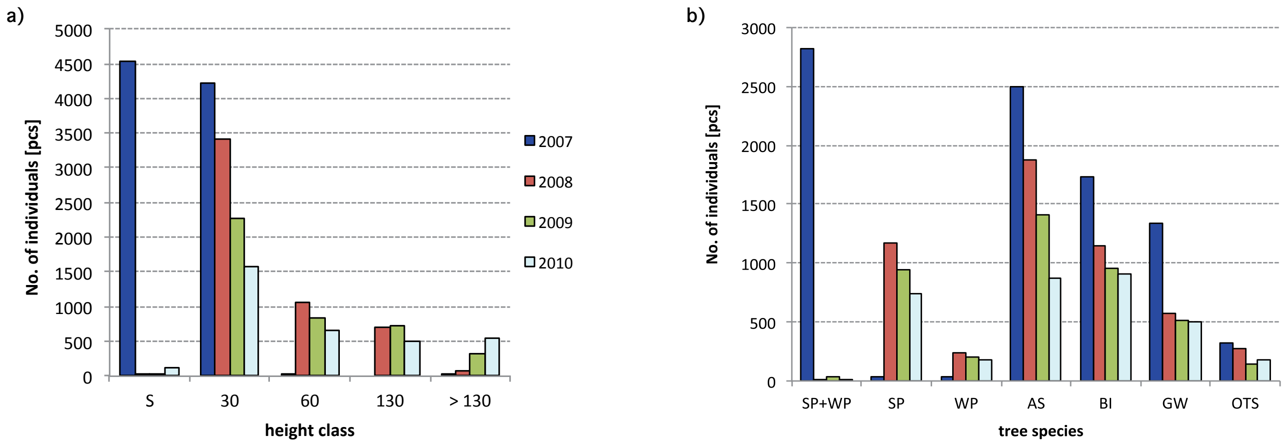

Fig. 2. a) Number of individuals in the permanent sample plots per height class in particular years. S: seedlings, 30: <30 cm, 60: 31–60 cm, 130: 61–130 cm, >130: over 130 cm in height; b) number of individuals per species in the permanent sample plots in particular years. SP – Scots Pine (*Pinus sylvestris*), WP – White Pine (*P. strobus*), AS – Aspen (*Populus tremula*), BI – Silver Birch (*Betula pendula*), GW – Goat Willow (*Salix caprea*), OTS – other tree species.

Results

Only one year after the fire, in 2007, the area was massively colonised by the youngest stages of pioneer tree species, i.e. seedlings and juvenile individuals prevailed (height class up to 30 cm). This year is characterised by establishment of the highest number of subsequently developing individuals (Figs. 2 and 3). The dominant species was pine (*Pinus* sp. – it was impossible to distinguish different species of seedlings) followed by *Populus tremula*, *Betula pendula* and *Salix caprea*, respectively.

Year 2008 was characterised by intensive growth (Figs. 2 and 4). All the height classes were already present in the studied plot, although still dominated by height class (ii). Seedlings were rare, found mostly in areas with harsher habitat conditions and delayed succession. Selection (self-thinning) was observed as a key process (see sharp drop in the total number of growing tree individuals in the burnt area in Fig. 2). Species composition also changed dramatically, with deciduous pioneer trees predominating: *Populus tremula*, followed by *Betula pendula*, and *Salix caprea*. Pines, already differentiated into the species *Pinus sylvestris* and *P. strobus*, represented rather marginal groups. There was a significantly higher proportion of *Pinus sylvestris* compared to *P. strobus*. This could lead to the assumption that in our conditions *P. strobus* is less adapted to fire and the subsequent succession. In terms of height growth both pines were well behind the pioneer species *Betula pendula*, *Populus tremula*, and *Salix caprea*.

Further gradual thinning of the lower height classes took place in 2009 and 2010. A slight increase in number of individuals was recorded only in the highest class (v). Year 2010 saw a second wave of seedling establishment. The proportion of tree species did not change significantly. Also a visible reduction in *Populus tremula* individuals was recorded while the numbers of other pioneer trees more or less stagnated (*Betula pendula* thus becoming the dominant species). There was also a slight increase in the "other species" group, mainly represented by species of later developmental stages (e.g. *Fagus sylvatica*, *Quercus petraea*, *Picea abies*, *Carpinus betulus*, *Alnus* spp.). This trend signalises the future shift to the next succession stage – from initial to transition forest.

Other lessons learned and future prospects

Recent experience shows that traditional clearing or at least control of the *Pinus strobus* invasion in Bohemian Switzerland NP can be successful only if it is performed consistently, on a long-term basis, and within an area clearly separated from the adjacent areas. Management is not always fully efficient as it is not performed all over the area and control is carried out for too short a period (Němcová 2007). Consistent application of efficient long-term procedures increases labour consumption and financial costs of the traditional (silvicultural) restoration management. The management set out by the National Park's management plan requires about €1.2 million annually (Drozd et al. 2010). To cover this, fundraising outside the budget is necessary.

Fig. 3. View of permanent sample plot, 2007 (establishment). (V. Jurek)

Fig. 4. View of permanent sample plot, 2008 (intensive growth). (V. Jurek)

Fig. 5. Colonisation by pioneer tree species after fire. (J. Trochta)

In contrast, the costs of managing the area after the fire did not include more than the construction of a fence and erosion-control measures.

Considering the promising results of secondary post-fire succession, the possibilities as well as the risks of prescribed firing should be discussed as an alternative (cheaper, faster, and closer to nature) form of restoration management. Fire is a natural disturbance factor which has always been present in nature. The latest anthracological research in the region (Novák et al. 2012) indicates that similar sites of pine forests in Northern Bohemia have been affected by forest fires during a substantial part of the Holocene. Recent human-induced accidental wildfire thus can imitate natural fire disturbances which the local pine forests experienced in the past. Local firing gradually applied over the area, generating complete succession series, would clearly lead to the desirable diversification of uniform forests, reduction in the number of non-indigenous species, and to an increase in forest biodiversity in the National Park: many anthracophilous fungi, mosses, and vascular plants have been found on the burnt sites, and bird and small ground mammal species diversity has increased as well (Marková et al. 2011). Attractiveness for tourists also plays a role in the National Park – after the fire, Raven's Rock has attracted numerous expert excursions as well as the general public (in contrast to the unattractive clear cuts produced in traditional management). Obviously it is necessary to consider all the pros and cons.

Fig. 6. Pine trees (*Pinus strobus* and *P. sylvestris*) damaged by wildfire. (K. Král)

Acknowledgements

The study was carried out with the support of project MSM 6293359101. Many thanks go out to Vilém Jurek for his help with collection of data in the field and to Dana Šteflová from the NP Authority for kind backing of the field research.

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Restoration of forests damaged by air pollution in the Jizera Mountains

František Pelc

Location 	Jizera Mountains, northeast Bohemia 50°49' N, 15°20' E; altitude 325–1,124 m
Protection status	PLA
Ecosystem types	Forest communities with prevailing herb-rich and acidophilous montane beech forests (*Fagion sylvaticae* and *Luzulo-Fagion sylvaticae*), climax montane and waterlogged spruce forests (*Piceion abietis*)
Restored area	269 km^2
Financial support	Landscape management programmes, Forest Stabilisation Programme, Operation Programme Environment, Forests of the Czech Republic; private funds from the non-profit sector, particularly the Foundation for the Preservation and Restoration of the Jizera Mountains
Costs	€2.6 million (Ministry of the Environment, 1992–2011), €400,000 (Foundation for the Preservation and Restoration of the Jizera Mountains), €1.44 million (Operational Programme Environment through Forests of the Czech Republic)

Initial conditions

In most of the Jizera Mts. native montane forests have been replaced by Norway Spruce (*Picea abies*) plantations of genetically inappropriate provenance. Thus, natural forest communities composed of local tree populations have been preserved only in fragments and patches of various sizes. In the 1980s, approximately one third of forests was found to be heavily damaged by strong air pollution from fossil-fuel power stations in Poland, Saxony and the current Czech Republic, and by inappropriate forest management, thus affecting biogeochemical soil properties.

In order to save timber for economic reasons, forest stands were cut on more than 90 km^2 during one decade (1980–1990), which caused extensive soil erosion. This seriously threatened the ecological integrity of the forest as a vegetation unit on the central plateau at an altitude of over 850 m, and homogenous Hairy Small-Reed (*Calamagrostis villosa*) grassland massively expanded.

In the early 1990s, extensive areas were reforested with genetically non-native *Picea abies* and allochtonous Blue Spruce (*Picea pungens*). In the 1980s, environmentally controversial aerial liming had been repeatedly applied here. Reproduction by seed, even in native populations of *Picea abies*, European Beech (*Fagus sylvatica*) and Silver Fir (*Abies alba*), was very low and efforts to enhance vegetative reproduction did not appear to be effective.

Fig. 1. Waterlogged spruce forests and peat-bogs are a unique gene pool source of *Picea abies*, *Pinus mugo*, *Betula carpatica*, and *Juniperus communis* subsp. *alpina*. Rašeliniště Jizery NR. (F. Pelc)

Fig. 2. *Picea pungens* planting on an area of nearly 30 km^2 is ecologically questionable. At present, they have to be restored in a well-designed way. (Archive Nature Conservation Agency Czech Republic)

In the 1990s, due to technological improvements and closure of some power stations, air pollution declined (Fig. 3). Consequently, the health of forest trees and their ability to reproduce by seed has improved. Nevertheless, the atmospheric deposition load in the area remains high. Ungulate game numbers have exceeded the carrying capacity of the Jizera Mts. ecosystem several times, strongly limiting forest recovery as well (Paschalis & Zajackowski 1994, Pelc 1994).

Objectives

Achieving healthier, ecologically more stable forests with a near-natural species composition and spatial structure by using native forest tree populations better able to face possible future stress factors, e.g. air pollution, climate change and insect pests.

Methods

In the early 1990s, the option of leaving the forests without any regeneration support was rejected, although there would have been some unquestionable advantages to this, e.g. deposition and low costs. A long-term strategy for forest restoration and stabilisation was established and under the Territorial System of Ecological Stability (a multi-level national ecological network) restoration biocentres were defined based on forest management principles (Pelc 1992, 1999, Pelc et al. 1993) (Fig. 5). These were included in forest management plans or realised as independent projects.

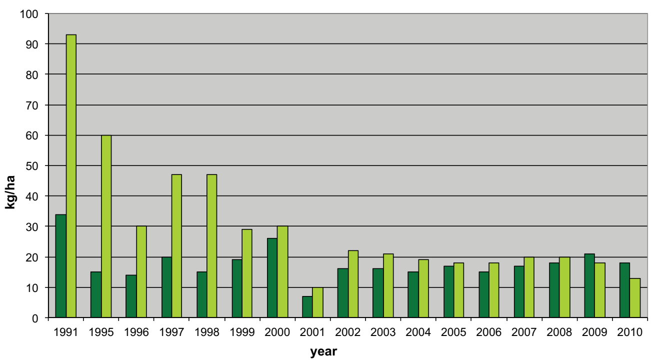

Fig. 3. Total atmospheric deposition dynamics, as shown by sulphur (light green) and nitrogen (dark green) loads in the Černá hora biocentre in 1991–2001. After an initial decline in the 1990s, atmospheric deposition has become stable but remained rather high. (Schwarz et al. 2009, and unpublished data)

Fig. 4. Semi-natural and near-natural beech forests on northern slopes of the Jizera Mts. form a unique tree gene pool, particularly of *Fagus sylvatica*, *Acer pseudoplatanus*, *Sorbus aucuparia*, *Picea abies* and *Abies alba*. They are a robust (2,600 ha) element stabilising the forest (Jizerskohorské bučiny NR). (F. Pelc)

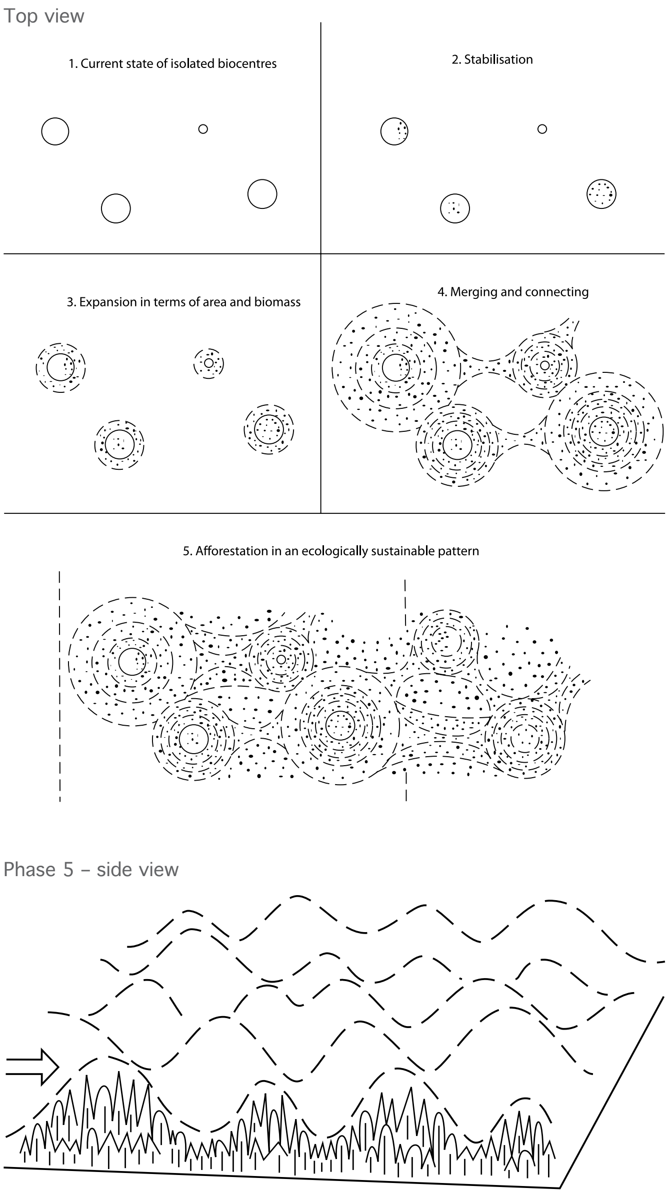

Fig. 5. Model strategy of general forest restoration on the plateau of the Jizera Mts. PLA (Pelc 1992).

Fig. 6. About 100 km² of forest damaged by air pollution and by uncontrolled large-scale clearcutting at elevations above 850 m with extreme geoclimatic conditions. (Archive Nature Conservation Agency Czech Republic)

One project was prepared for the preservation and reproduction of native or otherwise valuable tree populations: locally adapted varieties of *Picea abies*, *Fagus sylvatica*, *Acer pseudoplatanus*, *Abies alba*, *Betula carpatica*, *Pinus mugo*, *Ulmus glabra*, and *Sorbus aucuparia*. Their conservation was partially secured by means of existing and newly designated nature reserves and by delimiting gene pools. Collecting seeds, growing saplings and planting these, preferably in biocentres, was included in an agreement of the Forests of the Czech Republic and the Jizera Mts. PLA Authority.

Restoration measures

1990s	The extinction risk of the local *Picea abies* population (particularly its peat-bog ecotype) was reversed by securing more than 700 kg of seed, i.e. potentially 10 million seedlings enabling reforestation for ten years. During deforestation, planting of *Picea pungens* and *Pinus mugo* of Carpathian origin was stopped. The latter had contaminated native *Pinus mugo* populations in the 1970s and 1980s.
Since 1992	Increased collection of *Fagus sylvatica* seeds, particularly from the 6th and 7th forest vegetation zones, as well as *Betula carpatica* seeds, to be used in restoring humid stands in the 8th forest vegetation zone. Use of local *Pinus mugo* in reforestation. Inventory of *Abies alba* trees. Collection of seeds from populations of other native tree species, such as *Ulmus glabra*, *Sorbus aucuparia* and *Acer pseudoplatanus*, especially at altitudes of over 750 m.
2001	Jizerskohorské bučiny NR was established as a unique tree gene pool, covering more than 2,600 ha. Four other *Fagus sylvatica* and *Picea abies* gene pools, covering more than 2,270 ha in total, were also delimited. Here, sensitive stand restoration methods have been applied and the gene pool potential has been preserved.
2011	Forests of the Czech Republic submitted and launched a project on enhancing forest stability in the Jizera Mts. PLA.

Results

Despite some problems, partial successes have been achieved in implementing the long-term strategy. This is clearly indicated by the increasing proportion of *Fagus sylvatica*, and also tree composition has gradually become more natural.

In the representative Frýdlant Forest Management Unit, the *Fagus sylvatica* proportion increased from 2,445 ha in 1992 to 2,761 ha in 2001. Currently, 3,051 ha are covered by deciduous tree species, an increase by almost 20% in 20 years. The *Picea pungens* distribution, on the other hand, declined from 1,996 ha in 1992 to 1,487 ha in 2001 and 938 ha in 2011, i.e. less than half the area of 20 years ago (Fig. 7).

The number of *Abies alba* trees able to set seed is approximately 1,400 individuals, which is less than 0.05% of full-grown trees in natural forests of the Jizera Mts. The year 1998 was the most successful in this regard, because 1,750 kg of cones, 200 kg of seeds, i.e. hundreds of thousands of seedlings were harvested.

In total more than five million saplings have been used for improving the species and genetic composition in forest restoration and stabilisation during the last two decades. Suchopýr, a public service company, has contributed to forest restoration with more than 150,000 genetically valuable saplings, whereas Čmelák, another public service company, produced 65,000 *Abies alba* saplings, almost 200,000 *Fagus sylvatica* saplings and almost 36,000 *Ulmus glabra* saplings. Even greater numbers of genetically native and valuable saplings were provided by Dendria, a silvicultural company: more than 2 million saplings of *Fagus sylvatica*, over 2 million of local *Picea abies* and hundreds of thousands of *Abies alba*, *Ulmus glabra*, *Betula carpatica*, *Acer pseudoplatanus*, *Pinus mugo* and other forest tree species.

In the Jizerskohorské bučiny NR, after an agreement with the Forests of the Czech Republic, 75 hectares were left to spontaneous development under a specific monitoring scheme.

Restoration of damaged forests was included in the delimitation of the Territorial System of Ecological Stability.

Lessons learned and future prospects

Problematic issues, which may generate risks in the future, include the following:

1. The central plateau is inhabited by large and increasing even-aged stands of mostly *Picea abies* and *P. pungens*, which might face disruption within a few decades.
2. Nature conservation and foresters should prioritise stabilisation and restoration of biocentres by using natural regeneration and

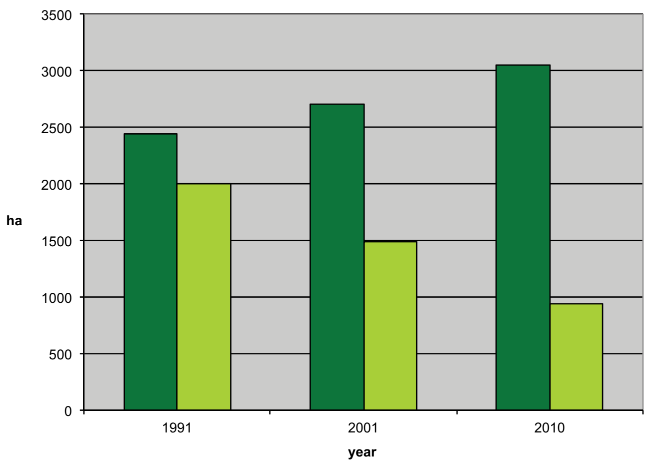

Fig. 7. Development of *Picea pungens* (light green) and *Fagus sylvatica* (dark green) ratios in the Frýdlant Forest Management Unit (Jizera Mts. PLA), 1991–2010.

Fig. 8. Silver Fir cone collection in the Jedlový důl gene pool and biocentre. (V. Vršovský)

genetically appropriate saplings, and by increasing their diversity in terms of species and distribution.

3. High game numbers remain locally a limiting factor in the increase of species diversity. However, also in case their numbers are reduced, it will be necessary to secure protection of natural regeneration stands and plantings.
4. Except for research projects, reappearing plans of large-scale measures, including aerial fertilising and liming, must be rejected, as they pose serious risks to montane ecosystems due to the heterogeneity and complexity of their biogeochemical processes.
5. In the interests of biodiversity conservation and natural processes and representative research, a large forest area needs to be left to spontaneous development.
6. It is necessary to update the agreement between the Forests of the Czech Republic, the Jizera Mts. PLA Authority and non-profit organisations on protection, reproduction and use of the native forest tree gene pool with special regard to legislation and the ecological condition of the forests.

Public support

One of the positive elements of the project has been fruitful co-operation between Forests of the Czech Republic, the Jizera Mts. PLA Authority and interested non-profit organisations, especially the Foundation for the Preservation and Restoration of the Jizera Mountains, Suchopýr, and Čmelák. We have also managed to raise the interest of foresters in rational utilisation of the native tree gene pool and forest stabilisation in biocentres.

Acknowledgements

I would like to thank Mr J. Antl (Čmelák), Mrs A. Hnídková (Suchopýr), and Mr I. Machovič (Dendria) for providing documents and expert estimations of the production of plant material, and Mr J. Hušek (Jizera Mts. PLA Authority) and Mr L. Dostál (Forests of the Czech Republic) for providing some recent information.

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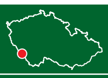
Fig. 9. Left: Production of genetically valuable saplings (here *Ulmus glabra*) is one of the preconditions of restoring forests with greater stability. (Archive Suchopýr)
Right: Planting of genetically valuable saplings but locally also natural regeneration plots need individual or large-scale protection against destruction by ungulate game. (V. Vršovský)

Spontaneous recovery of mountain spruce forests after bark beetle attack

Magda Edwards

Location 	Central part of the Šumava Mts. (Bohemian Forest), southwest Czech Republic 48°56'–8°59' N, 13°25'–13°29' E; altitude 1175–1280 m
Protection status	NP, UNESCO Biosphere Reserve, SCI
Ecosystem types	Montane *Calamagrostis* spruce forests (*Piceion abietis*), represented by the *Calamagrostio villosae-Piceetum* association with the tree layer dominated almost exclusively by Spruce (*Picea abies*) with some Rowan (*Sorbus aucuparia*) at the edges

Initial conditions

The area is covered by extensive complexes of both natural and management-influenced spruce forests. Climax mountain spruce forests occur in a mosaic with edaphically conditioned waterlogged and bog spruce forests, and treeless bogs. The current spruce forests originated partly from natural regeneration, and planting and sowing in clear-cuts after windstorm and bark beetle outbreaks in the 19th century. Waterlogged and bog spruce forests have remained the least influenced by management.

A large complex of mountain spruce forests situated in the central part of the Šumava Mountains was affected by a bark beetle outbreak in the 1990s. A non-intervention approach was adopted in some Core Zones of the National Park, while interventions against the bark beetle, in the form of salvage logging, were applied in all other parts of the Šumava Mts.

This study was performed as part of a long-term observation of recovery of spruce forests affected by bark beetle with and without interventions.

Abiotic conditions

The bedrock is predominantly gneiss, partly combined with granodiorites. Podzols are the prevailing soil type.

Fig. 1. Dead wood represents islands of high diversity in a spruce forest. (M. Edwards)

Fig. 2. Spontaneously regenerating spruce forest with uneven-aged natural regeneration distributed in clumps, 10 years after die-back of the tree canopy. (M. Edwards)

Methods

Permanent research plots, 400 m² each, were selected in representative parts of available stands of spruce forests both with and without interventions. In this study, we compared two types of plots:

1. Dead canopy, i.e. climax mountain spruce forest attacked by bark beetle in 1997 resulting in spruce mortality, left without intervention. Eight plots were established.
2. Clear-cut climax mountain spruce forest attacked by bark beetle and completely cut in 1997. The plots were artificially reforested with spruce (*Picea abies*) and rowan (*Sorbus aucuparia*). Five plots were established.

Vegetation composition was evaluated between 1998 and 2007 using four phytocenological samples of 100 m² in each plot. Seedlings and saplings of trees were recorded by species, height and age categories. The data were analysed with multivariate methods and repeated measurement ANOVA.

Results

Vegetation

Typical species of mountain spruce forests, such as *Lycopodium annotinum*, *Dryopteris dilatata*, *Homogyne alpina*, *Oxalis acetosella* and *Soldanella montana*, prospered under the dead canopy and even increased their cover. These species failed in the clear-cuts and were replaced mostly by grass and sedge species (Fig. 3). Three endangered herb species (*Lycopodium annotinum*, *Soldanella montana*, *Streptopus amplexifolius*) were found in plots under the dead canopy. The number of indicator species of mountain spruce forests and the number and cover of bryophytes were significantly higher under the dead canopy (Jonášová & Prach 2008).

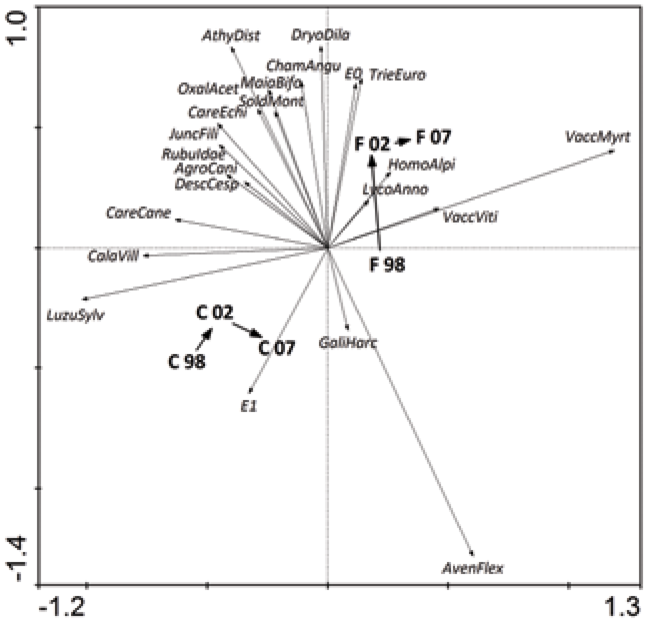


Fig. 3. PCA ordination diagram representing the projection of herb species and type of plot (as a passive variable) for 1998, 2002 and 2007. C – clear-cut plot; F – dead canopy; E0 – total cover of bryophytes; E1 – total cover of herb species. The species are labelled with the first four letters of the genus name and the first four letters of the species name.

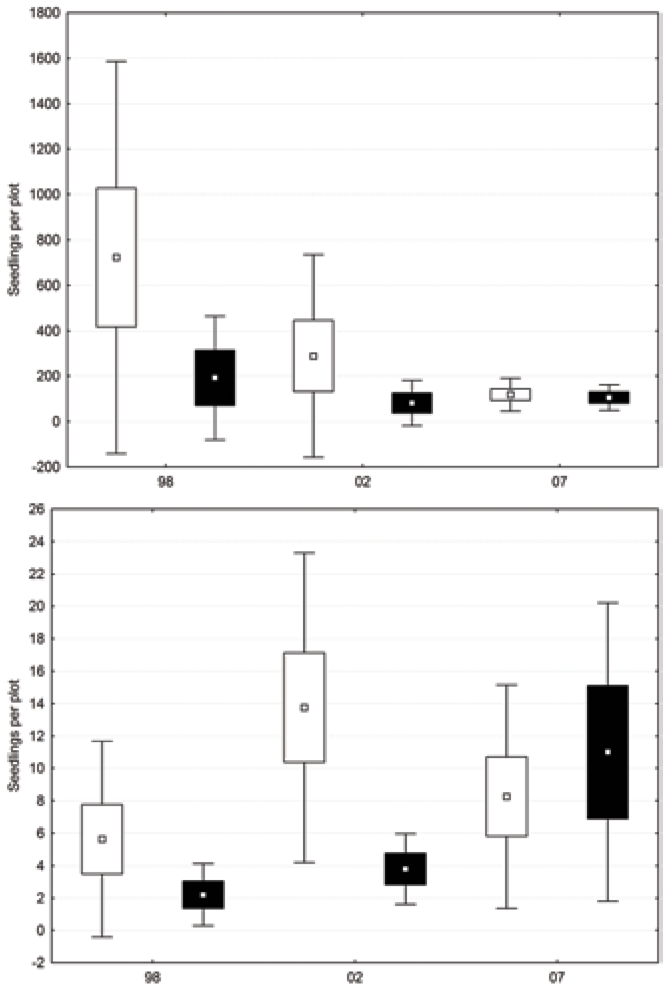


Fig. 4. Average numbers of spruce (top) and rowan (bottom) seedlings in 1998, 2002 and 2007 in the dead canopy (white) and clear-cut (black) plots. Numbers in 1998 and 2002 show only natural regeneration, while numbers in 2007 include also plantings in clear-cuts both for spruce and rowan.

Natural regeneration

A substantial part of the natural regeneration was formed by spruce in both types of plots, with rowan being the second most numerous species. Pioneer species, such as Birch (*Betula pubescens*), Willow (*Salix* sp.) and Aspen (*Populus tremula*), appeared in the first years on the disturbed soil surface after salvage logging (Jonášová & Prach 2004). The total numbers of Spruce and Rowan were significantly higher under the dead canopy in 1998 and 2002. The numbers in 2007 were similar, but in clear-cuts these numbers were achieved by plantings (Fig. 4). The height and age structure of spruce regeneration was reduced in clear-cuts compared to plots under the dead canopy (Jonášová & Prach 2004).

Fig. 5. Spruce saplings survive almost exclusively on dead wood and by the tree base. Buttresses of the tree on the right indicate that it also originated on dead wood. (M. Edwards)

Conclusions

Our results indicate that non-intervention in mountain spruce forests attacked by bark beetle is a much better option for the restoration of these forests than any forestry measures. The disturbance caused by salvage logging had a significant negative effect on vegetation and natural regeneration of indigenous species of mountain spruce forests, which led to the need for artificial reforestation. The non-intervention approach achieved, at no cost, similar numbers of Spruce and Rowan as with artificial reforestation. The age and height structure of the future forest and the condition of the original vegetation are more vigorous under dead canopy. Moreover, the non-intervention approach allows for natural selection, which will lead to the formation of substantially more resistant stands.

Acknowledgements

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Grasslands

Meadow near Strání, Bílé Karpaty PLA. (I. Jongepierová)

Introduction

Ivana Jongepierová & Igor Malenovský

Grasslands belong, in terms of plants and animals, to the most diverse communities in Europe, and this is true on various spatial scales (Veen et al. 2009). In Central European conditions most of the current grasslands, however, do not represent climax communities, but were created after deforestation of the landscape and are maintained by farming activities. They have been managed for centuries, in some areas possibly even since the Neolithic or Bronze Age (Hájková et al. 2011), particularly by grazing and mowing (Chytrý 2007). At present they therefore not only possess natural values, but are also of a high cultural-historic value, since they are the result of activities by dozens to hundreds of human generations.

In the early 20th century, nearly 1200 thousand hectares of grassland were registered on the territory of the present Czech Republic. Two thirds included meadows and a third pastures. This ratio was preserved throughout the century, although the total area reached a low of 800 thousand ha (Hrázský 2006) at the end of the era of socialism and collectivisation (1950–1989), when intensive agriculture caused the transformation of about one third of grasslands into arable land. The remaining grasslands were degraded by fertilising, draining, intensive grazing, additional sowing of commercial grass and legume seed mixtures, or conversely, by abandoning grassland management and by afforestation. All these changes led to an enormous loss in the species diversity of the original communities and a homogenisation of the landscape in general.

During Natura 2000 habitat mapping (Chytrý et al. 2010) approximately 396 thousand hectares of semi-natural grassland communities were recorded in the Czech Republic. Another hundreds of thousand hectares of grassland were classified as Intensively Managed Meadows. This means that grasslands of conservation value in the Czech Republic (e.g. for reason of high total species richness or presence of endangered plant and animal species) have declined strongly during the past few decades. Moreover, well-preserved fragments of such grasslands today often occur isolated in the landscape, and thus lack the metapopulation dynamics necessary for the survival of a range of invertebrate and plant species. Finally, many plots, mainly grassland enclaves in forests and at other inaccessible locations, on steep slopes, or small private plots around villages, have been abandoned or afforested in the past twenty years.

Fig. 1. *Lilium martagon* in Čertoryje NR, Bílé Karpaty PLA. (J. W. Jongepier)

Conservation management

The first attempts to secure the management of some valuable sites (at the time mostly fallow land or grassland encroached by shrubs and trees) were made in the late 1970s and early 1980s, thanks to volunteers of non-governmental organisations – TIS (Association for Nature and Landscape Conservation), later the Czech Union for Nature Conservation, and the Brontosaurus Movement. The situation generally changed after 1989, when particularly in submontane and mountainous regions grassland fertilisation was mostly stopped, and arable land was turned back into grassland. In that time (at least to a small extent) also state nature conservation bodies began to support the management of preserved grassland (and thus increase of biodiversity), mainly in protected areas, in an active way.

In 1996 the Ministry of the Environment and the Ministry of Agriculture created the Landscape Management Programme, a subsidy scheme which has been in operation up to the present. This has financially stimulated landowners and -tenants to take care of particular sites (e.g. nature reserves) or secure restoration and maintenance of abandoned sites. Unfortunately state finances are limited and therefore the total amount of subsidies has been gradually reduced in the past years.

Agri-environmental schemes

As of 1999, subsidies of the Ministry of Agriculture can be used for landscape maintenance, particularly for mowing and grazing. These have led to a resumption of the management of several thousand hectares of grassland which had been lying fallow after the disintegration of agricultural cooperatives. Many sites have unfortunately only been mulched. With the Czech Republic's entrance into the European Union, the subsidy system essentially changed thanks to access to Agri-environmental schemes. Their aim is to support agricultural land use respecting the environment and the landscape. Besides mowing, the Agri-environmental Programme has also supported grazing of particular sites, mostly by beef cattle and sheep.

Paradoxically, despite their intention, Agri-environmental schemes have unfortunately not contributed much to a higher biodiversity in the Czech Republic so far. Especially their too uniform and strictly enforced requirements for large blocks of land are a problem. Unifying management of large areas is, thanks to modern farming equipment, easy today, but it has a very negative effect on rare, but also common plant and animal species. The point is that the mowing of large areas in a short time practically removes all available food plants, nectar and shelter (including places for resting, patrolling and hibernating) from the sward, which are particularly important to a range of invertebrates. It also causes high mortality of animals in all development stages (especially when heavy equipment is used, e.g. rotary mowers) (Čížek et al. 2011). All this may lead to the extinction of formerly large populations of sensitive species, which are often important from the nature conservation viewpoint, within a few years (Konvička et al. 2005, 2008). Autumn mulching is also destructive, but farmers are forced to use it in case the sward exceeds a height of 30 cm. Mowing of ungrazed patches after each grazing cycle in pastures has a negative effect on biodiversity as well (Konvička & Mládek 2006). Currently nature conservation authorities can adjust management regimes on request. This is however administratively difficult and farmers are not stimulated to do so, hence such cases are in reality exceptional (Marhoul 2010). Another problem is that the Agri-environmental Programme does not support small landowners, since the minimum land area is set at 2 ha in protected landscape areas and even 5 ha outside of them. Although farming extensive 'cultural' grasslands leads to conservation of an open landscape, it does not conserve its biodiversity (Piro & Wolfová 2008). Also, there are no subsidies available at the moment for alternating grazing and mowing of unfertilised grasslands, but a change of the Programme is currently being prepared.

In summary, Agri-environmental schemes should pay more attention to the need to divide and diversify uniform landscapes, either by reducing land block sizes or introducing the obligation to farm in a diversifying manner, both in space and time. A possible solution would be the creation of individual farm plans, respecting the special features and natural conditions of each area.

In the past years also other European resources have been used to maintain and especially restore particular habitats, such as Operating Programmes, the LIFE programme, and Norway Grants.

Fig. 2. Pasture in Švařec NR, Bohemian-Moravian highlands. (Z. Patzelt)

Types of grassland restoration and recreation

Restoration of grasslands degraded by fertilisation

When grasslands are no longer fertilised and their biomass is regularly removed, the number of plant and animal species increases within a few years. Some sites in submontane and mountainous regions, which were until 1989 influenced by light fertilising, are good examples. In cases where mowing has continued, the original species composition has often recovered within 10–15 years, and sometimes protected and endangered plant and animals species have appeared (e.g. Královec et al. 2009).

Restoration of unmanaged or afforested grasslands

Abandoned sites are usually rapidly overgrown by fast-growing, competitive grasses (e.g. *Brachypodium pinnatum*, *Calamagrostis epigejos*, *Molinia* spp.) and shrubs and trees (*Crataegus* spp., *Prunus spinosa*, *Rosa canina*, *Populus tremula*, *Betula* spp., *Salix* spp., *Alnus glutinosa*, etc.), so that species confined to open vegetation gradually decline. In the past 30 years, management has been resumed on several thousand hectares of grassland which had been encroached by coarse grasses, shrubs and trees, particularly in protected areas. As documented by several case studies in the following chapters, rare and endangered plants have returned to many of these sites.

Several meadows and pastures have been afforested on purpose – mostly with conifers at lower elevations and with *Pinus mugo* in the Subalpine zone. The latter community is successfully being restored in the Krkonoše NP and described in the case study "Restoration of the tundra ecosystem above the timberline in the Krkonoše Mts.".

Many restoration efforts have also been focused on moist grasslands. The case study "Restoration and subsequent degradation of an alluvial meadow" describes the rate of restoration in experimental plots of a neglected alluvial meadow. The case study "Restoration management of wetland meadows in the Podblanicko region" provides a practical example.

Another example of successful restoration, including strong surface disturbance, is described in the case study "Optimising management at *Gentianella praecox* subsp. *bohemica* sites".

At several dry grassland sites, mostly thanks to initiatives of state conservation authorities, grazing by sheep and goats has been reintroduced. An example is described in the case study "Grazing of dry grasslands in the Bohemian Karst".

Grazing has also been reintroduced in other types of grassland communities, especially in submontane and mountainous regions. The results of an experiment aimed at monitoring the long-term development of mesophilous abandoned grasslands after resuming management are given in the case study "Restoration of grazing management on abandoned upland grasslands in the Jizera Mountains".

A separate problem is the maintenance and restoration of plant communities on open sands, which are currently extremely rare habitats. In the past, succession of these communities was often inhibited by regular fires or grazing. After cessation of these factors such sites are now changing due to shrub and tree encroachment, eutrophication, settling of invasive and expansive species, etc. Therefore the most urgent measures to be taken here are the elimination of shrubs and trees, removal of the eutrophicated top soil layer, and mechanical disturbance (see case study "Restoration of sands as part of the Action Plan for *Dianthus arenarius* subsp. *bohemicus*" and also the section on military training grounds and post-industrial habitats).

Restoration of mosaic management

Modern mechanisation has enabled farmers to mow dozens of hectares of grassland during one or a few days, which has negative effects on biodiversity, particularly invertebrates (see above). Long-term intensive grazing has a similar negative impact. Permanent preservation of plant and animal species diversity thus requires a type of management varied in space and time (the more small plots, the better) (Kirby 2001).

The necessity of mosaic management is demonstrated by the case study "Restoring heterogeneity in submontane meadows for the butterfly *Euphydryas aurinia*". See also Konvička et al. (2005, 2008), Marhoul (2010), and Čížek et al. (2011).

Conversion of arable to grassland

After 1989, land has come back into the hands of private owners, and agricultural cooperatives have been transformed. These changes have also meant the conversion of more than 230,000 hectares of arable land to grassland (regrassing). This conversion has taken place either spontaneously after the arable land was abandoned or by seeding with grass or grass-herb seed mixtures.

a) Spontaneous succession

About 30–40% of converted arable land has returned to grassland spontaneously by means of natural succession. In some areas, particularly in marginal regions, land has been abandoned due to disintegration of agricultural cooperatives. In many other areas spontaneous succession was deliberately applied as a cost-free way of converting arable land to grassland, e.g. in organic agriculture.

Spontaneously reverting swards can be used as low-productive pastures already a few years after the start of the succession. Less frequently such land is mown in the first years (in the weed stage), as it yields sparse hay of bad quality. However, quality pasture and meadow communities need to develop over a longer time depending on natural conditions and distance to seed resources of target species (Lencová & Prach 2011, Prach et al. 2012).

Spontaneous succession is useful if not obtaining productive grassland in a short time is the aim, but resistance and naturalness of the resulting sward is more important.

b) Grassland recreation with commercial seed mixtures

Half to two thirds of all regrassed land in the Czech Republic has been sown with seed mixtures available on the market. Species usually included in these mixtures are *Alopecurus pratensis*, *Arrhenatherum elatius*, *Dactylis glomerata*, *Festuca arundinacea*, *F. pratensis*, *F. rubra*, *Phleum pratense*, *Poa pratensis* agg., *Lolium perenne*, and *L. multiflorum*. Commercial grass mixtures are mostly applied in intensive farming. However, if swards created this way are located close to species-rich communities and are not fertilised thereafter, they are gradually colonised by grassland species from the surroundings and may eventually come close to semi-natural swards in terms of species composition (Lencová & Prach 2011).

In the Czech Republic, commercial species-rich seed mixtures – besides cultural grasses and legumes also including seed of other dicotyledonous species – have so far been used to a limited extent. This seed is offered by several companies and is mostly used in gardens and orchards.

c) Grassland recreation with regional species-rich mixtures

The only region in the Czech Republic where a species-rich mixture of regional grasses and herbs has been used on a large scale is the Bílé Karpaty Protected Landscape Area (PLA). This process was initiated by an NGO, the Czech Union for Nature Conservation, Local Chapter Bílé Karpaty, Veselí nad Moravou, in collaboration with the Bílé Karpaty PLA Authority and Grassland Research Station, Zubří. Since 1999 more than 500 ha of arable land have been regrassed with this mixture (Jongepierová 2008, Mitchley et al. 2012, Prach et al. 2012) – see case study "Recreation of species-rich grasslands in the Bílé Karpaty Mts." In a few other regions regional seed mixtures are being prepared or have been used at a small scale, again at the initiative of NGOs (Litovelské Pomoraví, surroundings of Karlovy Vary).

Fig. 3. Drahňovice wetlands, central Bohemia, are a well-preserved complex of wet *Cirsium* meadows of over 6 hectares. (M. Klaudys)

Fig. 4. Recreated grassland four years after sowing a regional seed mixture, Bílé Karpaty PLA. (I. Jongepierová)

Conclusion

Thanks to restoration activities, the total area of grasslands in the Czech Republic has markedly increased in the past 20 years, but to date their biodiversity has risen significantly in only a few areas. The future of grasslands is moreover dependent on subsidies from the Ministry of the Environment, the Ministry of Agriculture, and the European Union. At the moment the Ministry of the Environment is strongly reducing the finances it provides, which may have a catastrophic impact on the maintenance of preserved grassland communities. This is because these finances support particularly the management of remnants of the most valuable semi-natural habitats, which often require manual maintenance and special measures. Besides their immense natural and cultural-historic values such habitats are also irreplaceable as a resource for the spread of rare species to regrassed and degraded sites.

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Experimental restoration and subsequent degradation of an alluvial meadow

Karel Prach

Location	Horní Lužnice NR, Lužnice river floodplain, south Czech Republic, near the border with Austria 48°51'10" N, 14°54'39" E; altitude 455 m
Protection status	PLA and UNESCO Biosphere Reserve (Třeboňsko), NR
Ecosystem types	Mosaic of alluvial meadows, marshes, pools and willow scrub; experiment in degraded alluvial meadows (*Deschampsion cespitosae* and *Magno-Caricion gracilis*)
Experimental area	675 m^2

Initial conditions and restoration measures

The experiment was established in an area of floodplain which had been regularly cut until the late 1960s, and was then left unmanaged. In 1989, a strip 135 m long and 5 m wide was delimited between the riverbank and the foot of the terrace, and cutting management was resumed. Vegetation was cut three times a year in the first three years of the experiment, i.e. 1989, 1990, and 1991, and twice a year thereafter because of insufficient increase in biomass later in the seasons of 1992 and 1993. All cut biomass was removed. No management was performed since 1994.

Objectives

The following main questions were addressed: (a) how fast is the restoration of neglected alluvial meadows, (b) how much are target meadow species capable of establishing, and (c) do the rate and ways of degradation differ from that of restoration?

Methods

A transect was demarcated in the middle of the area along the mown strip, and vegetation was recorded in each 1 m^2 along the transect in early June, before the first mowing. The cover of all species was estimated visually. At the same time a species list was compiled for the whole mown strip. The vegetation records were repeated four and seven years after the mowing had been stopped. Target species were defined as those characteristic of the *Molinio-Arrhenatheretea* class (Ellenberg et al. 1992).

Results

Rapid changes in species composition and cover of constituent species were observed following both the re-establishment of regular mowing in 1989 and its cessation after 5 years (Tab. 1). *Phalaris arundinacea*, the dominant species at the start of the experiment, slightly increased in dominance after the first season of cutting, but

Fig. 1. Lužnice river floodplain. (K. Prach)

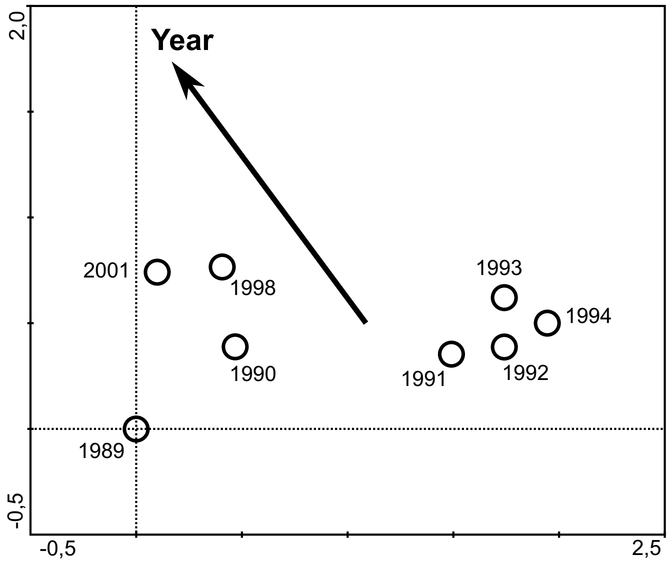

Fig. 2. Unconstrained ordination (DCA) of vegetation samples (centroids) from the entire restored strip in different years. Source: Prach (2007).

then decreased very rapidly. However, after the cessation of mowing, *P. arundinacea* was also able to attain its previous dominance rapidly. *Urtica dioica*, the prevalent species at drier elevations, started to decrease immediately, and nearly disappeared (average cover 0.001%) in the last year of the experiment. The typical dominant of managed alluvial meadows in the area, *Alopecurus pratensis*, increased up to the fourth year of the experiment, then stabilised before decreasing after the cessation of mowing. Many typical meadow species appeared after two seasons of mowing while others established in the following two years. Most of these species disappeared again after the cessation of mowing. The greatest increase in species number was recorded between the second and third year of the experiment (Tab. 1). During the experiment, the number of species increased nearly threefold. A similar trend was found in the case of species density, which increased by twofold in only two years. The number of target species peaked in the fourth year of the experiment, and when mowing was stopped, it decreased again.

Results of the Detrended Correspondence Analysis ordination of samples (Fig. 2) indicate that the greatest change in vegetation took place in the second year of the experiment (1990). After the cessation of mowing (1994), it took only 4 years for the vegetation to become close to that of the first year of the experiment. The first axis (eigenvalue 0.508) represents management, while the second axis (eigenvalue 0.052) is partly related to time.

Conclusions

Both restoration and degradation of the alluvial meadow under study occurred very rapidly. It took just four years to restore a typical managed alluvial meadow from a degraded one. After the cessation of mowing, both the cover of constituent species and species numbers after seven years returned nearly exactly back to the values before the experiment started (Tab. 1), degradation thus being only slightly slower than restoration. Rapid restoration was obviously supported by the fact that regularly managed meadows of comparable species composition occurred only 150 m upstream of the experimental site, where all the newly established meadow species were recorded. Propagules of the species were probably transported by regular flooding. The rapid degradation was obviously accelerated by the fact that the experimental strip was narrow (5 m wide), and the clonal dominants of the surrounding degraded meadows, i.e. *Phalaris arundinacea* and *Urtica dioica*, spread vegetatively very easily from the margins of the experimental strip.

Other lessons learned and future prospects

Re-establishment of mowing management is recommended for the entire floodplain, which is nowadays largely neglected. If this cannot be performed, it should at least be introduced in several large, rather than many small, portions of the floodplain. The management must be regular – if interrupted for even a few years, rapid degradation can be expected again.

Acknowledgements

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Tab. 1. Changes in average percentage cover of three species with the highest abundance, and some species diversity features along the experimental transect. Data in 1989 were taken before the experiment started; cutting was carried out in 1989–1993. Source: Prach (2007).

	1989	1990	1991	1992	1993	1994	1998	2001
Alopecurus pratensis	14.4	20.3	21.8	26.5	33.1	30.4	23.5	11.6
Phalaris arundinacea	28.0	35.1	9.5	4.4	0.7	0.9	32.8	37.0
Urtica dioica	18.4	7.8	2.6	0.2	0.1	0.0	1.8	13.6
Average species density per 1 m^2	4.0	7.3	8.9	6.9	8.1	8.2	5.0	4.5
Number of species in sampling plots	23	35	55	60	62	57	27	27
Number of target species	4	5	16	20	22	20	7	7
Total number of species along the transect	28	48	61	71	79	70	31	29

Fig. 3. Well-preserved part of the Lužnice river floodplain in the Třeboňsko PLA. (J. Ševčík)

Restoration management of wetland meadows in the Podblanicko region

Martin Klaudys

Location	SE part of the Central Bohemia Region 49°30'–49°52' N, 14°30'–15°10' E; altitude 280–630 m
Protection status	PLA (Blaník – 8 sites), NR (5 sites), SCI (4 sites)
Ecosystem types	Various types of wet meadows, where optimal with a range of well-developed communities following the water gradient: transition mires and quaking bogs (*Caricion canescenti-nigrae*), humid meadows (*Calthion palustris*), Molinia meadows (*Molinion caeruleae*) and Nardus grasslands (*Violion caninae*)
Restored area	63 ha (28 sites)
Financial support	Regional Authority of the Central Bohemia Region, Regional Authority of the Vysočina Region, landscape management programmes, Operational Programme Environment, own resources
Costs	Initially €1,000/ha (elimination of trees and shrubs on 42 ha), annually €800/ha (mowing 1–2 times on 63 ha, incl. mosaic mowing at selected locations)

Initial conditions

Meadows with rare plant species used to be a relatively common part of the landscape until the 1960s. The meadows were managed extensively in the time before that (Zelený 1976). The following intensification of agricultural production often led to adjustments of the water regime at the sites as well as to eutrophication and biodiversity decline. Some representative meadows were usually preserved only at the periphery of a village territory. In the past twenty years, these remnants of wet meadows have been threatened by lack of management. The meadows are inhabited by protected species, for example Broad-leaved Marsh-orchid (*Dactylorhiza majalis*), Small Lousewort (*Pedicularis sylvatica*), Round-leaved Sundew (*Drosera rotundifolia*), Common Bogbean (*Menyanthes trifoliata*), Grass-of-Parnassus (*Parnassia palustris*), Viper's-Grass (*Scorzonera humilis*), Marsh Cinquefoil (*Potentilla palustris*), Globe-Flower (*Trollius altissimus*), and Marsh Gentian (*Gentiana pneumonanthe*).

Since the beginning of its activities, the Czech Union for Nature Conservation (CUNC), Local Chapter Vlašim, has focused on the restoration and maintenance management of wetland meadows. Under the Landtrust for the Natural and Cultural Heritage of the Podblanicko Region, it has carried out several activities, incl. monitoring of sites, cooperation with landowners and implementing measures of its own. Since 1990, restoration measures have been gradually implemented at 28 sites. Another 10 sites are being monitored for the presence of

Fig. 1. Large population of Common Cottongrass (*Eriophorum angustifolium*) at the site "Na pramenech". The fens are regularly mown by hand. (M. Klaudys)

rare and protected species. This means that also sites where restoration measures have not been carried out or prepared are monitored.

One of the monitored species is *Dactylorhiza majalis*, whose presence indicates well-preserved aquatic conditions. Its abundance corresponds with the presence or absence of management.

Abiotic conditions

The sites have waterlogged or peated soils. There are also places with stagnant surface water, occurring either naturally or in artificially created pools. Some sites have a water regime disturbed by different alterations (open drainage channels, pipe drainage systems) which restrict expansion of the target species.

Objectives

Restoration and stabilisation of the wetland biodiversity of meadows in the Podblanicko region, including maintenance of populations of rare species.

Restoration measures

1990–2000	Assessment of the status of wet meadow sites, including the presence of particular species. Establishing site ownership and contacting the owners. Cleanups (cutting shrubs and trees, reducing scrub areas, mowing once a year) at 10 pilot sites.
2001–2005	Cleanups (cutting shrubs and trees, reducing scrub areas, mowing once a year) at most localities, maintenance management (mowing once a year) at most localities. At 13 sites pools for amphibians were created. Most of the landowners of the localities were contacted. Since it was not always possible to obtain consent of the landowners with carrying out management for the entire area of the sites, some parts of the sites remained without management or were mown once every two years.
2006–2011	Regular annual mowing management at the sites: at the end of June and July at sites of low and medium altitude, in August at higher altitudes. A second cut takes place at selected locations in October. Mowing is carried out with brushcutters or hand-guided mowers with a cutter bar. The cut biomass is manually raked up in piles and then mechanically loaded onto a lorry for transport to a composting facility.

Also specific forms of management have been realised at the sites – cleaning gullies, mosaic mowing in selected plots and deliberately leaving selected sites unmown in certain years. Monitoring of the abundance of selected species and area distribution of species has been carried out at selected locations.

Results

After implementation of cleanup management, the population of *Dactylorhiza majalis* usually responds sooner or later with an increase in number of recorded flowering individuals (Fig. 3). Flowering individuals originate partly from surviving individuals at the site (not flowering because of shading and being covered by plant litter), possibly also from the seed bank. The increase later slows down.

The observed abundance of flowering *Dactylorhiza majalis* individuals at the monitored sites grew from 0 to approximately 1000 individuals over the period 2006–2011. At the restored and long-managed locations the marsh-orchid populations are stable (cf. Dykyjová 2003), with fluctuations in the number of flowering individuals according to the course of the growing season or sometimes with a slight increase. At locations with recently resumed mowing this fluctuation is stronger. In contrast, the number of flowering individuals gradually decreases at sites where no management takes place (lack of interest in management by the landowners).

Fig. 2. Broad-leaved Marsh-orchid (*Dactylorhiza majalis*) in Podlesí NR, Blaník PLA – a very large population in the region. Management has created a patchwork of plots with different regimes (mosaic mowing, no mowing, mowing twice a year). (M. Klaudys)

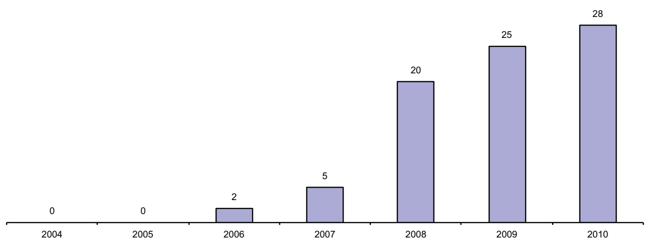

Fig. 3. Abundance of flowering individuals of *Dactylorhiza majalis* at Drahňovická mokřadla, where cleanup management was realised in 2005, after which the regularly mown area has been gradually expanded.

Other lessons learned and future prospects

The development of the *Dactylorhiza majalis* populations at the monitored sites shows that management is a necessary condition for the existence of this species at a site. After mowing (preferably in phases) has been reintroduced, the orchid's further spread is limited by the water regime alterations realised in the past (draining ditches, drainage systems). Removal of drainage systems and resuming waterlogging usually requires expensive separate projects.

Public support

The management of the locations in Blanik PLA (7) is supported by the Blanik PLA Authority, management of nature reserves in the Central Bohemian Region (2) by the Regional Authority of the Central Bohemian Region, management of a nature reserve in the Vysočina Region (1) by the Regional Authority of the Vysočina Region, and management of the other sites by the Nature Conservation Authority of the Czech Republic, local authorities, and landowners of the sites. The actual cleanups and following management is carried out by CNUC Vlašim members, volunteers, and also the landowners themselves. Landowners are key partners in favour of long-term continuity of site management and it is essential that they understand the importance of their site for nature conservation.

Acknowledgements

Collection of the documentary data was financed from the CNUC programme Biodiversity Protection, supported by the Ministry of the Environment in 2010.

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Fig. 4. Manual mowing at Řísnické louky, Podblanicko. (M. Klaudys)

Recreation of species rich grasslands in the Bílé Karpaty Mountains

Ivana Jongepierová, Karel Prach & Klára Řehounková

Location 	Bílé Karpaty Mts., southeast Czech Republic, near the border with Slovakia 48°50'–49°05' N, 17°19'–17°55' E; altitude 250–610 m
Protection status	PLA, UNESCO Biosphere Reserve, SCI (2)
Ecosystem types	The main grassland type in the area includes semi-natural, semi-dry grasslands (subatlantic *Bromion erecti* or subcontinental *Cirsio-Brachypodion pinnati*)
Restored area	500 ha (34 sites)
Financial support	Landscape management programmes, SAPARD, Agri-environmental schemes
Costs	800 €/ha

Initial conditions

In the second half of the 20th century several hundred hectares of grassland in the area were converted to arable land. Due to changes in agriculture after 1989, farmers became aware of the need to restore grasslands on the large arable fields. Some fields were left to spontaneous succession, but the majority has been turned into grassland using commercial clover-grass seed mixtures. However, these mixtures are prepared with high production in mind and are not tailor-made to suit specific local conditions. They lack most of the common grassland herbs, some of which are medicinal and nutritionally important to animals. This problem, as well as concerns about loss of genetic and species diversity, was the reason why in the early 1990s an environmental NGO, Local Chapter Bílé Karpaty of the Czech Union for Nature Conservation, started developing a regional grass-herb seed mixture in cooperation with the Bílé Karpaty Protected Landscape Area Authority and the Grassland Research Station, Zubří.

Abiotic conditions

Soil chemical analyses (sampled to a depth of approx. 5 cm) indicated neutral or slightly basic soils (pH 6.12–8.86) and a rather variable nutrient content partly caused by management of the previous arable land. Organic matter content varied between 7.33 and 16.08%, total N between 1309 and 3828 mg.kg^{-1}, and available phosphate between 16 and 161 mg.kg^{-1}. In terms of climate, the mean annual temperature is 7–9 °C, and the mean annual precipitation 500–800 mm.

Fig. 1. Vojšice, Hrubá Vrbka, regrassed in 2002. (I. Jongepierová)

Objectives

Creation of species-rich hay meadows, increasing biodiversity, improving of hay quality, reduction of erosion, improving of scenery.

Restoration measures

1993–1995	Seeds of common grassland species were collected from species-rich White Carpathian meadows and reproduced in seedbeds at several local farms and at the Grassland Research Station at Zubří.
1999–2006	A combine harvester was used to harvest local grasses, especially *Bromus erectus*.
2007–present	Seeds (mainly grasses) have been harvested with a brush harvester, which was constructed according to a model developed by the British company Emorsgate Seeds.
1999–present	A regional species mixture has been used, containing 85–90% grasses, 3–5% legumes and 7–10% other herbs (weight percentage). According to availability, 20–30 species are included in the mixture every year. The optimal seed rate is 17–20 kg.ha^{-1}. Until 2009, annually about 40–50 hectares were regrassed in the area by local farmers.
1999–2004, 2009	Succession after regrassing was monitored (vascular plants, soil fauna) in experimental permanent plots at a site called Výzkum (Jongepierová et al. 2007, Jongepierová 2008, Mitchley et al. 2012).
2009	Large-scale monitoring of vascular plant succession was carried out at 34 regrassed sites (Prach et al. 2012).

Management measures after sowing

- Mowing twice a year at least two years after regrassing to control weeds, once a year thereafter.
- Early cutting (June) to reduce grasses and encourage herbs.
- Autumn grazing to encourage biodiversity.
- Planting of trees, mainly oak (*Quercus petraea*), lime (*Tilia cordata*), and pear-tree (*Pyrus pyraster*) to improve scenery and further increase biodiversity.

Methods

In 2009, the vegetation of 34 regrassed sites was analysed by making three phytosociological relevés per site and comparing these with the vegetation of ancient, species-rich grasslands nearby (Fig. 2).

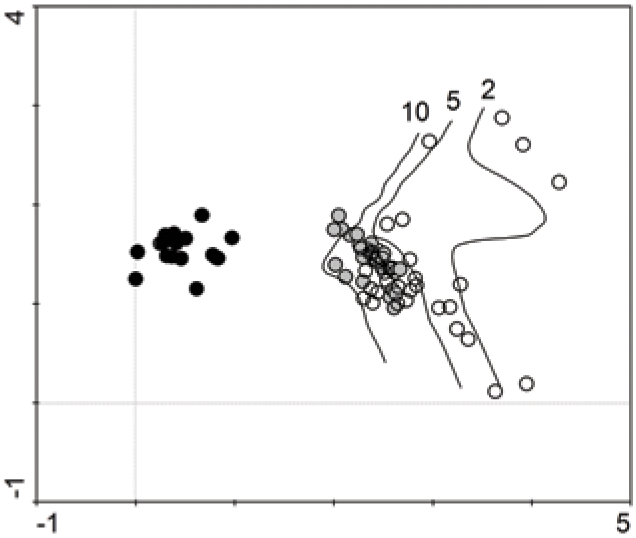

Fig. 2. Unconstrained ordination (DCA) of vegetation samples from restored sites (open circles) and reference sites (black dots) and the species composition of seed mixtures used for restoration (grey). Isolines represent the time since sowing the seed mixtures. Species composition of the restored grasslands 10 years after sowing corresponded to that of the regional seed mixtures used. It seems, restoration of species-rich grasslands is still approximately in a half-way (Prach et al. 2012).

Results

In total, 373 vascular plant species were recorded at the regrassed sites and 20 permanent reference grasslands. A total of 102 species were classified as target species, the remainder being either weeds or common grassland species.

Forty-four of the target species were sown at the restored sites and all, except one (*Helianthemum grandiflorum* subsp. *obscurum*), established (98%). Twenty-seven species established spontaneously, while 31 target species have not been found at the restored sites yet. Altogether, 248 species were recorded at the restored sites. However, only four species reached cover values at least equal to those at the reference sites (*Bromus erectus*, *Festuca rubra*, *Holcus lanatus*, and *Trisetum flavescens* – all sown grasses). The majority of the target species, both sown and spontaneously established, were present at the restored sites but so far only at low cover values. The two most successful spontaneously established target species were *Carlina vulgaris* and *Fragaria viridis*. Also some rare and endangered species arrived spontaneously at the restored sites, e.g. *Astragalus danicus* and *Gentiana cruciata* (Prach et al. 2012).

In a recent study (Mitchley et al. 2012), evaluating 10 years of a field experiment at a site called Výzkum including plots sown with regional seed mixtures, the trends were essentially similar to the large-scale study, i.e. restored plots developed a species composition heading towards the composition of the reference sites.

Fig. 3. Brush harvester. (I. Jongepierová)

Other lessons learned and future prospects

Until recently a late cut was recommended for recreated meadows and this was said to enhance the diversity of herbs in the grasslands. However, a preliminary analysis of the data acquired to date has shown that successful grassland restoration by means of regional grass-herb mixtures (as well as other ways of restoration) requires an early cut.

In the future, transfer of green hay may also be considered a suitable restoration measure.

Public support

Interest of farmers in the regrassing of other sites.

Fig. 4. Regional seed mixture. (P. Šrámek)

Acknowledgements

The study was supported by the following grants: GAČR P504/10/0501, P505-11-0256 and RVO67985939.

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Grazing of dry grasslands in the Bohemian Karst

Hana Mayerová, Tomáš Tichý, Petr Heřman, Kateřina Čiháková & Zuzana Münzbergová

Location 	Bohemian Karst (Český kras) between Prague and Beroun 49°52'–50°00' N, 14°02'–14°21' E; altitude 199–499 m
Protection status	PLA, NR (2), SCI
Ecosystem types	Dry grasslands belonging to the *Festucion valesiacae* alliance; transitions to the *Alysso-Festucion pallentis* and *Seslerio-Festucion pallentis* alliances, and to the *Bromion erecti* alliance
Restored area	25 ha
Financial support	Landscape management programmes
Costs	€700/ha/yr (grazing)

Initial conditions

The Bohemian Karst landscape has been occupied by human settlements continuously for the last 7000 years (Stolz & Matoušek 2006). Human settlements have always been connected to livestock grazing, which has significantly shaped the landscape (Poschlod & WallisDeVries 2002). Due to the relatively low yield of dry grasslands on shallow soils over limestone, sheep and goat grazing has been common in the Bohemian Karst, as they tolerate lower-quality fodder and rocky terrain.

Grazing has maintained open vegetation patches even in periods of closed canopy forest, and thus supported plant and animal species confined to this type of habitat. From the conservation point of view, grazing has played a positive role in the maintenance of species diversity. In the 20th century, the extent of grazing livestock decreased significantly in the Bohemian Karst, mainly after World War II, from roughly 10,000 to 100 goats and sheep (Novák & Tlapák 1974). Along with this, landscape changes occurred, whereby large open patches developed into woodland, either through succession (in remote and unprofitable places), or due to tree planting.

The remaining patches of grasslands are degrading due to increasing cover of dominant grasses and sedges at the expense of less competitive species, and plant and invertebrate species diversity is decreasing, small bare soil patches are disappearing, litter is accumulating, and microhabitat diversity is declining.

Fig. 1. Cattle grazing on dry grassland at "Pání hora". (T. Tichý)

Objectives

Restoration and maintenance of high-quality dry grassland habitats and of the scenery formed by a mosaic of various forest and open grassland vegetation.

Management measures

2005(2006)–2011: small-scale rotational grazing (Pavlů et al. 2003) in electrically fenced areas with mixed herds of sheep and goats (at a ratio of 3:1) during April to October. The herd included 100–130 animals per site. The presence of goats is important for suppressing shrubs and trees, and also for grazing taller flowering grasses.

At each site the herd spent a few weeks once or twice during the grazing season. The fences were moved every 2–7 days, when the tussocks were found to be grazed strongly. Grazing pressure changed during the season according to biomass production. During the grazing, ungrazed strips (located in different places for each grazing cycle) were left to help reproduce plants and invertebrates.

Methods

Before the re-introduction of grazing, permanent plots (1 × 1 m) were established for vegetation monitoring. Grazed plots were always paired with control plots, protected with a cage against grazing. Eight pairs of plots were monitored at two sites, 11 pairs at one site. In each of these plots, the percentage cover of each plant species was recorded every spring.

The monitoring of invertebrates was carried out for Lepidoptera as a representative group; using transect monitoring for diurnal species (Heřman & Vrabec 2010) and light sources at fixed points for nocturnal species (additionally by attracting them to baits or synthetic pheromones and by monitoring immature stages; data evaluation still in process).

For long-term monitoring of lepidopteran populations, primarily indicator species clearly associated with each habitat and being important species in regional nature conservation were selected. These were Grayling (*Hipparchia semele*), with probably the most abundant populations of the Czech Republic occurring in the study area, Safflower Skipper (*Pyrgus carthami*), the lichen moth *Paidia rica*, and the owlet moth *Euxoa vitta*.

Results

Vegetation

After six years of management, the impact of grazing on species number and species composition of the permanent plots is statistically significant. The species number is higher in grazed plots at all three sites. Species increase is most visible in grazed plots at Šanův kout (Fig. 4), the site with the lowest mean number of species per plot. Vegetation in grazed and ungrazed plots has taken significantly different courses since the beginning of management. This difference is reflected in the observed grazing response of particular species (Fig. 6). Positive grazing response is shown in typical dry grassland species whose common traits include a small height, tussock or rosette forms, and an annual life cycle (*Carex humilis*, *Festuca valesiaca*, *Potentilla arenaria*, *Scabiosa ochroleuca*, *Arenaria serpyllifolia*, *Salvia pratensis*, *Arabis hirsuta*, *Thlaspi perfoliatum*, *Thymus pulegioides*, and *Veronica praecox*). On the other hand, species in the control plots are better competitors of grasslands with a denser sward. This group includes more grasses and taller forbs (*Bothriochloa ischaemum*, *Sesleria caerulea*, *Brachypodium pinnatum*, *Bromus erectus*, *Knautia arvensis*, *Artemisia campestris*, *Stachys recta*, *Teucrium chamaedrys*). Some Fabaceae species (e.g. *Lotus corniculatus*, *Securigera varia*) also grow better in the control plots, because they are often grazed preferentially in grazed plots, and their survival is therefore more threatened than that of non-legumes.

Fig. 2. Small Pasque Flower (*Pulsatilla pratensis* subsp. *bohemica*) is common on rocky and dry open grasslands. (T. Tichý)

Fig. 3. Chequered Blue (*Scolitantides orion*) is an uncommon species inhabiting rocky outcrops at grazed localities. (P. Heřman)

Lepidoptera: preliminary results

During the period 2005–2011 a total of 62 butterfly species were recorded. Nearly one third (18 species, i.e. 29%) are species important in nature conservation – i.e. under legislative protection or included in the national red list (Farkač et al. 2005).

The impact of grazing management is only one out of a number of factors influencing the diversity, as can be seen in Fig. 5 (the clear deviation in 2010 mainly caused by wet weather).

Extensive and mosaic grazing represents the optimal form of management for 29 of the recorded butterfly species and is therefore a suitable instrument to both revitalise and preserve their populations. For example, the Lulworth Skipper (*Thymelicus acteon*) increased from a single record in 2009 to nine individuals recorded in 2011.

Conclusions

The grazing management reintroduced in 2005 and 2006 significantly contributed to restoration and maintenance of the dry grass-

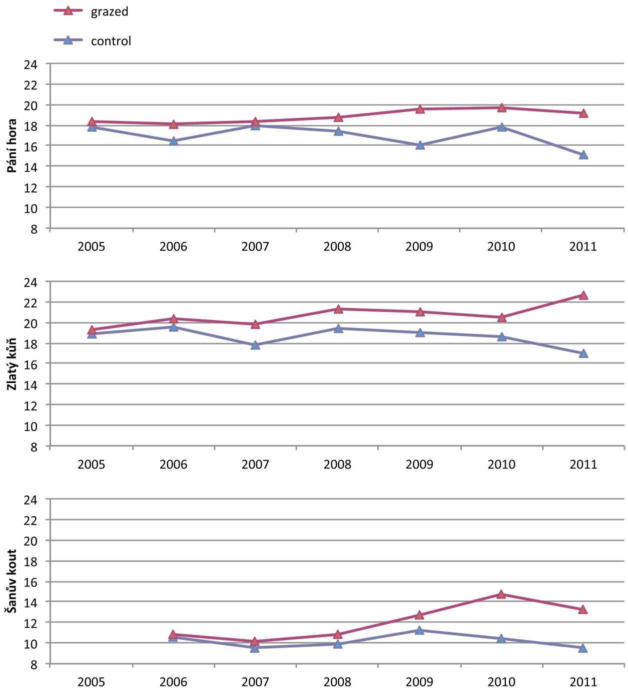

Fig. 4. Mean number of species at three sites in 2005-2011. Effect of interaction of grazing and time on mean number of species per plot tested by analysis of variance, significant results (p-value < 0.05) at all three sites.

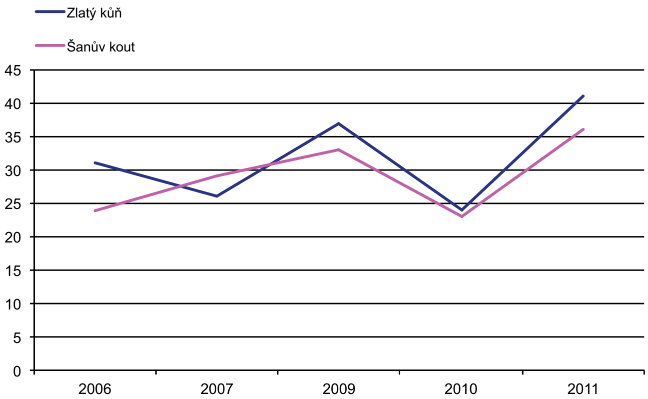

Fig. 5. Number of butterfly species observed during grazing management: localities Zlatý kůň and Šanův kout. The season of 2008 was excluded for methodical reasons.

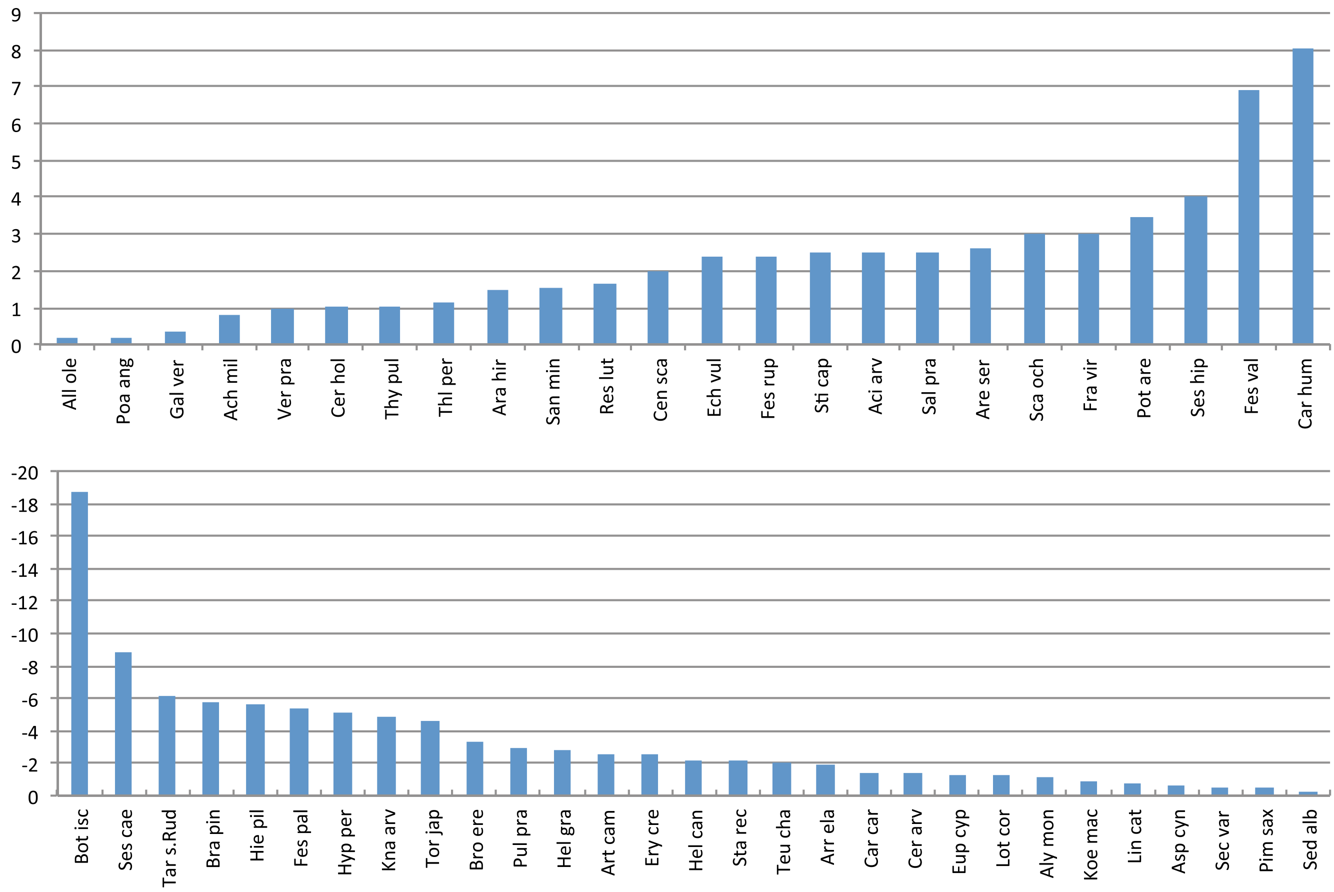

Fig. 6. Grazing response of plant species. Positive values: species prefer grazed plots; negative values: species prefer control plots. Grazing response was defined as the cover in a grazed plot in 2011 minus the cover in 2005 (or in 2006) minus the same difference in the control plot. These numbers were then averaged across all plots and localities. Abbreviations of species consist of the first three letters of genus and species names.

lands and raised or maintained a high species richness by increasing microhabitat heterogeneity on a small scale. Grazing is therefore an appropriate management tool and the current level of grazing intensity is adequate. As many studies have pointed out, extremes of grazing intensity (both high and low) lead to decline in species number, either through overgrazing or dominance of a few species (Milchunas et al. 1988, Dostálek & Frantík 2008). An important fact from the methodological point of view was that inter-annual variation in grazing strongly influenced vegetation dynamics, so that reliable conclusions could not have been drawn earlier: the effect of grazing could not have been confirmed after just three years of monitoring (Mayerová et al. 2010).

The inter-annual variation is also seen in the case of increasing butterfly diversity observed between the first and the most recent season. Evaluating the response to grazing management is rather complicated due to adult mobility, a delay in response to host plant occurrence, etc. However, due to the stable or even increasing abundance observed in indicator species, it can be stated that adequate grazing management has a positive influence on butterflies. Even more pronounced results are expected in the longer term.

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Fig. 7. Autumn grazing at "Zlatý kůň". The cage in the front protects a control plot. (T. Tichý)

Resumption of grazing management on abandoned upland grasslands in the Jizera Mountains

Vilém Pavlů, Jan Gaisler, Lenka Pavlů, Vendula Ludvíková & Michal Hejcman

Location	NW part of the Jizera Mts., north Czech Republic 50°50' N, 15°06' E; altitude 420 m
Protection status	PLA
Ecosystem types	Predominantly semi-natural grasslands (*Arrhenatherion elatioris*)
Experimental area	5 ha

Initial conditions

After the expulsion of German inhabitants from the area in 1946 a mosaic landscape management with grassland and arable land was maintained here. Large-scale management was introduced in the 1960s, but a large area of arable land remained. However, in the 1970s (contrary to the general trend in the Czech Republic) most arable land was sown with commercial grass mixtures and then intensively managed by grazing and cutting. After 1989, because of cattle reduction (to half), most grasslands were abandoned. As a result, grasslands degraded and became dominated by *Aegopodium podagraria*, *Galium album*, *Anthriscus sylvestris*, *Cirsium arvense*, *Elytrigia repens*, and *Alopecurus pratensis*. No shrub encroachment was recorded.

Abiotic conditions

The site lies on granite bedrock and medium deep brown soil (Cambisol) with the following attributes: pH (KCl) = 5.45, Cox = 4.5%, available P = 28 $mg.kg^{-1}$, available K = 67 $mg.kg^{-1}$, available Mg = 58 $mg.kg^{-1}$ (Mehlich 3). The mean annual precipitation is 803 mm and the mean annual temperature is 7.2 °C (Liberec Meteorological Station).

Objectives

Study of successional development of an abandoned grassland after introduction of intensive and extensive grazing management.

Restoration measures

1998	Establishing of grazing experiment on grassland unmanaged for five years.
1998–2011	Monitoring of successional development of the grassland after introduction of management.

Management regimes in the experiment

Intensive grazing, extensive grazing, unmanaged control (Pavlů et al. 2006a, 2006b, 2007, 2008, 2009).

Results

Already in the first year after grazing had been reintroduced, an increase of live vascular plant biomass was recorded while the amount of dead material significantly declined. The number of meadow and pasture plant species rose from the second year of management onwards (16 plant species.m^{-2} at the beginning of the experiment, 22 plant species.m^{-2} in the third year) at the expense of ruderal species. A higher sward density was recorded from the third year of management (Pavlů et al. 2006b). The relation between diversification of the structure and grazing intensity became evident only in the fourth year of the experiment (Pavlů et al. 2007).

Plant species richness was similar under both grazing intensities, but it was the lowest in unmanaged grasslands. Weedy species such as *Aegopodium podagraria*, *Anthriscus sylvestris*, *Cirsium arvense*, *Elytrigia repens* and the meadow species *Alopecurus pratensis* and *Galium album* had the highest abundance in the unmanaged control (Fig. 3) (Pavlů et al. 2008). The most abundant species in both the intensively and extensively grazed treatments were: *Agrostis capillaris*, *Festuca rubra* agg., *Phleum pratense*, *Taraxacum* spp., *Trifolium repens*, and *Ranunculus repens* (Pavlů et al. 2007).

The main difference between intensive and extensive grazing management was seen in the proportions of short and tall sward patches, while the proportion of moderate-height patches was similar under both grazing intensities (Ludvíková et al. 2012). Floristic composition in patches of the same sward height depended upon grazing intensity. Moderately tall and tall sward patches under a given grazing intensity had a similar botanical composition. The vegetation of short sward patches differed considerably from that of other patches under

Fig. 1. Extensively grazed pasture. (V. Pavlů)

Fig. 2. Intensively grazed pasture. (V. Pavlů)

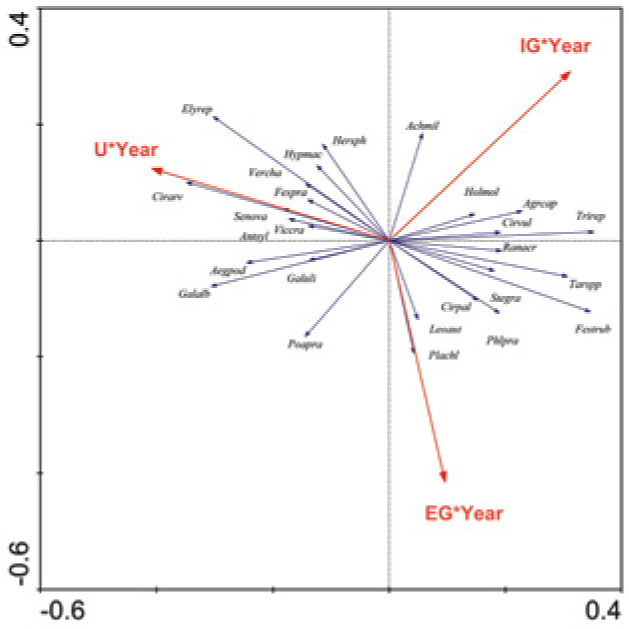

Fig. 3. Ordination diagram showing the results of the RDA analysis of plant species composition data. Treatments: EG – extensive grazing; IG – intensive grazing; U – unmanaged grassland. * – interaction of year and treatment indicates development of plant species composition in a particular treatment during the years. Vectors for species whose cover increased in a particular treatment have the same direction as the vector for a particular year*treatment interaction. Abbreviations of plant species are the first three letters of the genus and the first two or three letters of the species. Source: Pavlů et al. (2006b).

extensive grazing, whereas under intensive grazing the differences between short, intermediate and tall sward patches were small.

The highest thorny shrub encroachment (especially *Rosa* spp.) was revealed under long-term extensive grazing. It was less in intensively grazed areas due to grazing pressure and in abandoned areas because of worse conditions for shrub and tree establishment (Fig. 4). Plant species typical of pastures (*Cynosurion cristati*) are more often present under long-term intensive grazing, but very rare under extensive grazing (Pavlů et al. 2007).

Other lessons learned and future prospects

Preliminary results show that resumption of grazing management significantly changes the botanical composition of a degraded sward. The rate of pasture and meadow species gradually increases at the expense of ruderal species. A sward with a high plant species density has been created since the third year after management resumption, especially under intensive grazing (Pavlů et al. 2006b). Grazing management can substitute for mowing management but not completely, due to selective grazing, trampling and nutrient redistribution (faeces, urine). Plant species of the *Cynosurion* alliance are more often present under intensive grazing, but very rarely under extensive grazing. The tendency of thorny shrubs to sprout is higher under extensive grazing (trampling) than in unmanaged grassland. The result is that the desirable mosaic structure does not only have a higher plant species richness, but also offers animal species shelter, feeding and nesting opportunities.

Public support

Interest of farmers in grazing management under different intensities and their effect on sward structure.

Acknowledgements

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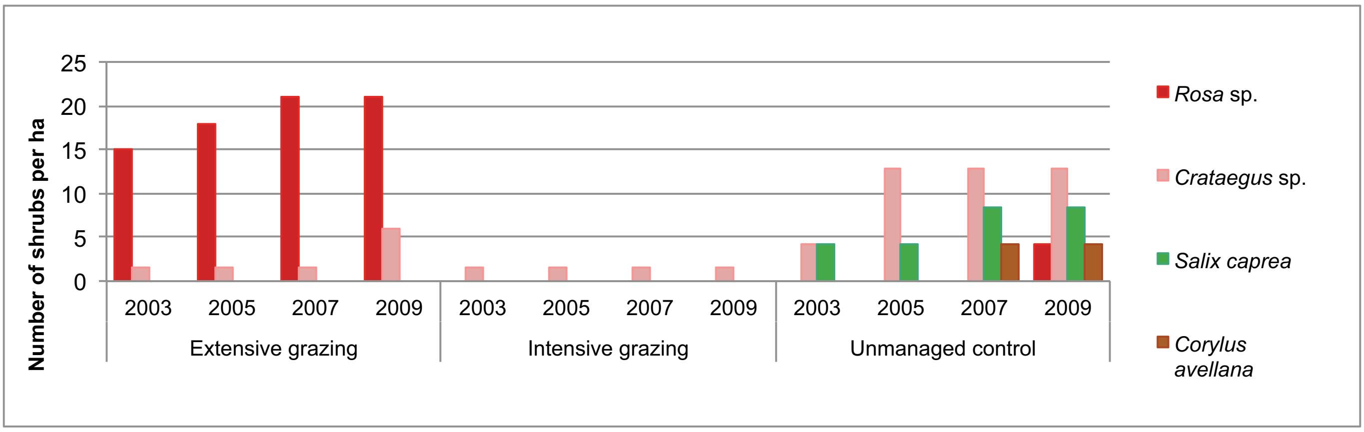

Fig. 4. Shrub abundance during the course of the experiment.

Restoring heterogeneity in submontane meadows for the butterfly *Euphydryas aurinia*

Kamil Zimmermann, Petr Jiskra, Michala Kopečková & Martin Konvička

Location 	West Czech Republic, near the border with Germany 50°27'–49°53' N, 12°5'–13°17' E; altitude 420–970 m
Protection status	PLA (Slavkovský les), Hradiště Military Training Area, NR (30), SCI (18), critically endangered species
Ecosystem types	Semi-natural submontane grasslands – predominantly oligotrophic wet meadows: Intermittently wet meadows (*Molinion caeruleae*) and Wet *Cirsium* meadows (*Calthion palustris*)
Restored area	398 ha (101 sites)
Financial support	Landscape management programmes, Agri-environmental schemes, Regional Office of Karlovy Vary Region
Costs	Mosaic mowing €800–920/ha

Initial conditions

The Marsh Fritillary (*Euphydryas aurinia*, Rottenburg, 1775), a species protected under the Habitats Directive (92/43/EEC), has declined rapidly across most of Europe, including the Czech Republic, due to a loss of semi-natural grasslands. At the beginning of the 21st century, only seven sites were known to Czech conservationists. Intensive surveys have increased the number of sites to 101, elucidated the intolerance of the species to eutrophication (Konvička et al. 2003), its sensitivity to intensive mowing – particularly in late summer/early autumn (Hula et al. 2004) – and evaluated the status of all colonies (Zimmermann et al. 2011). It has become clear that *E. aurinia* requires managed, but highly heterogeneous sward conditions. It is threatened by both successional encroachment by tall grass and scrub combined with dense litter accumulation (neglect), and by too frequent biomass removal by mowing of the entire site all at once (overmanagement).

Grassland management must therefore balance between too little (neglect) and too much (overmanaging). Whilst in the past small-scale farming maintained a diverse mosaic of habitats over vast stretches of land within which the species always found sites suitable for its development, modern land use has restricted its distribution to isolated habitat patches. Grassland management which does not respect the need for heterogeneity in the resulting ecological conditions may seriously threaten conservation targets (Konvička et al. 2008).

Abiotic conditions

Most sites are nutrient-poor grasslands situated in a rather cold, submontane climate, on acidic soils.

Fig. 1. Marsh Fritillary (*Euphydryas aurinia*). (K. Zimmermann)

Objectives

Supporting threatened species via a more sensitive, site-specific approach to its habitat. Maintaining species-rich grasslands, increasing biodiversity, improving landscape connectivity and scenic value.

Historical context

Prior to 1960s	Traditional management of grasslands as part of a fine-grained mosaic of land use (hay meadows, litter meadows, pastures, arable fields), interrupted by the expulsion of ethnic Germans in 1946 and partial resettlement of the area. Establishment of large military training areas. A narrow strip along the Czech–German border remained depopulated.
1960s–1989	Double effect of "agricultural collectivisation", including on the one hand consolidation of allotments, ploughing of baulks, large-scale grassland reclamation, establishment of intensive dairy farms and even conversion of mountain meadows (up to 800 m in altitude) to arable fields, and on the other hand, abandonment of marginal land with subsequent successional changes. Complete loss of oligotrophic meadows was prevented by protection of parts of the area as balnaeologic water sources for (e.g. reduced use of agro-chemicals, local prevention of drainage) for nearby spas, establishment of two freshwater reservoirs, designation of the Slavkovský les PLA, and establishment of the Hradiště Military Training Area (disturbance by military activities preventing vegetation succession).
1990–2001	In the years following the downfall of Communism, much of the land in mountainous and submontane conditions was abandoned. Parts of previously ploughed fields were re-seeded with grass mixtures and converted to hay meadows, while others were used as year-round cattle pastures.
2001–present	Monitoring the status of all known sites of the Marsh Fritillary, along with annual census of larval nests.

2002–2007	Intensive local surveys, monitoring of all known colonies. Increasing knowledge of the species habitat requirements and evidence of its vulnerability caused by uniform mowing of the grasslands. Accession to the EU increased financial support for grassland management (Agri-environmental schemes). However, payment provisions, requiring repeated mowing, have a destructive effect on the habitat of the butterfly on farmland.
Present	Most sites not located on farmland are managed by local conservation authorities or groups, respecting the need for environmentally-friendly, mosaic site management. The management of sites on farmland is gradually improving thanks to modifications of conditions in Agri-environmental schemes, which allow for patchy mowing varied in space and time.

Fig. 2. Successful restoration of a degraded *Euphydryas aurinia* site. Scrub removal and sensitive patchwork mowing has enabled recolonisation of the site. (K. Zimmermann)

Management measures

— More sensitive mowing of sites where the butterfly occurs, while leaving some patches temporarily uncut until the next season (meadows), or by maintaining lower grazing livestock densities, while temporarily excluding grazing.

— Gradual modification of Agri-environmental scheme provisions in the broad environs of the sites (leaving temporarily unmown patches, temporal variation in mowing dates).

— Introduction of alternative farming methods which imitate traditional extensive methods: (1) strip mowing (suitable for larger areas where 10–20% of the area is left uncut, the position of the strips being altered with each mowing term), (2) mosaic mowing (suitable for small areas inaccessible to mechanisation), while rotating temporarily uncut patches and eliminating competitive species.

— Individual (site-specific) approach for each locality.

Results

Currently, about one third (area and number of sites) of *E. aurinia* colonies in the Czech Republic is being managed by conservation groups, using sensitive approaches as strip- or mosaic mowing, leaving parts of meadows temporarily uncut. These uncut patches ensure a high survival rate of larval nests, and subsequent increase of local densities (Fig. 3B). Another one third of sites are unmanaged and left to succession, with stagnating or even decreasing local *E. aurinia* numbers (Fig. 3A). The last one third of sites, mostly managed under inappropriately designed Agri-environmental schemes, is still managed too intensively, again causing decreasing butterfly numbers (Fig. 3C).

Moreover, long neglected grasslands can be restored using mosaic management approaches, as documented by cases of spontaneous recolonisation of temporarily extinct populations, such as the one shown in Fig. 2 (Zimmermann et al. 2010, 2011).

Restoring heterogeneous (patchwork) management in submontane humid grasslands probably benefits other sensitive insect species as well, including other butterflies (e.g. *Melitaea diamina*, *Boloria aquilonaris*) and moths (*Rhyparia purpurata*, *Lithacodia uncula*). Its positive effect on vertebrates is demonstrated by the fact that *Euphydryas aurinia* sites serve as nesting grounds for birds such as Common Snipe (*Gallinago gallinago*), Corn Crake (*Crex crex*) and Common Crane (*Grus grus*).

Acknowledgements

The study was supported by the following grants and projects: Karlovy Vary District – D723/2007, monitoring of Natura 2000 species (Nature Conservation Agency of the Czech Republic), MSMT LC-6073 and 6215648905, GACR P505/10/2167 and 206/08/H044, Institute of Entomology CAS – Z50070508, Faculty of Science USB – MSM 6007665801.

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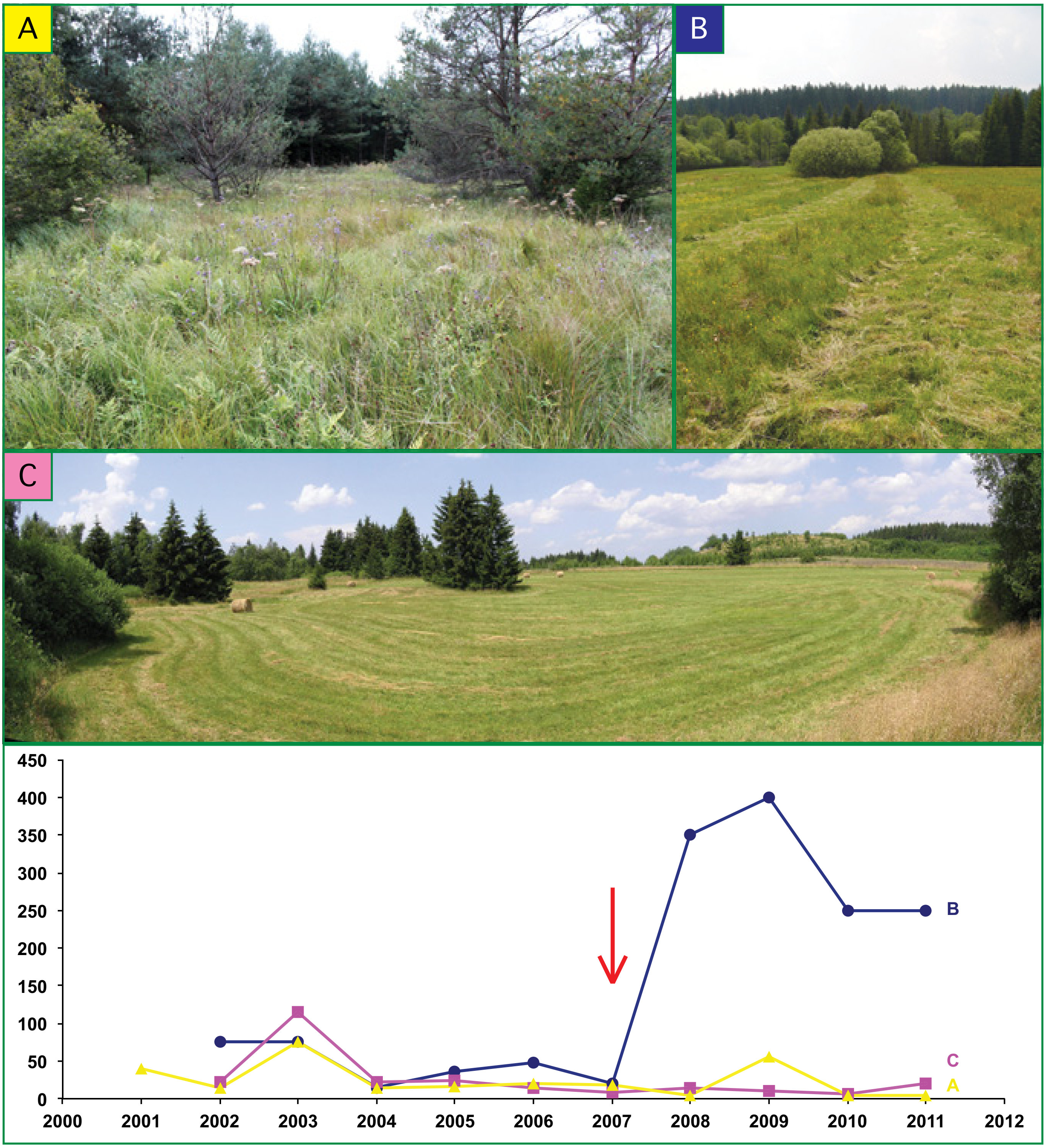

Fig. 3. Ten-year monitoring of Marsh Fritillary (*Euphydryas aurinia*) larval nests enables comparison of its local population dynamics at differently managed sites.
A – neglect and successional changes, causing stagnation in colony size. (K. Zimmermann); B – sensitive strip-mowing (red arrow indicates the start of this management in 2007) led to an increase in annual number of larval nests. (D. Novotný); C – too intensive management, consisting of two cuts per year, results in stagnation of colony size. (K. Zimmermann)

Optimising management at *Gentianella praecox* subsp. *bohemica* sites

Jiří Brabec

Location 	Southwest and south Czech Republic 48°49'–49°24' N, 13°22'–14°51' E; elevation 414–870 m
Protection status	PLA (Blanský les – 1 site), NP (Šumava – 1 site), NR (9 sites), SCI (all 13 sites)
Ecosystem types	Broad spectrum of grassland types classified as Subatlantic broad-leaved dry grasslands (*Bromion erecti*), Extensive hay meadows (*Arrhenatherion elatioris*), Species-rich Nardus grasslands (*Violion caninae*), locally also dry grasslands on acidic soils (*Koelerio-Phleion phleoidis*)
Restored area	6.8 ha in total (13 sites)
Financial support	Regional Authority of the South Bohemian Region, Regional Authority of the Plzeň Region, landscape management programmes, Operational Programme Environment
Costs	Initially €40,000 (elimination of shrubs and trees, site levelling, mowing or grazing, and turf disturbance); annually €10,000 (mowing once to twice or rotational grazing, turf disturbance)

Initial conditions

Gentianella praecox subsp. *bohemica* is an endemic to the Bohemian massif and a Czech subendemic. Its historic distribution area includes the Czech Republic (most of the territory except W and NW Bohemia and SE and E Moravia), north Austria, the W part of Lower Bavaria and southernmost Poland. It is a strict biennial, which has been observed to decline radically in site number and population size (Königer et al. 2012). These changes are particularly connected with an overall decrease in pasture area and area of grassland enclaves, changes in agricultural practice, and habitat fragmentation. Since 2000 the taxon has been recorded at only 113 sites in its entire distribution area (70 of them in the Czech Republic). At 23 of them, however, not a single flowering plant has been recorded in the past five years.

Our study focuses on SW and S Bohemia, including 50 recent localities (Fig. 1), where population abundance and site management have been monitored for more than 10 years. Assessment of the recovery of the populations was nevertheless carried out at only 13 sites, where high-quality cleanups were realized and suitable management was maintained at an optimal level for at least four years.

The monitored sites had various starting conditions, not only in terms of the condition of the habitat, but also of the *Gentianella praecox* subsp. *bohemica* populations. Three sites were more or less regularly mown without turf disturbance; four were farmed very irregularly, which had led to a strong accumulation of living and dead biomass; six sites were overgrown by shrubs and trees or by planted pines (see Fig. 5). The average number of flowering plants three years before restoration was zero at three sites, up to 20 at three, 20 to 100 at four, and more than 100 at three sites. Based on studies of population-biological features (summarised by Brabec et al. 2011, Brabec & Zmeškalová 2011, Bucharová et al. 2012), it was considered useful to add more or less regular turf disturbance to the traditionally recommended regular farming of the sites by means of mowing or grazing.

Fig. 2. Flowering *Gentianella praecox* subsp. *bohemica* originating from the seedbank after restoration of the site. (R. Ouředník)

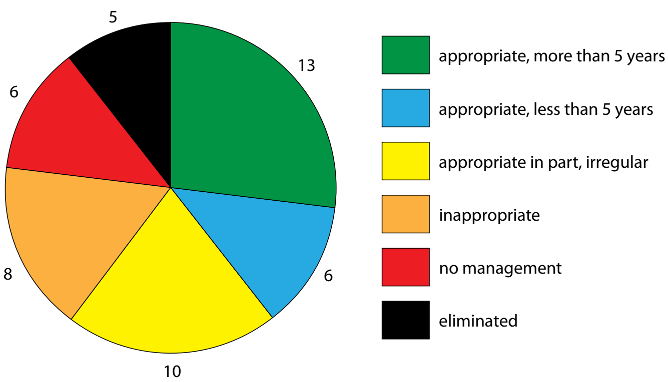

Fig. 1. Type, time length and quality of farming at 50 sites in S and SW Bohemia where *Gentianella praecox* subsp. *bohemica* was recorded at least once in 2000–2010.

Abiotic conditions

Chemical analyses of the soils showed a wide range of abiotic conditions at the monitored 13 sites. At a depth of ca. 5 cm the soil reaction varied from acidic (pH 4.7) to slightly basic (pH 7.7), which is correlated with the contents of Ca (661–7898 mg.kg^{-1}) and Mg (52–1204 mg.kg^{-1}) ions. The sites are poor to moderately rich in nutrients: total carbon content varied from 0.9 to 11.9%, nitrogen from 0.1 to 0.8%, exchangeable phosphorus from 2.8 to 19.3 mg.kg^{-1}.

Objectives

Recovery and stabilisation of present *Gentianella praecox* subsp. *bohemica* populations.

Restoration measures

2000–2005	First experimental study of the impact of various types of management (no management, mowing, mowing and disturbance) and timing (June, October–November). Recommendations to nature conservation authorities included in action plan documents (Brabec 2003).
2005–2008	Large-scale cleanup (9 cases) or optimisation (3 cases) measures at various sites. In one case, a site had already been cleaned up in 1995 (0.1 ha). The cleanup included cutting of most shrubs and trees, whereby stumps were partly or completely pulled out; complete mowing and cleaning of the site, turf disturbance by harrowing or raking (see Fig. 5–8), in one case also levelling with light machines.
2006–2011	Yearly repeated, optimised farming of the sites. Mesic grasslands: first cut May–June, second one October/November, turf disturbance by harrowing or raking up litter, or by performing a vertical cut at the end of October, in November or in early spring (not later than mid-April). Dry grasslands: one to three years after the cleanup mowing twice a year (May–June, October/November) and annual turf disturbance; following, a transition to one cut a year either in May–June or October/November and every other year turf disturbance by harrowing or raking up litter, or by performing a vertical cut at the end of October, in November or in early spring (not later than mid-April).
1999–2011	Yearly monitoring of all known recent populations of *Gentianella praecox* subsp. *bohemica*.
2011	Endorsement of *Gentianella praecox* subsp. *bohemica* Action Plan (see www.zachranneprogramy.cz), compilation of management principles (Brabec & Zmeškalová 2011) – emphasis on the importance of turf disturbance and regularity of management.

Fig. 3. Gentianellas are pollinated by Hymenoptera. (J. Brabec)

Results

Population recovery was assessed at 13 sites. As shown in Fig. 4, site restoration and introduction of optimal management including turf disturbance led to a rapid (mostly several fold) increase in the number of flowering plants in the first three years in 10 cases. At two sites, where not more than one flowering plant per year appeared in a five-year period before the intervention, the populations could not be recovered. In one case the number of flowering plants first decreased slightly, after which the population began to increase slightly.

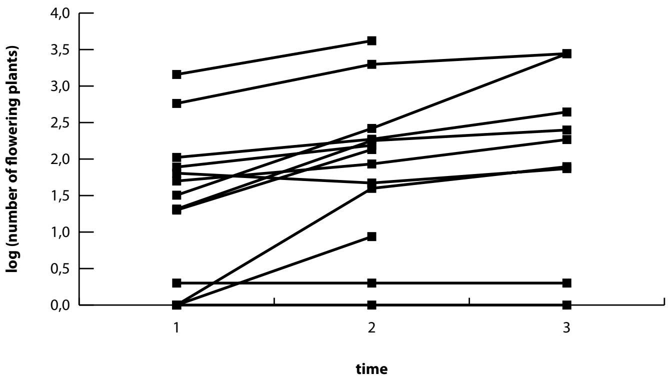

Fig. 4. Numbers of flowering plants before site restoration (Time 1 = three-year average, i.e. two years before restoration plus the year of restoration), three years after site restoration (Time 2 = three-year average), and in the past three years (Time 3 = average of the years 2009–2011). The last number is not indicated if management started later than 2007 (and Time 3 would thus equal Time 2).

Other lessons learned and future prospects

The previous recommended management of *Gentianella praecox* subsp. *bohemica* sites most often included regular mowing (leaving a relatively tall stand was often recommended in order not to damage young plants) or extensive grazing. However, when restoring, stabilising and maintaining sites, cutting as low as possible combined with raking up and removing all hay carefully, or intensive rotational grazing is necessary. The aim is to disturb the turf and create small gaps before the time of seed germination, which is each year at the turn of April and May. The management must not be carried out at the time of growth, flowering and seed ripening of the gentians, i.e. roughly from July to mid-October. Conversely, intensive farming (mowing twice a year, rotational grazing) from mid-October to the end of June in the following year is ideal. Although management in autumn and spring partly leads to disturbance of plant development (cutting off followed by compensational branching) and to direct destruction of rosette seedlings, at the same time it lowers competition and enables germination of seed from the short-term or long-term seedbank, which compensates for these losses by up to tenfold. As demonstrated in experimental studies (Brabec et al. 2011, Bucharová et al. 2012), germination of seed from the seedbank is the most important factor in the life cycle phase of this biennial taxon and at the same time the one best to be influenced by farming.

Public support

The management of the 13 sites is organised by five different nature conservation bodies. As of 2011 all activities are coordinated by the Nature Conservation Agency of the Czech Republic as part of the species action plan for this gentian. The actual cleanup and management is carried out by various actors – landowners (2 cases), tenants (1), private farmers (4), specialised firms (4), and NGOs (2). Especially when starting regular management or optimising management, also work by volunteers at the sites was very important. This mostly included additional turf disturbance, but in two cases volunteers carried out the whole cleanup on their own and managed the site (with consent of the landowner) for three years.

Acknowledgements

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Fig. 5. View of Kozlovská stráň, 18 September 2004. In 2003–2007 not any *Gentianella praecox* subsp. *bohemica* plant flowered at this site, which was gradually colonised by pine trees. (J. Brabec)

Fig. 6. Cleanup at Kozlovská stráň, March 2007. (R. Ouředník)

Fig. 7. Cleanup at Kozlovská stráň, March 2007. (R. Ouředník)

Fig. 8. Kozlovská stráň, denuded plots after autumn cut and spring raking incl. turf disturbance, May 2009. (R. Ouředník)

Restoration of sands as part of the Action Plan for *Dianthus arenarius* subsp. *bohemicus*

Anna Šlechtová & Jiří Bělohoubek

Location	Kleneč NR, near the town of Roudnice nad Labem, northwest Czech Republic 50°23' N, 14°15' E; altitude 200–220 m
Protection status	NR, SCI, critically endangered species
Ecosystem types	Open vegetation of inland sand dunes (*Corynephorion canescentis*)
Restored area	0.55 ha
Financial support	Landscape management programmes, EEA Financial Mechanism and Norwegian Financial Mechanism
Costs	€44,320 (3-year total)

Initial conditions

Bohemian Sand Pink (*Dianthus arenarius* subsp. *bohemicus*) is a heliophilous species growing in communities of open sand and grasslands on sandy soil. The subspecies is a critically endangered, endemic taxon occurring at only two localities in the Czech Republic. An essential condition for successful establishment of seedlings and their further development is open (disturbed) substrate, since the species is not able to withstand the competition of grasses and other competitive species of undisturbed habitats.

The main causes of threat to *Dianthus arenarius* subsp. *bohemicus* are (1) successional changes due to land use change, especially abandonment of traditional management methods, and (2) tree plantings of Scots Pine (*Pinus sylvestris*) and Black Locust (*Robinia pseudacacia*) at Sand Pink sites from the 1940s.

Fig. 1. Orthophotographic view of Kleneč NR (red line). *Dianthus arenarius* subsp. *bohemicus* occurs in sections A (99% of the population), B and C.

Fig. 2. *Dianthus arenarius* subsp. *bohemicus* tufts two years after restoration in 2011. (A. Šlechtová)

Various measures with the aim of preserving one of the two *Dianthus arenarius* subsp. *bohemicus* populations have been carried out at Kleneč since the end of the 1980s, when the condition of the site was already critical with no more than approx. 200 old tufts of the plant. Activities realised included both direct reinforcement of the population by adding plants grown in culture (originating from seeds collected at Kleneč) and by direct seeding. Habitat management was carried out as well, including the elimination of shrubs, trees and competitive grasses, topsoil disturbance and mowing (in accordance with the management plan of the site), but without significant success.

In the late 1990s, only two hundred old plant tufts were left and it was uncertain whether the species could be preserved for the Czech flora.

Abiotic conditions

The physical composition of the substrate is one of the most important ecological factors for successful development of *Dianthus arenarius* subsp. *bohemicus* populations. When gravel-sand is covered by a layer of humus, growth of competitive grasses is facilitated, causing senescence and gradual decline of the sand Pink population. This humus layer was formed during years without grazing or mowing, and facilitated self-seeding trees and shrubs to colonise the habitat.

Chemical analyses (to a depth of ca. 5 cm) indicated strongly acidic to very strongly acidic soils (pH 3.43–5.38), depending on the depth of the humus layer. Organic matter content varied between 0.62 and 5.3%, total N between 0.58 and 0.261%, and phosphates between 3.8 and 44.8 $mg.kg^{-1}$ (Macurová et al. 2008).

Objectives

Creating suitable conditions for the development of *Dianthus arenarius* subsp. *bohemicus* and its population at Kleneč.

Restoration measures

1999	The humus layer was removed to a depth of 20–40 cm reaching the gravel-sand substrate in a section of about 1,500 m². This intervention was proposed rather intuitively and opened a way to save *Dianthus arenarius* subsp. *bohemicus* for the world flora. Many seedlings appeared on the bare sand substrate in the following years.
2008	The *Dianthus arenarius* subsp. *bohemicus* Action Plan was approved by the Czech Ministry of the Environment, which enabled financial support for following restoration measures. Pedological survey (Macurová et al. 2008), focusing on the stratigraphy of individual layers, was carried out. This survey allowed for selection of the most suitable places to remove the humus layer in the following years.
2009	Mechanical removal of the humus layer was repeated in another section of about 1,500 m² next to the first, already restored one. This measure was performed at the turn of the summer and autumn, according to the demands of the insect fauna found at the locality in a survey (2008–2009), because in this period the insects are active and can leave an area if it is disturbed.
2010	The humus layer was removed from another two smaller sections with a total area of about 2,500 m².

Management measures

A) Regular

- Mosaic mowing twice a year according to insect fauna demands, i.e. the area is not mown in one go, but is divided into four-metre wide strips of which every other one is mown four weeks later than the first one.
- Removing competitive tree saplings.
- Disturbing the soil surface (not in the restored area).

B) After humus layer removal

When the humus layer is removed down to the gravel-sand substrate, no management is needed for 5 years after restoration. No later than 10 years afterwards, regular management (mowing, removing tree seedlings, disturbances) must begin.

When the humus layer is deeper than the removed surface, mowing should start the first year after restoration.

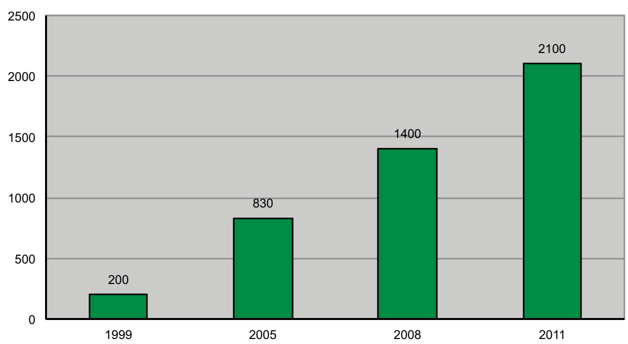

Fig. 3. Number of *Dianthus arenarius* subsp. *bohemicus* tufts at Kleneč over time. 1999: before restoration measure. 2005, 2008, 2011: after restoration measures.

Fig. 4. Removal of the humus layer in 2009. (J. Bělohoubek)

Fig. 5. Restored sand one year later, in 2010. The mosaic mowing layout is visible in the background. (J. Bělohoubek)

After restoration of the habitat in 2009 and 2010, seeds of *Dianthus arenarius* subsp. *bohemicus* were sown in a planned experimental design, after which germination and survival rate all quadrats were monitored three times during the season. The dataset from this experiment will be used for population modelling in 2012.

Results

Monitoring of *Dianthus arenarius* subsp. *bohemicus* (see Fig. 3) shows that the restoration measures have resulted in an increase in its population size. Before restoration all sowing experiments were unsuccessful, after the restoration sowing success was almost 5% (expressed as the ratio of number of one-year old seedlings to sown seeds, Špalová 2010).

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Restoration of the alpine tundra ecosystem above the timberline in the Giant Mountains

Josef Harčarik

Location	Giant Mountains (Krkonoše Mts.), ridges above the timberline, north Czech Republic, near the border with Poland 50°41'–50°48' N, 15°29'–15°47' E; altitude 1250–1600 m
Protection status	NP, UNESCO Biosphere Reserve, SCI, SPA
Ecosystem types	Mosaics of different types of alpine non-forest vegetation, mostly made up of native *Pinus mugo* scrub (*Pinion mugo*), alpine grasslands (*Nardo strictae-Caricion bigelowii*, *Nardion strictae* and *Calamagrostion villosae*), alpine and subalpine dwarf-shrub vegetation (*Loiseleurio procumbentis-Vaccinion* and *Genisto pilosae-Vaccinion*) and subalpine tall-herb vegetation (*Adenostylion alliariae* and *Dryopterido filicis-maris-Athyrion distentifolii*)
Restored area	43 ha
Financial support	Operational Programme Environment, landscape management programmes
Costs	€4,800–22,000/ha, depending on technology and accessibility of the locality

Initial conditions

Mountain Pine (*Pinus mugo*) stands are among the most important vegetation types of the Giant Mountains. Native and planted *Pinus mugo* shrubs cover 1500 ha and 680 ha of the mountain ridges, respectively. Pine saplings were planted during two periods (1879–1913 and 1952–1992) on an area of 550 ha above the timberline and 125 ha below the timberline, respectively. The aim was to return mountain ridge ecosystems back to their original state, which (according to foresters) had been affected by human impact for several centuries (see e.g. Lokvenc 1995, Lokvenc 2002).

Results of research into the local tundra ecosystem (Soukupová et al. 1995, Štursa et al. 2010) suggest that the dense, regularly placed *Pinus mugo* plantations dating from the second half of the 20th century are considerably different from natural *Pinus mugo* cover, e.g. the plantations are dense and have a regular spatial and age structure (Vaněk 1999, 2004, Soukupová et al. 2002), and that the plantations have negative effects on site conditions. Most significantly, the area of open tundra diminishes, and many plant and animal species occurring in these open areas decline or disappear. Planted *Pinus mugo* shrubs also cause damage to geomorphological phenomena, e.g. levelling of the natural microrelief of frost-sorted soils. The plantations also affect microclimatic conditions (for examples, see e.g. Sekyra et al. 2002).

These studies not only led to the end of artificial plantations in 1992, but also to a new management plan aimed at integrating the new plantations into the tundra environment and thus maintaining the geobiodiversity of this unique site (Harčarik 2007). The plan proposes a reduction in cover of 10–90% on 180 ha of the most recent *Pinus mugo* plantations according to microlocality and e.g. condition of the plantations, ruderalisation, and presence of native *Pinus mugo* shrubs. Approximately 110 ha of these plantations should not be changed (Harčarik 2007).

Fig. 1. Site of the latest *Pinus mugo* plantations with 'floating stones' in the foreground, before reduction in 2010. (J. Vaněk)

Figs. 2, 3, 4. Examples of technologies used to reduce *Pinus mugo* plantations in the Krkonoše Mts., 2010. (K. Antošová, K. Antošová, J. Vaněk)

Objectives

- Mimic the natural structure of *Pinus mugo* stands by selective removal of recent *Pinus mugo* plantations.
- Restore natural processes (e.g. microclimate dynamics, snow distribution).
- Maintain or even restore the geobiodiversity of the tundra ecosystem.

Restoration measures

1982	Removal of approximately 1 ha of *Pinus mugo* plantations (Štursa, pers. comm.)
1994	Removal of 0.72 ha of the plantations in monitoring plots.
1997	Reduction of *Pinus mugo* plantations on 1 ha.
2005–2008	Reduction of *Pinus mugo* plantations at Pančavská louka (3 ha) aimed not only at restoring the habitat itself but also at testing the most suitable restoration technology (i.e. with minimum environmental impact, e.g. manual work, low-noise machinery).
2010–2011	Reduction in cover of 10–90 % on 37.7 ha of *Pinus mugo* plantations at Pančavská louka and Labská louka.

Management monitoring

- 1997, 1999, 2009 and 2010 – monitoring of changes in microrelief of the tundra soils on Mt. Studniční hora.
- Since 2005 – monitoring of spontaneous succession including Mountain Arnica (*Arnica montana*) at Pančavská louka in places where *Pinus mugo* was removed.
- Since 2011 – monitoring of spatial distribution of *Pinus mugo* and selected endangered plant species in permanent plots at Pančavská louka and Labská louka (established in the years 1995 and 1998).

Results

At localities where *Pinus mugo* plantations were reduced, plots have been established to monitor e.g. changes in microrelief of tundra soils, shift of "floating" stones, microclimate changes, and succession after *Pinus mugo* removal. Preliminary results confirm a relatively rapid colonisation of the microsites opened by *Pinus mugo* removal with natural vegetation from the vicinity. This includes some rare or endangered species, e.g. *Hieracium alpinum* agg., *Arnica montana* and *Carex bigelowii* (Fig. 5). The data show changes in abundance of *Hieracium alpinum* agg. and *Arnica montana* in the permanent plots at Pančavská louka. The abundance of *Hieracium alpinum* agg. was re-estimated in 2011, ten years after its first monitoring (Pašťálková 2006), six years after the *Pinus mugo* removal. The abundance of *Arnica montana* has been estimated yearly since it colonised the plots after *Pinus mugo* removal. Synantropic species have not spread to the open microsites at any of the monitored localities.

Other lessons learned and future prospects

We have examined the most 'nature-friendly' management measures during the reduction of *Pinus mugo* shrubs realised so far. It is confirmed that reduction of after-war *Pinus mugo* plantations in the proposed extent can be realised and economically justified. This is true despite the large proportion of manual work and use of costly technologies (transfer of part of the *Pinus mugo* biomass by helicopter, woodchipping, etc.).

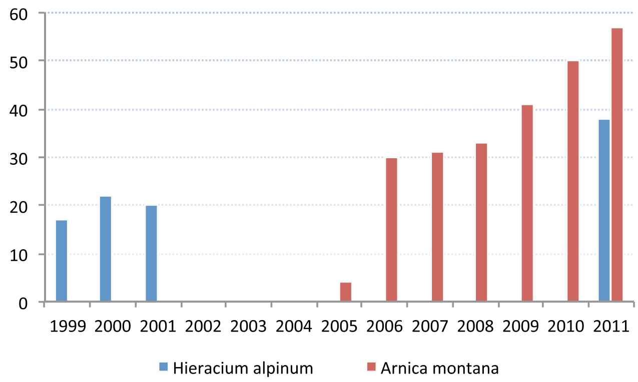

Fig. 5. Number of individuals of *Hieracium alpinum* agg. and *Arnica montana* in monitoring plots (10 × 20 m and 1 × 1 m, respectively) at Pančavská louka and their response to the removal of *Pinus mugo* shrub in 2005. *Hieracium alpinum* was not monitored in 2002–2010.

Public support

It has been clear from the beginning that reduction of *Pinus mugo* plantations is a controversial activity in the eyes of the public. Therefore the aims of the project need to be explained thoroughly. The main management work has been situated in the Core Zone of the Krkonoše NP, where no human intervention is preferred. Moreover, the Core Zone has the strictest rules for visitors. The situation is even more complicated because of the indigenous nature of *Pinus mugo* in the Giant Mts. However, long discussions with foresters in the preparatory phase of the management plan have led to general understanding and acceptance of the project among experts. Realisation of the measures in the years 2010–2011 also helped testing the opinion about the project by the public. Information and thorough explanation of the reasons why the project was realised convinced most of the visitors about its necessity and meaningfulness. We hope that this will remain true also in future.

Fig. 6. Detail of spontaneous succession including *Arnica montana* one year after removal of *Pinus mugo* shrubs at Pančavská louka, 2006. (J. Harčarik)

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Wetlands and streams

Velký močál NR, Krušné hory Mts. (Z. Patzelt)

Introduction

Tomáš Just, David Pithart & Ivana Bufková

Restoration of the natural character of wetlands and streams and their ecological functions in the landscape is a growing trend (e.g. Verdonschot & Nijboer 2002, Palmer et al. 2005, Dudgeon et al. 2006). The main drivers of this trend are the serious consequences of disturbed ecological structure and processes, which have an impact on landscape hydrology, nutrient cycles and biodiversity. Moreover, these impacts directly affect the lives of humans, for example by increasing the frequency of extreme flood events.

The history of human impacts on streams and wetlands in the Czech Republic is similar to the situation in the rest of Europe in many aspects. Since the Middle Ages, the natural character of streams and rivers has been changed by the construction of weirs and races, and large obstacles have been removed from riverbeds (Cílek 2002, Just et al. 2005). River engineering works mainly dealing with large watercourses boomed in the 19th century. At that time, the first flood control works and works to make the Elbe and Moldau rivers navigable were carried out. Also the first regulation works of small streams and related drainage aimed at acquiring more agricultural land appeared (Just et al. 2005). As early as the 1940s, subsurface pipes were introduced, later becoming the most frequent drainage method of agricultural land in Bohemia (Vašků 2011).

Both stream regulation and other interventions in the landscape hydrology continued with growing intensity in the 20th century. During the second half, these measures were supported by socialist farming methods causing further extensive changes in the landscape. This was the main period of large-scale drainage and small stream regulation linked with collectivisation and intensification of farming. All these interventions culminated in the 1970s and 80s, when they also reached marginal and less productive regions. Thus, many valuable natural sites were destroyed (Just et al. 2005), often without producing the expected economic benefits. Most of these activities (e.g. large-scale drainage) were reduced or ceased after the political changes at the beginning of the 1990s. However, the technical approach, both to watercourse management and the role of wetlands in the landscape, is still deeply entrenched, especially with water management authorities and the agricultural sector, making changes slow. This has become evident, for example, after the extreme floods affecting the Czech Republic during the last 20 years (1997, 2002), when strictly technical flood prevention was promoted again.

Fig. 1. Natural meanders of the Křivice stream, Bohemian Switzerland (České Švýcarsko) NP. (Z. Patzelt)

Fig. 2. Restored section of the Polečnice stream, Kájov. (T. Just)

Due to this development, the current state of watercourses and wetlands in the Czech Republic is unfavourable and about a quarter of agricultural land is drained by subsurface pipes. In 1995, more than a million hectares of land drained this way was registered (1,064,999 ha, Kulhavý et al. 2006). An additional 450 thousand hectares were probably drained but remained unregistered for various reasons. Only 350 thousand hectares of wetlands have remained undrained from the original extent of about 1300 thousand ha recorded in the 1950s (Just et al. 2005). In 1989 a total of 14,167 km of regulated small streams and 11,712 km of drainage channels (both open and piped) were registered (Vašků 2011). The total length of watercourses (76,000 km), particularly larger streams and rivers, has been reduced by one third, and regulated watercourses now account for about 21 thousand km (Simon et al. 2008). Natural large watercourses have become rare and almost unknown in the Czech Republic (Prach et al. 2003).

The extensive changes in the aquatic environment between the ends of the 19th and 20th centuries clearly exceeded the level of sustainability. Besides a considerable loss of natural values and biodiversity, these changes have led to an acceleration of both ordinary and flood discharge from the landscape, a rise in flood risk and damage caused by extreme floods, reducing groundwater resources and increased impacts of dry periods, and also to increased nutrient wash-off from soils and deteriorated self-purification processes in the landscape (Just et al. 2005). Awareness of the need for restoration as a corrective tool is now apparent, not only among experts or special-interest groups, but also the public.

Restoration of streams and their floodplains

The main goal of stream and river restoration is improvement of their ecological state and renewal of functions lost after technical regulations. In many cases, such a renewal proceeds spontaneously by renaturalisation – e.g. by gradual filling of the bed with washed-off material, encroachment of vegetation and decaying technical water works. Although a long-term process, spontaneous renaturalisation may have a significant overall restoration effect, if not interrupted by repeated servicing (Just et al. 2005). It rather works in small streams with a simple infrastructure (e.g. in channelised but not reinforced beds), however sudden post-flood processes can also affect larger watercourses.

Even though spontaneous renaturalisation is important in regenerating the landscape and needs support, a natural state of most watercourses and their floodplains can only be achieved by technical measures, initiating and allowing for natural processes. This is particularly necessary in strongly affected streams (with strongly deepened, reinforced beds) and in nearly all larger regulated watercourses.

Successful restoration should not merely result in rehabilitation of the natural stream geomorphology, but also in renewal of its dynamics, including floods and bed formation, reconnection of the stream with its floodplain, and increase in diversity along the entire river corridor. Subsequently biodiversity should be improved, natural functions and ecosystem services of freshwaters regenerated (see e.g. Haslam 2008), and water retention of the landscape increased by natural processes without any additional costs.

Stream restoration became a reality in the Czech Republic in 1992 thanks to establishment of the national River System Restoration Programme by the Ministry of the Environment. In the beginning, restoration efforts encountered many problems, amongst others misapprehension by some watercourse authorities. Experience from more progressive European countries were not fully applied here and even the idea of removing reinforcements in streams was hardly accepted during the first years of restoration. Finances were seldom invested in stream course restoration but commonly used for the (re)construction of small reservoirs, mostly ponds. This approach was often reprehensible, because technical reservoirs rather than natural habitats were restored this way.

Although nation-wide support of stream restoration was declared by the state already in the 1990s (State Nature Conservation and Landscape Protection Programme, 1998), real stream course restoration first appeared around 2000. Especially the restoration of the small Borová stream was a milestone in our understanding of restoration as an important flood control measure. At this site, the former channelised, artificial bed was replaced by a new near-natural, meandering stream. This restored streambed resisted the following extreme one-hundred-year flood (2001) with just small morphological changes and moreover, the flood peak at the end of the stream profile was about 20% lower than expected before restoration (Matoušek 2002). Another important work of that time was the restoration of floodplain forests at the confluence of the Morava and Dyje rivers in south Moravia. Although regular spring flooding was rehabilitated here by a rather




Figs. 3, 4, 5, 6. Restoration (1999–2000) of two formerly channelised streams in arable fields, Dolní Moravice, N Moravia. After removing concrete tubes and filling the grooves, a shallow, differentiated streambed and several retention reservoirs were created with an excavator. Subsequently autochthonous trees were planted in the space between the reservoirs to create a local biocorridor. (L. Bureš)


Figs. 7, 8. Pekelský stream in open landscape before (2007) and after restoration (2010). (T. Just)

technical reconstruction of channels in the forest, the whole complex of re-flooded forests retained about 60 million m³ of water during the extreme flood in 1997 and thus significantly contributed to a reduction of flood damage downstream (Prach et al. 2003).

More projects dealing with stream course restoration have been realised since 2000, but design of shallow streambeds with a low flow rate has been promoted only rarely. On the contrary, over-dimensioned (resulting from fears that too small streambeds cannot hold enough water), less diverse and too tidy streambeds were the norm at the beginning. Only later, spontaneous vegetation succession was supported and some basic rules were accepted, such as: (i) no restoration without removal of reinforcements, and (ii) restoration of a broad river corridor is better than mere streambed restoration. Locally, municipalities played an important role in acquiring the land needed for more comprehensive stream restoration including strips of adjacent alluvial wetlands. Their interest was however in many cases conditioned by pond building or reconstruction.

Another milestone was the year 2007, when important subsidies were facilitated through the Operational Programme Environment (from the group of EU funds). Although at the start, due to badly set financial rules, the same faults of supporting pond restoration were made as before, the proportion of real stream course restoration has grown. A positive effect of the EU Water Framework Directive is also evident. Water management authorities are involved now, and restoration measures are already incorporated in their plans.

Thanks to this, the first proposals to restore larger watercourses are being made, although the authorities are still limited by problems with acquiring the necessary land and by unresolved rules for the use of areas restored outside the actual streambed. Again a pioneer role has been played by the South Bohemian Region, where the Moldau Catchment authority has restored a section of the Polečnice stream near Kájov, a larger watercourse with a rather dynamic flow regime. Also a large project aimed at restoring a long section of the Stropnice stream at Nové Hrady is being prepared. Simultaneously smaller projects are being realised, e.g. restoration of the Černý potok stream (described in the case study "Restoration of the Černý potok stream") in the Krušné hory Mts. and rehabilitation of an inappropriately drained area with a capillary stream at Domašín near Vlašim (2011).

An important part of these restoration projects, from the viewpoint of biodiversity, is securing the passability of the stream for migrating organisms. The Operational Programme Environment has financed a range of structures supporting the continuity of watercourses with fish bypasses (e.g. at weirs on the Blanice rivers at Vlašim). An example of a fish bypass construction and its impact on the biodiversity of the watercourse is described in the case study "Revitalising effects of a near-natural bypass at a migration barrier on the Blanice river". A new element in restoration projects is the building of near-natural streambeds in towns and villages aimed at flood control, planned in e.g. the Moldau floodplain in Prague-Karlín and Prague-Libeň, and on the Blanice river in Vlašim.

It can be concluded that restoration of small stream courses, mainly aimed at reinstating the natural geomorphology and stream route, currently prevails in the Czech Republic. These are often local

Fig. 9. Roklanský stream, Šumava NP. Example of one of the rare natural streams in the Czech Republic. (I. Bufková)

projects dealing with sections of just a few hundred metres (mainly older projects) or in the best case a few kilometres. It is a positive point that, especially in the latest projects, knowledge about river morphology is increasingly being applied, whereby the original route, as well as the shape of the streambed, is restored by shallowing bottoms, and by diversifying banks, bottoms, the natural substrate (including small geomorphological elements) and stream gradients. Restoration works on larger rivers which include conspicuous geomorphological elements (e.g. eroded riverbanks, sand- and gravel-banks or islets) are, just as restoration of complete floodplains, still rare.

Usually, only a little amount of large woody debris is left in the beds of restored streams or it is fixed due to fears for the damage it could cause during floods. These components not only influence the diversity as a whole, but also functional processes linked to water retention and the capture of nutrients and their return into the system (Prach et al. 2003, Giller & Malmqvist 2008, Bukaveckas 2007).

A very important aspect of watercourse restoration is natural flooding. Even if many restoration projects in the Czech Republic renew the natural course of a streambed, natural dynamics and flooding were until recently reduced by various measures (e.g. reinforcing banks or strongly deepening the streambed), but due to ownership problems with the surrounding land, flooding has not been dealt with. However, flooding contributes to water retention of the river landscape and decreases flood waves (Langhammer & Vilímek 2004). It is also an important mechanism in capturing nutrients and sediments, and maintains the dynamics, habitat biodiversity and floodplain biodiversity (Prach et al. 2003).

A shortcoming of the practice so far is that restoration works are still badly coordinated and flood control is usually conceived strictly technically. At several sites, natural elements spontaneously created after extreme floods were even removed again (e.g. Litavka river 2002).

The attention of water management and nature conservation should not be directed to costly restoration projects only. They should be comprehensive, directed at limiting negative influences within the entire catchment and more frequent use of spontaneous renaturalisation processes. The point is that there is a broad scope of various 'lighter' and more economical measures supporting natural processes between costly restoration projects and spontaneous renaturalisation of watercourses.

At present it is hardly stressed that restoration of a watercourse and its surroundings may, besides improving landscape and flood control, also have a positive socio-economic effect by attracting visitors and tourists, especially around larger towns and in lowlands where agriculture has eliminated all near-natural ecosystems. This has been observed after finishing large restoration projects as well after spontaneous renaturalisation caused by the heavy floods of 1997 and 2002.

Restoration of other wetlands in the landscape

Appreciation for wetlands and their landscape functions is gradually growing also in our country, resulting in wetland restoration projects being more frequently implemented during the past two decades. The available subsidy programmes such as the River System Restoration Programme, landscape management programmes and the current EU funds have played an important part in this process.

Fig. 10. Roklanský stream, Šumava NP, with large woody debris, an important component of natural streams. (I. Bufková)

Figs. 11, 12. Creation of pools and marshes with tree plantings on 5.6 ha, Hladoměř, Central Bohemia. Left: pool in spring 2011; dry parts are covered with green hay. Right: vegetation in summer 2011. (T. Just)

Water pools and shallow water bodies

Among restoration projects focusing on wetlands in the Czech Republic, partial renewal or regeneration of existing wetland habitats prevail. These projects often include local restoration of small natural water bodies or pools as appropriate habitats supporting amphibians and other wetland fauna of still, shallow waters.

In many cases this approach is also used when restoring later successional stages of alluvial pools terrestrialised due to isolation from the stream and regular flood pulses. Monitoring in the Litovelské Pomoraví region has showed that restored habitats are quickly colonised and increase the diversity of water invertebrates in the area (Šmaková & Rulík 2000). Construction or renewal of shallow pools is also frequently included in nature-friendly restoration of some stone quarries and sandpits (in e.g. the Moravian Karst and the Třeboň Basin). These restoration measures are mainly important for their support of rare species or communities and general improvement of biodiversity. A positive effect on the local hydrology is evident as well. Another very frequent type of project is the restoration of wetland habitats linked with man-made structures, such as natural littorals and marshes around ponds, and the bottoms of polders in flood areas. Besides state institutions (Nature Conservation Agency of the Czech Republic) also several NGOs (namely the Czech Union for Nature Conservation) participate in restoring shallow pools.

Restoration of wet grasslands

Especially in recent years, thanks to suitable subsidies (landscape management programmes, Agri-environmental schemes), meadow fens are commonly and rather successfully restored by reintroducing management (most often manual mowing and shrub removal). These measures are primarily aimed at supporting valuable communities and species richness of mostly slightly to moderately disturbed sites, often situated in national parks, protected landscape areas and nature reserves. Restoration by suppressing competitive plant species and later successional stages with shrubs and trees is mainly applied to various wet *Cirsium* meadows, *Filipendula* grasslands, acidic moss-rich fen meadows, wet *Molinia* grasslands, continental inundated meadows, and also tufa springs and inland salt marshes (Hájková et al. 2009). Although these projects do usually not deal with hydrologically destroyed wetlands and do not include rehabilitation of the water regime, they are extremely important for biodiversity. Detailed examples are given in the case studies 'Experimental restoration and subsequent degradation of an alluvial meadow' and 'Restoration management of wetland meadows in the Podblanicko region' in the 'Grassland' section.

More important for the overall water regime in the landscape are projects restoring natural hydrological conditions of area-wide drained, strongly degraded wetlands in agricultural landscapes. These projects are however less frequent, the main limitations being land ownership and persisting intensive farming on drained land. Also registered draining equipment (especially drainpipes), which has to be maintained according to law, is a complication. Attempts to restore the water regime of wetlands on farmland moreover conflicts with farmers' interests supported by other landscape management subsidies (Agri-environmental schemes), paradoxically also in nature reserves. In spite of that, several projects aimed at complete removal of drainpipes on farmland have recently been realised, many of them connected to the restoration of small channelised streams and agricultural landscapes (e.g. Domašín near Vlašim, Ploučnice river).

Fig. 13. Complex of fens and wet *Cirsium* meadows seven years after reinstalling traditional management (manual mowing), Šumava NP. (I. Bufková)

Restoration of mires

Mires are restored relatively often in the Czech Republic. Although not very common, they receive great attention thanks to their high biodiversity value. Yet, mire restoration may include the rather complicated rehabilitation of strongly damaged industrially exploited raised bogs (see case study 'Restoration of the mined peatbog Soumarský Most'), but also the recovery of non-exploited sites mostly degraded by draining (case study 'Restoration of drained mires in the Šumava National Park'). In both cases the key measure to be taken is restoring the natural water regime (raising the groundwater level and stabilising it, restoring natural draining, and retaining sufficient water in dry periods) in order to restart the peat-forming process and reinstate the ecological functions and structures of the mire. Restoring mires is best realised as part of water regime remediation in a catchment, not separately. It is also important for these habitats to maintain the environment at an appropriate low trophy and carry the work out sensitively by exceptionally using heavy machinery. In addition to the positive impacts on biodiversity and landscape hydrology, mire restoration is also important from the viewpoint of the carbon cycle and release of greenhouse gases (Charman 2002).

In the past 20 years a range of successful peatbog restoration projects have been carried out in the Šumava Range, the Ore Mountains, the Jizera Mountains, Třeboňsko, Slavkovský les and the Giant Mountains (Lanta et al. 2006).

In conclusion, many watercourse and wetland restoration projects have been realised in the Czech Republic over the past 20 years, although their proportion is still very low in relation to the total area of disturbed and degraded sections and areas. One of the reasons for this is that, although such projects help the landscape as well as the human society to function in a sound way, their impact on the involved landowners or the local community is not immediately positive. Moreover, assessments of the pros and cons are often disputed and cannot always be quantified for a lack of concrete data. Combining ecosystem services and assessing them in a holistic way would certainly be beneficial. The total benefit expressed also in economic (financial) figures might then be evident and convincing to decision-makers (Turner et al. 2008, Pithart et al. 2010).

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Fig. 14. Restored water pool, Blazice, Hostýnské vrchy. (M. Girgel)

Fig. 15. Božídarské rašeliniště NR, Krušné hory Mts., after water regime restoration. (P. Marek)

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Restoration of the Černý potok stream, Krušné hory Mts.

Jiří Rous & Vít Rous

Location 	Černá louka NR, Krušné hory Mts., northwest Czech Republic, along the border with Germany 50°44'4" N, 13°53'26" E, 690–760 m
Protection status	NR, Ramsar Site (Krusnohorska Mountains mires), SCI, SPA
Ecosystem types	Meadow wetlands and springs, fens (*Montio-Cardaminetea* and *Scheuchzerio palustris-Caricetea nigrae*), wet and mesophilous meadows (*Molinio-Arrhenatheretea*), water courses
Restored area	Ca. 7.4 ha; 4 km of restored stream sections
Financial support	Free State of Saxony, Operational Programme Environment
Costs	2001–2003: €52,000; 2008–2010: €264,000

Initial conditions

Waterlogging is an important factor determining the character of the habitats in Černá louka NR. The main watercourse in the area is the Černý potok stream over a length of 1.9 km, which is supplied by water from another four tributaries. After World War II, the entire landscape was considerably changed. Former German inhabitants were expelled and the new settlers usually did not continue in the former traditional land use.

The most harmful impact on the present Nature Reserve was large-scale drainage installed during reclamation of mostly grassland in the 1960s to the 1980s. As a result, both the Černý potok stream and its tributaries were channelised and deepened. Subsurface drainage pipes on several dozen hectares led to the channelised stream courses. Surface drainage and peat cutting in the peatbog situated in the headwater of the Černý potok also negatively influenced the area, resulting in subsequent gradual degradation of mires and other wetland habitats.

Changes in the natural stream courses, degradation of stream habitats as well as considerable changes in natural hydrology were the main motivations for working out a restoration project. Restoration works originally started as partial re-establishment of small shallow pools and adjustments of the channels, but finally led to a comprehensive project aimed at restoring the natural hydrology in the entire Nature Reserve.

The area of interest is an important site for many rare and endangered plants (e.g. *Menyanthes trifoliata*, *Pinguicula vulgaris*) and animals (e.g. shore-birds, amphibians) of wetlands (Ondráček 2006). It was necessary to take the conservation of these species into account during the restoration works.

Abiotic conditions

The terrain is moderately sloping with an average gradient of ca. 3%. The bedrock consists of old rock of the crystalline complex, particularly orthogneiss, granulites and migmatites, with rhyolite veins.

Fig. 1. Section of Černý potok stream after restoration, 2010. (J. Rous)

The crystalline complex is in the floodplain covered by quaternary, mainly clayey-stony slope sediments with a topsoil layer of 0.15 m on average. Annual precipitation varies from 700 to 900 mm (long-term mean precipitation being ca. 850 mm). The mean annual flow rate in the Černý potok stream upstream of the left tributary (Mokřadní potok) is 24.5 $l.s^{-1}$, the mean annual flow rate of this tributary is 7.2 $l.s^{-1}$ (Anonymus 2009).

Objectives

Comprehensive remediation of the hydrology of the area, initiation of natural, dynamic re-development of the stream channel and cessation of degradation processes in valuable habitats. These restoration measures are the main prerequisite for biodiversity protection including both stabilisation of local populations and spontaneous return of important wetland species, e.g. Snipe (*Gallinago gallinago*). Also expected are flood control elements, e.g. reduction of the outflow velocity and retardation and flattening of flood waves.

Restoration measures

1998–2001	Elaboration of project study and documentation for partial restoration.
2001–2003	Partial restoration by EPS Servis, s.r.o., including construction of 26 pools, partial adjustments of the regulated streambed and restoration of two sections of natural streambed.
2006–2007	Development of investment plan for comprehensive restoration.
2008	Assignment and development of project documentation (Terén Design, s.r.o., Nature Conservation Agency of the Czech Republic).
2009–2010	Realisation of comprehensive restoration project for the Černý potok stream and its tributaries (EPS Servis, s.r.o.).

The project was based on common principles of stream restoration. The main aim of the restoration was to decrease the volume of the restored streambeds especially by reducing their depth. Other important criteria included re-establishment of a natural gradient, near-natural proportions of the stream cross-section, and natural variety in current and calm riffles (Just 2003, Doll et al. 2003, Just et al. 2005, Bernard et al. 2007).

Modifications within the channelised streambed were not sufficient to respect all these criteria, therefore new streambeds were proposed and constructed. They were reconnected with the remains of the original stream course or directed freely to the alluvial meadows. The volume of the new beds was designed at 30-day design flows (or max. one-year flows). The new beds were shaped with a rectangular profile or as broad "basins" with a mean depth of ca. 0.2 m, locally up to 0.5 m. The width of the stream near the bottom varied from 0.6 to 1 m upstream and downstream end of the restored section, respectively. The width range was flexible, reflecting surface, soil and geological conditions. The longitudinal profile of the new stream sections corresponded as much as possible with the natural surface gradient. The appropriate slope was achieved by re-establishing stream meandering (dependent on local conditions) and particularly by including near-natural current sections (e.g. rapids, stones, sills and low steps) between calmer pool-like sections. The new bed of the main left tributary of the Černý potok was designed in similar dimensions (depth 0.2 m, bottom width 0.6 m). In the other two smaller tributaries, water freely running out of the channelised streambed into the alluvium was proposed. This method had already been tested at the site before restoration and, although at a small scale then, it has turned out to work well. At the same time, the deepened and channelised streambeds were blocked by dams to halt artificial drainage of the site.

Results

Changes in the area of interest after restoration are summarised in the following table:

Restored habitats	
Restored stream sections (including adjustment of channelised streambeds and making water flow into the alluvium)	4,030 m
Natural overflow in case of Q100 floods (along meandering segment in the alluvium)	74,000 m^2
Pools with marshes (restored or created marsh habitats)	9,630 m^2
Both new and restored marshes with still or running waters	43,000 m^2

The restoration was assessed with respect to the impact on flow rate. The courses of flood waves in the Černý potok stream before and after restoration were compared using the two dimensional hydrodynamic SRH-2D model (Lai 2008). Only a small effect of the stream restoration on the peak flow was found with the exception of less frequent floods (N1, N2 and N5 peak flows were reduced by only 50–80 $l.s^{-1}$). On the other hand, a very significant effect was recorded on the delay of the flood wave. In a model of a restored stream section of ca. 1 km in length, the delay was up to 2 hours for the 1-year flood compared to the regulated stream and a considerable 20 minutes for a 100-year flood. As a consequence, the peak flow downstream can be reduced due to delayed peak flows from the tributaries (Just et al. 2005). Also dynamic meandering of the restored streambed is being studied, but long-term monitoring is necessary to obtain statistically significant results.

Fig. 2. Section of Černý potok stream before restoration, 2005. (J. Rous)

Figs. 3, 4. Section of Černý potok stream before restoration (left, 2008) and after restoration (right, 2011). (P. Kříž)

The effect of restoration on the local fauna and flora was monitored as well (Nature Conservation Agency of the Czech Republic, Czech Union for Nature Conservation, Local Chapter Teplice – Fergunna, 2007–2011) but only preliminary results are available at present because of a relatively short post-restoration phase. The abundance of some amphibians has considerably increased in the constructed pools (e.g. hundreds of individuals of frog species, e.g. *Bufo bufo*, *Rana temporaria*, and dozens of individuals of *Triturus vulgaris*). A more frequent occurrence of some bird species of waterlogged meadows and marshes (such as *Crex crex* and *Gallinago gallinago*) was recorded mainly in the restored wetland habitats created by conducting small tributaries to the floodplain. In 2011 about 20 dragonfly species were recorded. The local population of the endangered plant species *Menyanthes trifoliata* has increased in the floodplain.

Other lessons learned and future perspectives

The described restoration project, dealing with stream restoration including a large flooded alluvium, represents the first of its kind in the Czech Republic in extent and approach. New methods were applied in the design of shape and course of the streambed, and their successful implementation was enabled by good collaboration between investor, designer and subcontractors.

Public support

Also NGOs were involved in the restoration project. Members of the Czech Union for Nature Conservation (Local Chapter Teplice – Fergunna) participated in study, project preparation and implementation. The restored site is used for education, and both experts and the public from the Czech Republic and abroad have visited it.

Acknowledgement

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Revitalising effects of a near-natural bypass at a migration barrier on the Blanice river

Petr Hartvich & Petr Dvořák

Location 	Weir on the Blanice river at Bavorov near Vodňany, South Bohemia 49°12'23" N, 14°09'08" E; altitude 420 m
Protection status	Important landscape element, riverine biocorridor
Ecosystem types	Alluvial river ecosystem
Restored area	6-km river section (with 35 m long bypass)
Financial support	Landscape management programmes
Costs	€19,920

Initial conditions

The Blanice river springs at 972 m above sea level in the Šumava Mountains and joins the Otava river at an elevation of 362 m, where it is characterised as a lowland river with preserved oxbows. The gradient of the 93.3 km long river is 5.15% and the average flow is 4.23 $m^3.s^{-1}$ at its lower end.

Many damming-up devices have been built for water mills, hammer mills and sawmills, increasing the need for water. The river was fragmented into parts with still water and parts where the flow was regulated. The character of the river ecosystem has changed, affecting the natural development of fish populations (Hartvich et al. 2004).

A high dam works as a migration barrier. It cannot be overcome by fish moving upstream and so the long-term loss of upstream migration negatively influences the exchange of genetic information during reproduction. Separated fish populations become smaller as well as less resilient. Fish which are flushed downstream by the flow cannot get back to their habitat (Peter 1998, Lucas & Baras 2001).

For this reason fish passes with damming-up devices (weirs etc.) are built. They allow fish and other aquatic animals to pass the barriers and move freely along the river. Fish passes transfer the backwater to the stream below the barrier and are either a part of the migration barrier or placed on the grounds next to the barrier. In this case the fish pass functions as the bypass of a barrier. These fish passes are built in such a way that their character, structure and stream flow are similar to the conditions of natural rivers (Kubečka et al. 1997, Cowx & Welcomme 1998, Gebler 2009, Lusk et al. 2011).

In total 17 fixed or mobile barriers (weirs, dams) have been placed across the Blanice river. These barriers are not migration-permeable, with one exception. The river continuity is disrupted mainly by the Husinec Dam-lake (area 61 ha, backwater 3.5 km long, maximum 25.5 m deep). Below the dam, the river has a weir impassable for migrating aquatic animals. On the right bank a ground overgrown with deciduous trees and a part of a former oxbow connected to the river below the weir were available. Because of these conditions, a near-natural bypass was proposed as the most convenient solution.

Objectives

Restoring and preserving healthy populations and diversity of the original fish species in Blanice river by building a bypass.

Restoration measures

In 2002, a 35 m long bypass was built at the weir to allow upstream migration. It runs from the upper weir through natural terrain around the body of the weir and joins the river 20 metres downstream of the weir. The average gradient is 5%. Fig. 3 shows the placement of this near-natural bypass. At a medium flow rate (Q_{180}), up to 250 $l.s^{-1}$ flows through the bypass. The 2.5 m wide upper part of the bypass is a torrent fish pass with an inlet device placed upstream of the weir. The construction includes 9 stone sills for the necessary backwater, in which 7 to 16 cm wide gaps between the stones (boulders) enable fish to swim through either at the bottom or below the water surface. Gravel and smaller stones on the bottom decrease the flow in the lower water layers. The sills differ no more than 15 cm in height and their depth ranges from 0.3 to 0.5 m.

The lower part of the bypass is formed by the oxbow (which was first cleaned) with slowly flowing water. The width of the lower part

Fig. 1. Upper torrent segment of the bypass. (P. Dvořák)

Fig. 2. Torrent and lower, fluvial part of the bypass. (V. Šámal)

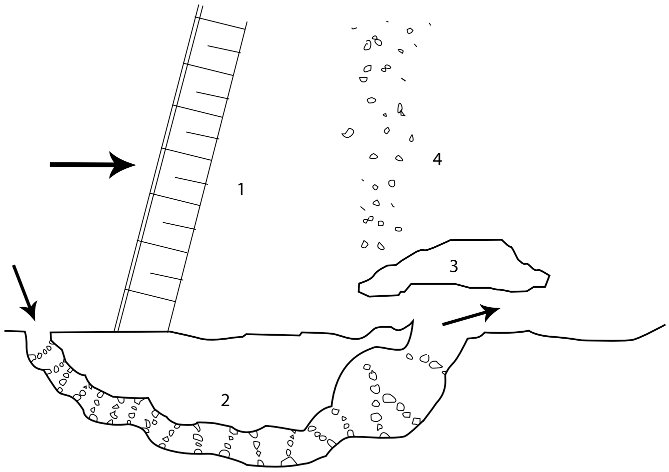

Fig. 3. Placement of near-natural bypass at the migration barrier. 1 – migration barrier (weir body); 2 – bypass with stone sills; 3 – gravel island in baffle platform; 4 – gravel sand deposition under water.

ranges from 3 to 5 m and the gradient is only 2%, but a few stone sills form up to 1 m deep pools. In places over sand and gravel banks shoals have been formed by high-water flows.

Management measures

— Bypass maintenance after floods, in spring and autumn.
— Removal of sediments to keep the bypass clear.
— Seasonal monitoring of local fish fauna diversity in the bypass passable for migration.

Results

The presence of fish in the bypass was monitored once a month during the year 2002 (except during ice cover in winter and high-water) to assess species diversity (Hartvich et al. 2004). This was done by damming up the inlet profile with a board to stop the stream, so that the fish present could be collected and the remaining ones caught with electric current. A small net was placed in the lower part to prevent the fish from escaping. The fish were measured using common ichthyologic methods and returned immediately.

The critically endangered Brook Lamprey (*Lampetra planeri*) and 13 species of six families were detected during the first monitoring period (Tab. 1). According to ecological preference rheophilous (living in fast streams) species (8) were the most abundant, followed by eurytopic (5) and one limnophilous (living in standing water) species, namely Tench (*Tinca tinca*). The total fish fauna counted 610 individuals weighing 8,939 g in total. The most abundant species were *Pseudorasbora parva*, *Leuciscus leuciscus*, and *Perca perca*. In the lower part of the bypass, a few individuals of the critically endangered European Crayfish (*Astacus astacus*) were found.

In the following period (January to November 2003), the number of species grew to 18, including the newcomers *Alburnus alburnus*, *Barbus barbus*, *Scardinius erythrophthalmus* and *Anguilla anguilla* (Hartvich et al. 2004), amounting to 993 individuals and a biomass of 7,876 g. The detected species assemblage corresponds, except for *Cottus gobio*, to the results given by Krupauer (1984) for the Blanice river upstream of the Husinec Dam-lake, and later mentioned by Křížek et al. (2004) for the upper and central part of the Blanice river.

Other lessons learned and new perspectives

1. Grassland and self-seeded trees (willows and aspen) permanently reinforce and protect the banks of the bypass against erosion. The open inlet device passes water level fluctuations into the bypass. High-water flows do not endanger the bypass construction. Loosely placed stones on the bypass banks slow down the flow, prevent lateral erosion and create shelter for fish. Coarse gravel on the bottom is an appropriate substrate for the settling of benthos.
2. Monitoring results show that fish not only migrate through the bypass but also settle there for a certain period of time. The detected 18 species of fish and lamprey correspond to the composition found in ichthyologic research conducted in the upper and central part of the Blanice river. Fish migration in the bypass takes place during the whole year, except when there is ice cover.
3. Monitoring of bypass passability not only provides ichthyologists, nature conservationists, water authorities, and designers and builders of fish passes with a lot of new information, but it also shows the real state of the fish fauna in fishing grounds, especially in the case of functional passes such as the one at Bavorov.

Tab. 1. Detected species and their abundance (individuals/g) in each month during the first year of monitoring of the bypass.

Species	Ecological group	IV ind./g	VI ind./g	VII ind./g	IX ind./g	X ind./g	XI ind./g	XII ind./g
Gobio gobio	eurytopic	12/151		1/5	16/106	2/7	16/148	8/100
Leuciscus leuciscus	rheophilous	43/441	12/502	20/1079	59/136	1/45	3/5	5/183
Leuciscus cephalus	rheophilous	7/134	8/459		7/510		2/13	2/37
Tinca tinca	limnophilous							1/4
Thymallus thymallus	rheophilous			2/17	1/67			2/243
Lota lota	rheophilous	1/105			1/30	2/220	1/140	
Barbatula barbatula	rheophilous		2/14	5/47	4/22	1/35		
Perca fluviatilis	eurytopic	5/177	8/247	6/224	22/410	1/100	5/160	4/33
Rutilus rutilus	eurytopic	1/6	1/20		4/17		1/64	2/47
Salmo trutta m. fario	rheophilous	6/166	3/83	4/213	3/30		1/125	
Phoxinus phoxinus	rheophilous	3/16	4/11	11/48	2/6		1/0,8	1/2
Pseudorasbora parva	eurytopic	14/16	2/11	120/49	80/207	11/41	12/9	15/34
Esox lucius	eurytopic			1/100	5/637	2/225		
Petromyzonidae: *Lampetra planeri*	rheophilous				1/11			1/10

Fig. 4. Removal of sediments and objects from the bypass during reduced stream flow. (P. Dvořák)

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Restoration of drained mires in the Šumava National Park

Ivana Bufková & František Stíbal

Location 	Šumava Mts., southwest Czech Republic, along the border with Germany and Austria 48°59'–49°0' N, 13°47'–14°28' E; altitude 750–1200 m
Protection status	NP, UNESCO Biosphere Reserve, SCI, Ramsar Site (Šumava Peatlands)
Ecosystem types	Open raised bogs with dwarf shrub, lawn and hollow vegetation surrounded by *Pinus ×pseudopumilio* krummholz, bog pine (*Pinus rotundata*) forests on valley bogs, transitional mires, spruce mires, waterlogged spruce forests (*Oxycocco-Sphagnetea*, partly also *Scheuchzerio palustris-Caricetea nigrae* and *Piceion abietis*)
Restored area	Ca. 500 ha (19 sites), nearly 60 km of blocked ditches
Financial support	Landscape management programmes, Šumava NP and PLA Authority
Costs	Ca. €510,000

Initial conditions

Many mires in the Šumava NP have been modified by various human activities like forestry, agriculture and peat extraction in the past (Schreiber 1924). Various interventions in the hydrology, mainly surface drainage, are generally the most harmful impacts on mires in the area. A recent mire survey revealed that almost 70% of mires have been influenced at least once by drainage. However, disturbance intensity varies largely across the area depending on e.g. human population density and land use. Drainage ditches from the turn of 19th and 20th centuries are rather shallow and usually less damaging for mires. In contrast, deep channels made from the 1960s to the 1980s are less frequent but represent a much more serious problem (Fig. 2).

Drainage in the past has caused significant degradation, both in mire ecology and mire structure (Bufková et al. 2008), and has negatively influenced mire biodiversity including rare and relict species. In order to improve the situation, a long-term project called Mire Restoration Programme has been realized in the area since the year 1999. Since 1996, the position of the water table and its basic chemistry (pH, conductivity) was monitored, but since 2005, the restoration project has been coupled with detailed research and a monitoring programme.

Abiotic conditions

All restored sites monitored in detail were situated on the central mountain plateau (at an elevation of ca. 1000 m). The bedrock is nutrient-poor and acid. It is formed mainly of paragneisses, with some granite in places. The mean annual temperature is 3.2 °C and the annual precipitation is 1200–1330 mm (Svobodová et al. 2002).

Fig. 1. Blocked ditches in an open raised bog four years after restoration, Březnické slatě. (I. Bufková)

Fig. 2. Heavily drained spruce mire before restoration, Ztracená slať. (I. Bufková)

Fig. 3. Volunteers helping with mire restoration at Vrchové slatě (2010). (I. Bufková)

Objectives

The main objectives of the mire restoration programme were: (i) restoration of natural (or near-natural) mire hydrology; (ii) enhancement of peat-forming vegetation and processes, (iii) conservation of natural mire biodiversity; and (iv) involvement of the public into local mire conservation.

Regarding hydrology, the aim of the restoration was to raise the water table to a natural (pre-drainage) level, decrease the fluctuations, and retain sufficient water in the mires especially during the driest periods. These measures were expected to halt or moderate degradation processes and to enhance peat-forming vegetation and spontaneous mire regeneration.

Restoration measures

The restoration of drained mires was based on the target water table concept. The target water table corresponds with the natural water table in undisturbed mires, and differs per mire type. The main restoration technique was the blocking of ditches with a set of board dams (Fig. 1) followed by filling the dammed ditches with natural material. The target water table and slope of the ditches were the key parameters to establish the number of dams and their distribution along the ditch. In deep ditches, the water-filled segments between the dams were then partly filled with peat, fascines (brushwood bundles), branches, *Sphagnum* clusters, etc. to enhance their terrestrialisation. In shallow ditches, especially under good light conditions, spontaneous terrestrialisation usually proceeds very well without any support. Because of the high vulnerability of the restored habitats, all work was carried out manually.

All restoration measures were limited in time (usually carried out during 1–2 years) and focused on the re-establishment of natural or near-natural hydrological conditions, after which subsequent autogenic plant succession including peat-forming vegetation and self-regulating development of a particular mire type are expected to start.

Since 2005, under the Mire Restoration Programme, mire sites in various stages of degradation have been studied. Permanent plots (97 in total) were established to study the microtopographical, vegetation and drainage patterns of the different mire sites. The water table height was measured manually in all boreholes at roughly fortnightly intervals. Automatic gauging (at 1 h intervals) with piezometers was used in 49 selected boreholes. Water samples from boreholes, ditches, runoff profiles from drained sites, and control streams were taken monthly for a detailed hydrochemical analysis, including the main cations and anions (SO_4, NO_3, NH_4, PO_4, Ca, Mg, Al, Fe), pH, conductivity and dissolved organic carbon (DOC). Runoff from drained sites as well as precipitation were measured continually.

1994–1998	Survey of mires in the Šumava NP including human impacts (e.g. drainage) and rough assessment of degradation changes.
1999	Initiation of the Mire Restoration Programme. Realization of pilot project called Restoration of the Kamerální slať Mire.
1995–2011	Basic monitoring (water table, groundwater pH and conductivity) of two selected raised bogs, the first one being restored in 1999, the second one in 2004.
2003	Update of the Mire Restoration Programme conception – target water table concept included.
2003–2010	Restoration of 18 sites.
2005–2007	Detailed monitoring – pre-restoration phase.
2008	Restoration of two sites monitored in detail.
2009–2011	Detailed monitoring – post-restoration phase.

Results

First results suggest that the restoration has had a positive effect on the hydrology at the moderately degraded site (Schachtenfilz). The mean water table rose and its fluctuations were reduced, especially in the dwarf-shrub bog sites and wet forests (Fig. 4). The water table beneath *Trichophorum* lawns remained at almost the same level, but also

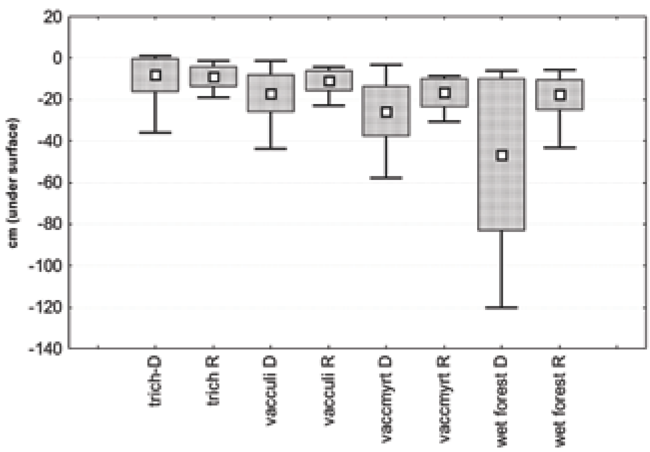

Fig. 4. Mean water table of moderately disturbed mire at Schachtenfilz, before and after restoration. D – before restoration; R – after restoration; trich – bog lawns dominated by *Trichophorum cespitosum*; vacculi – dwarf bog shrubs dominated by *Vaccinium uliginosum*; vaccmyrt – dwarf bog shrubs with both *Vaccinium uliginosum* and *V. myrtillus* (heavily drained); wet forest – waterlogged spruce forest.

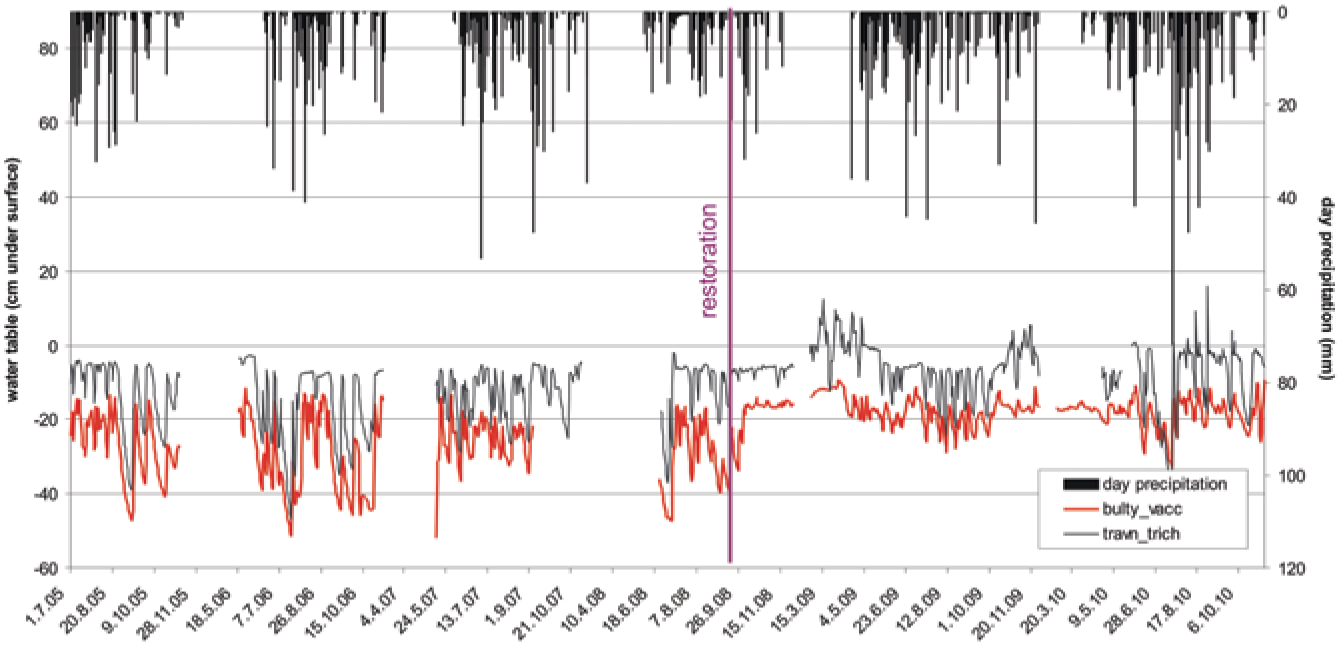

Fig. 5. Water table fluctuations before and after restoration in moderately disturbed raised bog at Schachtenfilz. Restoration time is indicated with a purple vertical line; bulty_vacc – dwarf bog shrubs dominated by *Vaccinium* spp.; travn_trich – bog lawns dominated by *Trichophorum cespitosum*.

here fluctuations were reduced (Bufková et al. 2010). The positive effect of the restoration on water table fluctuations can be seen in Fig. 5.

The various mire types differed in hydrochemical response to the restoration. The results suggest that hydrochemical changes are more prominent in wet forests than in bogs. Electrical conductivity, PO_4, Al and Fe concentrations increased in wet forests but remained almost the same in bogs after the restoration. However, data two years after the restoration only show the short-term response of a mire to drain-blocking and may differ from the long-term response (Worrall et al. 2007). As a result, long-term monitoring will be necessary for a full understanding of the ecological processes and changes caused by restoration.

Other lessons learned and future perspectives

The target water table concept seems to be a useful tool in mire restoration especially in the case of bogs and various sloping mires. Long-term monitoring including a pre-restoration period of several years is necessary to evaluate restoration success both in mires and adjacent habitats. When assessing hydrochemistry effects of restoration on the catchment level, the various conditions of restored minerotrophic mires and bogs should be taken into consideration.

Public support

Involvement of the public into mire restoration and providing information on it are included into the aims of the project. Both visitors and local people regularly attend "Mire Days", which have been organised in the Šumava NP since 2008. In the first half of such a mire day, people help with mire restoration after which they can visit undisturbed mires during the afternoon excursion. Similar "Mire Weeks" have also been organised in collaboration with NGOs for already 8 years. These "Mire Weeks" are attended mainly by young people and students. In this way several hundred people from the whole Czech Republic have taken part in mire restoration (Fig. 3).

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Restoration of the mined peatbog Soumarský Most

Petr Horn & Marek Bastl

Location 	Šumava Mts., southwest Czech Republic, near the border with Germany 48°54'45" N, 13°49'33" E; altitude 745 m
Protection status	NP, UNESCO Biosphere Reserve, SCI, Ramsar Site (Šumavská peatlands)
Ecosystem types	Degraded valley bog (*Oxycocco-Sphagnetea*) originally covered by bog pine (*Pinus rotundata*) forest and dwarf shrub vegetation dominated by *Vaccinium uliginosum*
Restored area	53 ha
Financial support	Landscape management programmes, Šumava NP and PLA Authority
Costs	€3,193/ha

Initial conditions

The Soumarský Most peatbog (total area ca. 80 ha) is part of a large mire complex developed in the basin of the Upper Vltava river. Initially, the peatbog was covered by typical bog pine (*Pinus rotundata*) forest (Schreiber 1924), but was partly damaged by manual peat digging on an area of approximately 15 ha at the beginning of 20th century. In 1959–1960 a detailed survey of the peatbog including peat profiles was carried out by the former Research Institute for Soils and Reclamation. Based on the results of this study, peat mining was proposed on an area of 75 ha indicating a supply of 1,850,000 m^3 of peat (Anonymus 1960). Industrial peat milling was started shortly after the survey (in 1962) on large areas. Only a small remnant of the original bog remained in the SE edge of the exploited area. Peat milling was stopped by the National Park Authority between 1998 and 2000.

Fig. 1. Redeveloped *Sphagnum* carpet between *Eriophorum vaginatum* tussocks on former bare peat (2011). (I. Bufková)

Abiotic conditions

After peat mining had ceased, the peatbog consisted of large areas of abandoned bare peat strongly drained by a system of open ditches. Several large ditches (both central and peripheral) were connected with a large number of small lateral ditches and in many places even piped. The residual peat layer was up to 3 m thick, but the prevailing peat layer thickness was only 0.5 m and average peat thickness about 0.8 m. The bare peat surface was characterised by a harsh microclimate, especially high temperature extremes near the peat surface and a strong fluctuation of the water table and peat moisture, causing extreme desiccation in some places. Colonising plants and spontaneous revegetation were strongly limited by these conditions. The mean annual temperature in the area is 6.2 °C, the total annual precipitation is ca. 760 mm (Svobodová et al. 2002), but the entire valley is under strong influence of temperature inversion and a high amount of horizontal precipitation from frequent fogs.

Objectives

Restoration of a raised bog almost completely destroyed by industrial peat mining. Establishment of wetland communities and peat-forming vegetation with possible return of relict peatbog species in parts with a high water table and low nutrient contents.

Restoration measures

1995–1996	The first negotiations about further use and the future of Soumarský Most peatbog with the former owner (Rašelina Soběslav, a private company) started.
1999	Ownership of the peatbog was changed from private to state (Šumava NP and PLA Authority).
1998–1999	Shallow surface depressions were created in collaboration with Rašelina Soběslav using their machinery.
1999	Peat milling was definitely finished.
2000	Project documentation was compiled.
2000	The peatbog came in the hands of the town of Volary. Negotiations on the future of the bog took place.
2000–2004	Implementation of the restoration project.
2000–2011	Hydrology and vegetation monitoring.

The restoration measures were based on the concept of directed succession. First of all a few shallow depressions were made in the bare peat surface and subsequently the highly fluctuating water regime was stabilised by blocking drainage ditches with boards (Fig. 5).

Fig. 2. Bare peat immediately after peat milling was finished in 2001. (Archive University of South Bohemia, České Budějovice)

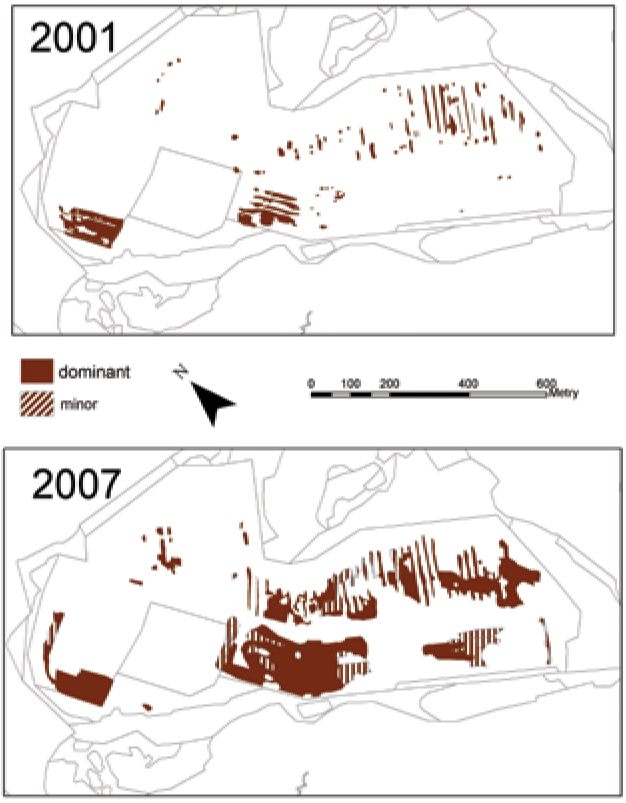

Fig. 3. The area covered by dominant *Eriophorum vaginatum* (brown patches) has grown tenfold between 2000 and 2007.

This improved the water regime in a large area and some parts of the bog were even shallowly but permanently flooded (Fig. 4). Sphagnum mosses – fundamental in peat-forming communities – were reintroduced, especially into these shallow basins. The bare peat surface was covered with mulch from adjacent minerotrophic sedge mires to accelerate colonisation by appropriate vascular plant species. In dry areas selected groups of trees mostly including *Betula pubescens* and *Pinus sylvestris* were felled to reduce water loss through transpiration.

Results

The initial vegetation on the peat bog immediately after peat mining had finished was dominated by wetland species growing mostly on the wet bases of the draining ditches, e.g. *Eriophorum angustifolium*, *E. vaginatum*, *Carex rostrata*, *Molinia caerulea*, and *Juncus effusus* (Zývaľ et al. 2000). These species were also later the main colonisers of bare peat areas, and the different proportions of them at the sites were probably determined by moisture and nutrients. The colonisation process was later strongly accelerated by experimental planting of *Carex rostrata* and *Eriophorum angustifolium* during restoration. The main factor facilitating successful regeneration of peatbog vegetation was the restoration of the water regime. The main factors influencing the vegetation of flooded areas are water table height, depth of the remaining peat, and successional age. The vegetation of flooded areas did not significantly respond to relatively small differences in water chemistry.

Initially Common Cottongrass (*Eriophorum angustifolium*) spread very successfully over both wet and dry areas. This species formed ring polycormons in drier parts which facilitated the establishment of other plants in their centre (Lanta et al. 2008). Therefore the increasing abundance of *E. angustifolium* in drier parts was only temporal and occurred in the first five years after the restoration measures had been carried out.

The main process observed during the vegetation development after 2006 was rapid colonisation of bare peat by Hare's-tail Cottongrass (*Eriophorum vaginatum*) tussocks (Fig. 1) (Horn 2009). Considerable changes in the total cover of this species after restoration (in 2000–2007) are shown in Fig. 3. It is very probable that *Eriophorum vaginatum* will also be reduced and facilitate establishment of other species in the future.

Tab. 1. Transition matrix of vascular species interaction between years 2000 (rows) and 2007 (columns). Bare – bare peat; flooded – permanently flooded areas without vegetation; yellow cells show the probability of an unchanged status, red cells show for each species in 2000 the highest probability of replacement with another species in 2007.

	bare	*CalaEpig*	*Carx.spp*	*ErioAngu*	*ErioVagi*	flooded	*JuncEffu*	*MoliCaer*	*PhalArun*
bare	0.7088	0.0147	0.0159	0.0452	0.1081	0	0.0601	0.0473	0
CalaEpig	0.1528	0.3426	0.0463	0.0417	0	0.1042	0.2836	0.0289	0
Carx.spp	0.176	0.0035	0.1851	0.0871	0.2441	0.1347	0.0782	0.0912	0
ErioAngu	0.2073	0	0.0462	0.4608	0.1847	0.0418	0.0496	0.0096	0
ErioVagi	0.1489	0.0014	0.0349	0.0973	0.6016	0.0183	0.0088	0.0888	0
flooded	0	0.0009	0.1159	0.091	0.2344	0.4053	0.0751	0.0773	0
JuncEffu	0.2108	0.0309	0.0419	0.0153	0.1062	0.0498	0.4358	0.1093	0
MoliCaer	0.2176	0	0.0452	0.0304	0.1813	0.2155	0.0897	0.2203	0
PhalArun	0	0	0.75	0	0	0	0.2222	0.0278	0

Fig. 4. Shallow waterlogged basins at the end of the restoration (2004); bare peat partly covered with vegetation in the background. (M. Bastl)

Fig. 6. Successfully expanding *Eriophorum vaginatum* and reintroduced *Sphagnum* a few years after restoration (2009). (M. Bastl)

Margins of flooded areas and shallow basins were colonised by reintroduced *Sphagnum* species, especially *Sphagnum fallax* and *S. cuspidatum*. These sites have the best potential for establishment of peat-forming processes and communities (Fig. 6). The total area of *Sphagnum* carpets considerably increased in the restored peatbog. In 2002, the estimated *Sphagnum* cover was only about 1–2% of the total peatbog area, but in 2007 it was already about 8% (P. Horn, unpubl.).

Dry parts of the site were mostly colonised by trees such as *Betula pubescens* and *Pinus sylvestris* (Lanta & Hazuková 2005). At flooded sites, however, their proportion was significantly reduced by death. The interaction between vascular plant species recorded after restoration in 2000 and 2007 can be read from the transition matrix in Tab. 1. The matrix clearly shows that the most expansive species in 2000–2007 was *Eriophorum vaginatum*, which has the highest success not only in the colonisation of bare peat, but also in replacing other vascular plants (e.g. *Carex* spp., *Eriophorum angustifolium*). The second most successful plant was *Juncus effusus*, which colonised rather thin remaining layers of probably strongly mineralised bare peat.

Public support

Some restoration measures at the site were carried with the help of volunteers, mainly students. The site is also used as a tourist information point with connection to the nearby Vltava river floodplain. The nature trail with observation tower is under construction at the moment.

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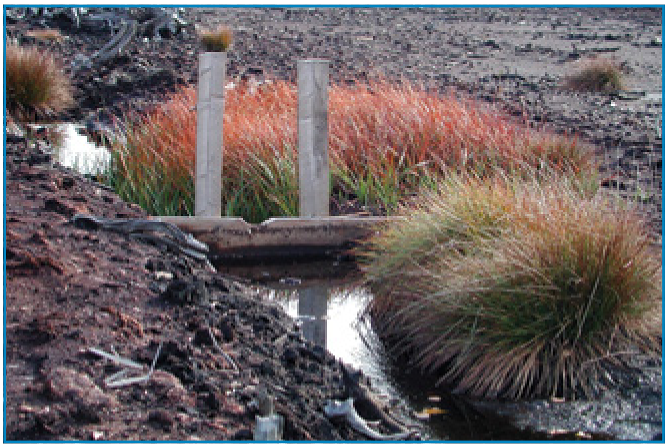

Fig. 5. Simple board dam used for blocking small open ditches (2001). (M. Bastl)

Fig. 7. Example of experimental planting plots with *Carex rostrata* and *Eriophorum angustifolium* (2001). (M. Bastl)

Mining and post-industrial sites

Large limestone quarry, Čertovy schody, Bohemian Karst. (J. Řehounek)

Introduction

Robert Tropek & Karel Prach

Mining has a long tradition in the Czech Republic and is an important part of the country's economy. Despite its recent decline, it still has a significant impact on landscape and nature. Given that the excavation of various materials will remain an important economic activity, restoration efforts should address the remarkable biodiversity potential of extraction sites. As a by-product of other industrial activities, various post-industrial anthropogenic sites represent a growing component of many landscapes and regions in the Czech Republic. Here, we consider significantly modified sites such as quarries, spoil heaps created by mining, sand and gravel pits, clay pits, ash and slag deposits, brownfields, road verges, and railway embankments.

The traditionally negative view of such sites among ecologists and conservationists is rapidly changing. It is becoming clear that in human-altered regions, their early successional and highly heterogeneous surfaces with extreme abiotic conditions and low productivity may offer valuable refugia and/or compensatory habitats for a range of species rapidly declining in modern impoverished landscapes. Several important studies showing the conservation potential of post-mining sites, such as coal spoil dumps (Prach 1987, Hodačová & Prach 2003, Frouz et al. 2008, Tropek et al. 2012), limestone quarries (Beneš et al. 2003, Tichý 2006, Tropek et al. 2010), acid rock quarries (Novák & Prach 2003, Tropek & Konvička 2008, Trnková et al. 2010), sandpits (Řehounková & Prach 2006, 2008, 2010), extracted peatlands (Bastl et al. 2009, Konvalinková & Prach 2010), and ash/slag deposits (Kovář 2004), originate from the Czech Republic. There are still other unpublished data from various sites and regions, which can be used to assess the importance of particular sites in biodiversity conservation and restoration planning.

Fig. 2. Examples of by-products of energy production from coal in the Sokolov region: in the foreground ash-slag deposits of the Vřesová power station, in the background Smolnická spoil heap, where spoil substrate from the layers above the coal are deposited during mining. (O. Mudrák)

Main types of mining and post-industrial sites

Quarries

Quarries are relatively numerous in all regions of the Czech Republic. Several dozen million tons of decorative and building stones are mined annually from more than 200 active quarries (Starý et al. 2008). Especially limestone excavation, concentrated in the warmest parts of the Czech Republic, is important. It has repeatedly been shown that excavated sites (especially limestone quarries) provide specific abiotic conditions fundamental for the development of non-productive habitats of great conservation potential. These habitats are often colonised by many species specialised in growing on rocks, in sparse steppe-like grassland and in forest steppes, including dozens of critically endangered species.

Sand- and gravel pits

Sand- and gravel pits occur in many regions of the Czech Republic, owing to the importance of sand and gravel for the building sector and various industries (Řehounková & Prach 2006). Sand and gravel are currently being excavated at more than 80 active sites and there

Fig. 1. Environmentally-friendly reclamation supporting strong increase in biodiversity in Růženin lom quarry, Hády near Brno. (L. Tichý)

are a similar number of currently inactive sites (Starý et al. 2008). The main factor influencing the vegetation development of sand-gravel pit communities is the fine-grained and nutrient-poor substrate. Mainly depending on the depth to which the substrate is mined and the location of the site, valuable dry or wet sandy habitats are formed (Řehounková & Prach 2006). Sand-gravel pits are also one of the most intensively studied anthropogenic sites and there is increasing evidence that they provide surrogate habitats for communities of both dry and wet sands (Řehounková & Prach 2008).

Spoil dumps

Post-mining spoil heaps are important components of the landscape in some regions of the Czech Republic, especially in the western part, where lignite coal is excavated in open-cast mines. However, deep coal mining is also significant in especially the central and northeastern parts of the country. In addition to coal mining, spoil heaps were also created during uranium excavation, but no mine is recently active. Mining of other resources has been rather rare, if we do not consider historical mining. Spoil heaps with various successional stages, especially if not completely covered by woodland, also provide valuable surrogate habitats for a range of species vanishing from the surrounding landscape.

Ash-slag deposits

The Czech energy production still predominantly relies on coal burning. Therefore deposits of the by-products (ash and slag) are relatively frequent in the landscape, adjacent to practically every power plant, heating plant and many of the larger factories (Kovář 2004, Kovář et al. 2011). The negative impacts of fly-ash, easily dispersed from the deposits by wind erosion, on the human environment (e.g. Borm 1997) are well known. Recently published studies thus consider a rapid reclamation of these sites as the only possibility. On the other hand, the biodiversity of communities inhabiting these deposits has rarely been studied. To date, all the studies are restricted to plants (e.g. Ash et al. 1994, Vaňková & Kovář 2004), lichens (Palice & Soldán 2004) and fungi (Kubátová et al. 2002), whereas animals seem to be neglected. Nevertheless, the results of a few unpublished preliminary studies indicate a great potential of these sites to become strongholds of vanishing psammophilous arthropods (Tropek et al., unpubl.). The existing information is however very limited, so that further comprehensive research considering both the risk to human health and the benefit for biodiversity conservation is urgently needed.

Restoration of mining and post-industrial sites

Because of the relatively large area of industrially affected sites (both currently and in the future) and their great conservation value, restoration should aim at strengthening their biodiversity potential (Prach & Pyšek 2001, Pyšek et al. 2001; Young et al. 2005).

Therefore, any current and future restoration project should be based on scientific knowledge and fundamental biological assessments.

Besides biodiversity, each restoration project should consider all other public concerns in a balanced way. Among others, reduction of erosion and risk of contamination, recreational activities and aesthetic aspects can be considered. However, at sites where these concerns are not relevant or important, biodiversity should become the main restoration target.

There are three approaches to restoration of disturbed sites (sensu Prach & Hobbs 2008, Tropek et al. 2012):

1. Technically oriented reclamation, typically comprising covering the sites with fertile topsoil, sowing grass-herb mixtures, and/or planting trees. This approach still strongly dominates in the Czech Republic.
2. Spontaneous succession without any human intervention, which is only exceptionally used as an intentional restoration measure. The overwhelming majority of spontaneously developed sites are left abandoned for other reasons, such as planned continuation of exploitation in the future, lack of finance or labour shortage.
3. Directed succession is a rarely used method, in which natural processes are actively influenced; e.g. through support of plants desired for reasons of biodiversity (by sowing or species-rich hay transfer), or by suppressing invasive plants (Rydgren et al. 2010, Novák & Prach 2010).

Fig. 3. Pískovna u Dračice NR, Třeboňsko PLA: an advantage of sandpits from the viewpoint of nature conservation is their great habitat diversity. (J. Řehounek)

Reclamation

In reclamation, re-establishment of a landscape corresponding to the one before mining or with other both economic or amenity benefits for the local people is preferred. In mined pits, hydrological reclamation creating anthropogenic lakes by artificial inundation represents a common approach usually appreciated by the public. Other routinely used methods are aimed at creating forests for timber production (although formally being considered as protective forests, i.e. not of economic interest), agricultural land, public parks and other recreational or sport areas. Czech legislation provides relatively powerful rules restricting the loss of farm- and woodland; hence the re-establishment of forest and agricultural land is mainly desired by the authorities even in places where any re-establishment of forest or agricultural land is problematic or useless. The biodiversity issue is still not generally considered.

The most common reclamation approach includes the following procedures. First, usually after several years of substrate stabilisation, the surface is re-modelled erasing any terrain unevenness and het-

Fig. 4. Grayling (*Hipparchia semele*) females lay their eggs on almost bare spots, especially on slopes, where larvae feed on grasses. Males observe their territories from solitary trees, shrubs and concrete structures. Both sexes feed on spots with ruderal vegetation and seek shelter in solitary trees and shrubs during bad weather. (M. Hrouzek)

Fig. 5. The natural mosaic of early successional habitats on the Tušimice ash deposit is the main reason for the occurrence of one of the largest Grayling (*Hipparchia semele*) populations (about 2000 specimens) of the Czech Republic. (Archive Hutur)

erogeneity. Then the surface is covered with fertile topsoil, usually removed before mining and then stored. If a productive dense forest is to be created, trees are planted in regular rows. Saplings usually come from different regions, often non-indigenous species are planted, and even invasive ones are still commonly used.

Unfortunately, strict application of these reclamation methods generally leads to the destruction of valuable habitats and/or the local extinction of rare and endangered species, which is often in conflict with nature conservation laws. Moreover, the economic importance of such newly created meadows, arable fields, and forests is in most cases low.

Reclamation is also a very expensive method. For instance, the reclamation costs of lignite spoil dumps is 2 million CZK (ca. €80,000) per 1 ha in the Most region, and 0.5 million CZK (ca. €20,000) per 1 ha in the Sokolov region. In the Sokolov region, an area of about 2000 ha is currently under reclamation and another 3000 ha are planned to be reclaimed. This adds up to 1.5 billion CZK (€60 million), which could be spent in more useful ways by reinstating the natural values of the mining district landscape.

Spontaneous succession

As a consequence of historical environmental policy, many of both post-mining and post-industrial sites in the Czech Republic have not been actively reclaimed, giving us the unique chance to study natural processes and spontaneous succession there. During mining, spoil depositing and other industrial activities, the surface is often highly reshaped and diversified. This abiotic diversity is the best premise for creating a heterogeneous mosaic of diverse habitats. In terrain depressions, water accumulates creating oligotrophic wetlands and small pools. Conversely, elevations are excessively free-draining, often sustaining sparse dry grassland for a long time. Various microhabitats in between these relative extremes occur in a relatively small area and provide an environment for a range of species and their communities.

From hundreds of studied plots at spontaneously developed sites (Prach et al. 2011) it has been sufficiently documented that these natural processes have a great potential to restore almost all human-made habitats (Řehounek et al. 2010). Depending on site conditions, near-natural habitats develop within several years to a few decades. In most areas, spontaneous succession leads to near-natural sparse forests with a diverse structure. In a part of the post-industrial sites, early successional habitats, such as non-productive wetlands, sparse steppe-like grassland and open sandy habitats, may persist for a long time. These open habitats host a large number of endangered species and are crucial for biodiversity conservation.

Reclamation vs. spontaneous succession

Since reclamation and spontaneous succession are by far the most common restoration methods in the Czech Republic, their plant and animal communities have been compared at various post-mining sites. The most studied sites were reclaimed and spontaneously developed lignite spoil dumps, namely plants in the Most region (Hodačová & Prach 2003), and ants (Holec & Frouz 2005) and plants (Mudrák et al. 2010) in the Sokolov region. In limestone quarries of the Bohemian Karst (Tropek et al. 2010) and in the black coal spoil dumps of the highly anthropically impoverished Kladno region (Tropek et al. 2012), the influence of restoration methods on vascular plant communities and several arthropod groups has been studied. In all mentioned studies, the spontaneously developed habitats were consistently found to host highly valuable communities with a number of nationally endangered species. Reclamation, however, damages this conservation potential and the reclaimed plots are colonised almost exclusively by common generalists. In addition, plots covered with fertile topsoil support the spreading of some invasive and expansive species (e.g. Hodačová & Prach 2003). These results are also supported by several not yet published studies of various groups of organisms at different post-industrial sites, such as dragonflies on lignite spoil dumps (Tichánek & Harabiš), wild bees on ash-slag deposits (Tropek et al.), and higher plants in sandpits (Schmidtmayerová).

Despite the strong arguments above and the effort of scientists, non-governmental organisations and some mining companies, reclamation of post-industrial sites still strongly prevails (not only) in the Czech Republic (Prach et al. 2011). We offer three interconnected explanations (cf. Tropek et al. 2010, Tropek & Konvička 2011) for this. The first one is based on the long persisting but obsolete idea of stable natural communities ("equilibrium paradigm" sensu Wallington et al. 2005), emphasising such restoration goals as soil formation, prevention of erosion, nutrient cycling, and water accumulation. Taken to extremes, this obsolete paradigm regards disturbances as largely undesirable and barren land as an unhealthy environment. The other reason for reclamation is the need to 'heal' human-damaged post-industrial sites, a view still persisting among technically oriented practitioners and the general public. To their reassurance, these sites are erased from the landscape, creating inconspicuous common habitats, such as dense forest, productive meadow, and arable land. Last, but not least, reclamation is sometimes preferred out of narrow economic interests, since some mining and/or industrial companies have reclamation subsidiary companies or business partners for whom the expensive reclamation is profitable.

Directed succession and post-mining management

As the best solution for almost all mining and post-industrial sites, we offer near-natural restoration, combining spontaneous succession at most of the site supplemented with reclamation in particular parts where other public concerns (e.g. erosion risks, acid rock drainage, stream sedimentation, toxin leaks, public safety issues) prevail (Prach & Hobbs 2008, Tropek & Konvička 2011). In certain cases, directing the succession, as described above, towards valuable target habitats is desirable. To maintain or support the biodiversity potential of these sites, it is necessary to arrest or reverse succession by disturbance management, since the initial sparsely vegetated habitats are valuable for biodiversity, especially animals (insects and other arthropods, amphibians and birds). The restoration scheme should ideally consider the restoration of valuable habitats during the mining process or spoil dumping, e.g. formation of a heterogeneous surface with both wet depressions and dry elevations. It is also necessary to leave untouched (semi-)natural communities, which can later serve as sources of desirable species, in the close surrounding of the mining sites. However, a careful biological assessment has to precede any seriously intended restoration project.

Conclusions

If by mining or similar activities a naturally, historically or aesthetically valuable site is not destroyed or damaged, it can often be considered a contribution to biodiversity conservation. However, high biodiversity can only be achieved under certain conditions: surface heterogeneity should be created and then preserved; the low nutrient content must be preserved; a mosaic of differently aged successional stages should be maintained. Traditional reclamation must be avoided. Following these simple principles, we should grasp the unique opportunity to increase the natural value of these landscapes.

Acknowledgements

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Fig. 6. Houbův lom quarry, Bohemian Karst hosts many endangered species. (J. Řehounek)

Fig. 7. Spontaneously restored stone quarry in the Šumava Mts. approx. 50 years after mining was stopped. *Dactylorhiza majalis* and other rare plants grow here now. (K. Prach)

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Restoration and conservation of sand and gravel-sand pits

Klára Řehounková & Jiří Řehounek

Location 	Czech Republic (51 sites throughout the country)
Protection status	NR (9), SCI (10), temporarily protected area (4)
Ecosystem types	Various successional stages of 1 to 75 years old, established on dry, wet and slightly flooded sites (aquatic habitats not included); endangered habitats such as open sands, dry grasslands, oligotrophic marshes; reclaimed areas (forest, agricultural and hydrological reclamation)
Restored area	18 sand and gravel-sand pits of 0.05 to 6 ha
Financial support	Reclamation mostly funded by mining companies, subsequent management by the state (e.g. landscape management programmes), foundations, and from the "Adopt a Sand Martin!" project (www.calla.cz/brehule)
Costs	Ecological restoration of mining sites: €400–2,000/ha, agricultural and forest reclamation €20,000–40,000/ha, restoration of vertical faces for Sand Martin nesting €400–600/face

Initial conditions

Sand and gravel-sand pits are important features affecting the landscape in several regions of the Czech Republic. Mining of sand and gravel-sand in many cases results in a new landscape type, often with large water bodies or conspicuously high vertical faces. Mining sites often have great nature conservation potential, because such sites may become secondary habitats for many endangered plant and animal species (mostly of early successional stages, e.g. open sands, dry grasslands and oligotrophic marshes). A typical example is the Sand Martin (*Riparia riparia*), whose population in the SW part of the country decreased from nearly 5,000 to approx. 2,000 pairs between 1999 and 2009 (Heneberg 2009).

Abiotic conditions

Sand and gravel-sand originate mainly from river, lake and sea sedimentation or aeolian processes (shifting sands). Most of the deposits are of Quaternary origin, but a few originate also from Tertiary and Mesozoic periods. Mining may reveal important geomorphological processes (e.g. water erosion and landslides) and phenomena (e.g. stratigraphic profiles) which deserve protection.

Soil creation processes on bare substrate start from the very beginning and are slow. Provided that an abandoned pit is not overlaid with organic material, oligotrophic conditions in the substrate and the water can sustain for a long time.

Fig. 1. Area left to spontaneous succession in the Cep I mining area, Třeboňsko PLA. (J. Řehounek)

Restoration measures

2002–2004	Study of spontaneous succession in 36 sand and gravel-sand pits across the Czech Republic (Řehounková & Prach 2006, 2008).
2005	Survey of approx. 110 sites in the SW part of the country, selection of sites with prevailing spontaneous succession, and determining their nature conservation potential.
2005–2011	Introduction of management to support *Riparia riparia* and hymenopterous insects, mainly creation and restoration of vertical faces (repeated annually or every other year), restoration of bare sand areas in a mosaic pattern by mechanical removing the topsoil layer, and removal of pioneer shrubs and trees from open sand habitats (11 localities). Monitoring of *Riparia riparia* at the 11 sites (Heneberg 2009).
2009	Management to support amphibians including creation and restoration of oligotrophic pools and small marshes (8 localities).
2010–2011	Monitoring of realised management and its impact on amphibians and invertebrates, mostly aculeate Hymenoptera, spiders and water beetles at most sites (Heneberg 2010, 2011, Boukal 2010), protection of the most valuable localities.

Objectives

Maintenance or increase of biodiversity in sand and gravel-sand pits after exploitation; restoration and conservation of habitats important for endangered species, and stabilisation of their populations; protection of the most valuable localities (e.g. as protected or temporarily protected areas).

Fig. 2. Sands in Pískovna u Dračice NR, Třeboňsko PLA. (J. Řehounek)

Results

In total, 452 vascular plants (ca. 16% of the Czech flora) were recorded in 224 phytosociological relevés in 36 selected sand and gravel-sand pits situated across the Czech Republic. Nearly 10% of the species are included in the Czech Red List (Holub & Procházka 2000), two of them as critically endangered – Variegated Horsetail (*Equisetum variegatum*) and Field Needleleaf (*Polycnemum arvense*).

Ordination analyses showed that the water table was the most important site factor influencing the course of spontaneous vegetation succession. Succession was further significantly influenced by soil texture, pH, macroclimate, the presence of nearby (semi-)natural vegetation and land cover types in the surrounding landscape.

Spontaneous vegetation succession usually leads (at various rates) to the formation of woodland (Fig. 3). Wet sites are dominated by willow and alder carr after about 25 years, dry sites typically show broad-leaved woodland with Silver Birch (*Betula pendula*), Scots Pine (*Pinus sylvestris*), Pedunculate Oak (*Quercus robur*) and Rowan (*Sorbus aucuparia*). Valuable successional stages of forest-steppe vegetation persist only at dry sites in the warmest regions of the Czech Republic. Shallowly flooded sites are dominated by stands of tall sedges (*Carex* spp.), Common Reed (*Phragmites australis*) and bulrushes (*Typha* spp.).

Restoration of vertical faces for the nesting of *Riparia riparia* appeared to be very effective. In 2009, nearly 57% of Sand Martins in South Bohemia nested in managed pits and the introduced management halted its rapid decline and led to stabilisation of population

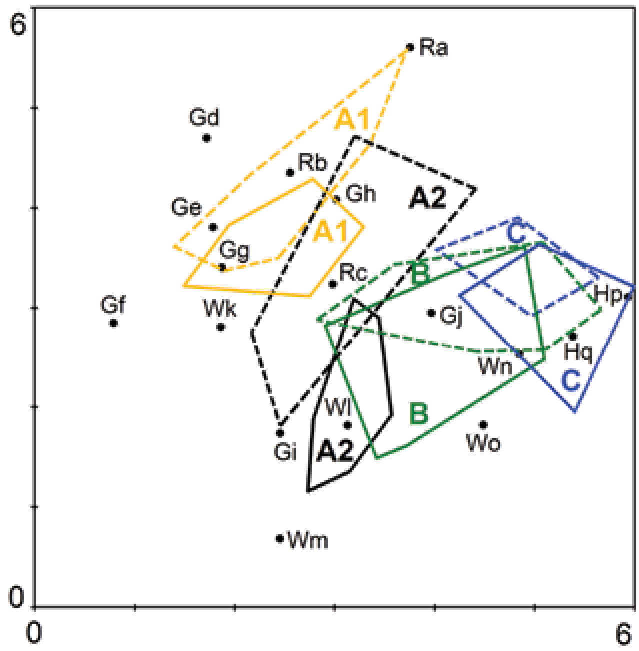

Fig. 3. Spontaneous vegetation succession expressed by DCA ordination of species groups and samples. Polygons enclose the vegetation records of initial (1–3 yrs, dashed line) and old (> 41 yrs, solid line) stages of each series. **Series:** A1 – dry, lowlands; A2 – dry, uplands; B – wet; C – shallowly flooded. **Grassland:** Gd – open herbaceous grassland on unstabilised soils; Ge – dry grassland with continuous vegetation; Gf – dry shrubby grassland; Gg – open-sand grassland with *Corynephorus canescens*; Gh – mesic grassland; Gi – Nardus grassland & heathland; Gj – wet grassland. **Woodland:** Wk – Robinia grove; Wl – coniferous forest; Wm – broad-leaved forest; Wn –willow scrub and willow-poplar forest; Wo – alder and willow carrs. **Marshes:** Hp – annual vegetation of wet eutrophic soils; Hq – reed and tall-sedge stand. **Ruderal vegetation:** Ra – with prevailing annuals; Rb – with prevailing perennials on dry sites; Rc – with prevailing perennials on mesic and wet sites.

numbers (Heneberg 2009). Moreover, it was found that the management of pit walls also improved habitat conditions for other endangered species, mainly hymenopterous insects (Heneberg 2010).

Generally it is important for invertebrates to maintain a heterogeneous mosaic of habitats, where patches of bare sand, vertical sand faces and other early successional stages are present (Heneberg 2010, 2011, Tropek & Řehounek 2012).

Other lessons learned and future prospects

Spontaneous succession and other ways of ecological restoration are utilised only seldom, although they represent a cheap and nature-friendly alternative to classical reclamation still prevailing in the Czech Republic. Moreover, reclamation usually leads to a decrease in landscape heterogeneity and biodiversity and often destroys habitats of protected and endangered species (Řehounek et al. 2010).

Management measures usually arrests or reverses the vegetation succession. Species typical of open sands or oligotrophic marshes respond fast to management measures. Newly created pools must fulfil conditions not only appropriate for amphibians but also for other endangered species. Therefore, shallowly flooded sites, diverse littoral areas and gentle water–land transitions should be a part of each restoration plan (Boukal 2010).

In abandoned sand and sand-gravel pits, ecological restoration and nature conservation are often in harmony with recreational activities. Holidaymakers and tourist activity maintains the mosaic of sparse vegetation, which is an important biotope of many endangered species. A combination of nature conservation and sand/gravel-sand exploitation might even improve the conditions for endangered species, if appropriately directed.

Fig. 4. Wall with nests of the Sand Martin (*Riparia riparia*) at Lžín sandpit, a temporarily protected area in the Soběslav region. (T. Doanová)

Fig. 5. *Riparia riparia* at a nest burrow. (J. Ševčík)

Recently, the area of ecologically restored sites in sand and sand-gravel pits has gradually increased in spite of the unfavourable legislation. Popularisation of scientific results and presentation of examples of good practice in the field to the public have helped to make ecological restoration more visible.

Public support

Scientists, enlightened officials, NGOs and even some mining and reclamation companies participate in the promotion of ecological restoration as an alternative to reclamation in sandpits after their exploitation has stopped. Public support for ecological restoration at the expense of traditional reclamation is still low but gradually increasing due to the popularisation mentioned above.

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Coal mining spoil heaps in the Most region: restoration potential of spontaneous succession

Karel Prach

Location	Most Basin, northwest Czech Republic 50°29'–50°34' N, 13°30'–13°51' E; altitude 260–300 m
Ecosystem types	Various successional stages 1–55 years old, from aquatic to dry habitats; uniform technically reclaimed sites, mostly afforested
Restored area	Approximately 150 km^2
Costs	Reclamation approximately €80,000 per ha, spontaneous succession without any cost

Initial conditions

Spoil heaps in the Most region are mainly formed by grey Tertiary clay sporadically mixed with sand and volcanic debris. Some spoil heaps or parts of them are left unreclaimed, not because they were scheduled for spontaneous development, but for other reasons, such as the presence of coal reserves underneath the heaps. As far as we know, only 60 ha of the heaps have been recently left to spontaneous succession, while in the rest of the area reclamation was or is in progress or planned.

Heaping machines make a system of parallel elevations and depressions of various depth and size, thus an undulating surface usually develops. Water often accumulates in the deeper depressions. In this way, heaping creates a variety of microhabitats and promotes biodiversity.

Reclamation predominantly consists of the following procedures. After stabilisation of the spoil substrate, usually after about eight years, the surface is levelled with heavy machinery and depressions with accumulated water are drained. On such a surface, organic material like milled timber or bark, or a humus layer stripped from mining sites is usually spread. When a heap is prepared in this way, trees are planted, usually one tree per m^2. Tree species are sometimes indigenous, but not always. The second most common method of reclamation is directed at agricultural use. The heap surface is prepared similarly as in the previous case (a humus layer is deposited on the levelled spoil), but then it is sown with various commercial grass mixtures, usually with a large proportion of nitrogen-fixing legumes. A third common way of reclamation is creating water bodies, in which the excavations of abandoned mines are purposely flooded.

Fig. 1. Spontaneously developed part of a spoil heap in the Most region, approx. 15 years old, with a mosaic of wetlands, grasslands and scattered shrubs. (K. Prach)

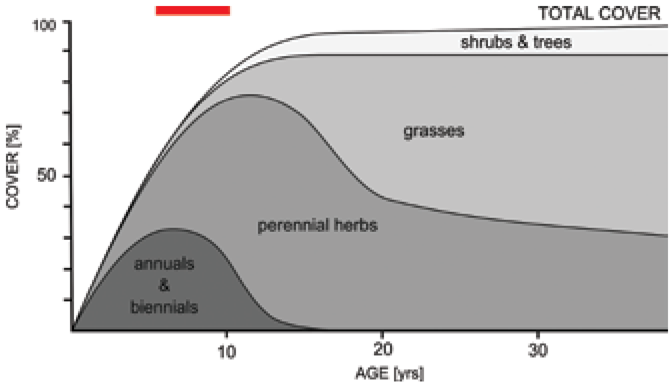

Fig. 2. Process of spontaneous succession in the spoil heaps expressed as percentage of the main life-forms. The red bar indicates the period when reclamation is usually conducted.

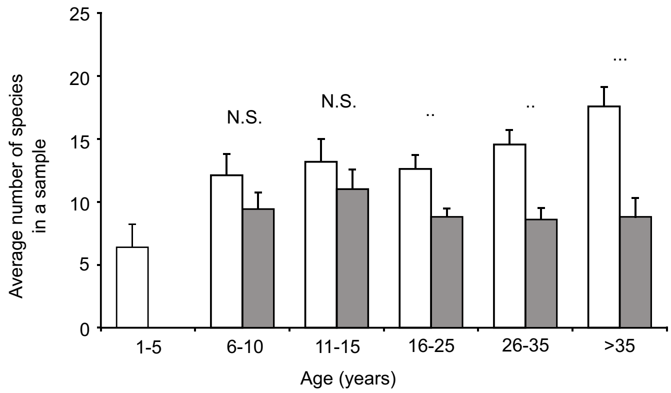

Fig. 3. Average number of vascular plant species in vegetation samples 5 × 5 m, recorded in spontaneously re-vegetated (open bars) and reclaimed (hatched bars) plots. Statistical differences using the two-sample t-test are indicated. Source: Hodačová & Prach (2003).

Objectives

The following main questions were addressed: (a) how fast is restoration of vegetation if we rely on spontaneous succession in comparison with reclamation, and (b) how do spontaneous succession and reclamation differ in terms of species diversity?

Spontaneous succession and its comparison with reclamation

The main methodological approach to describe vegetation succession consisted of vegetation records (phytosociological relevés) made in representative stages of different age on various spoil heaps in the region. Species cover was visually estimated (in %) in sampling plots of a regular size (5 × 5 m).

Spontaneous succession usually proceeds in the following ways (Prach 1987, Hodačová & Prach 2003). Seeds of plants reach the heaps by wind, animals and sometimes also by man during heaping. Annual species (*Atriplex sagittata*, *A. prostrata*, *Chenopodium* spp. (mainly *Chenopodium strictum*), *Persicaria lapathifolia*, *Polygonum arenastrum*, and *Senecio viscosus*) and biennials (e.g. *Carduus acanthoides*) dominate in the first few years. Between the 5th and 15th years of succession, broad-leaved herbs (e.g. *Tanacetum vulgare* and *Artemisia vulgaris*) prevail. *Cirsium arvense*, followed by grasses, mainly *Elytrigia repens*, *Calamagrostis epigejos* and *Arrhenatherum elatius*, form the next successional stage, in which the cover of ruderal species decreases and that of meadow species increases. A more or less continuous vegetation cover is formed between the 10th and 15th year of spontaneous succession (Fig. 2). Sites without vegetation are quite rare; these are mostly found on acid sands (with pH < 3.5). However, even such habitats have their value, being important for some retreating groups of invertebrates, mainly terrestrial bees and wasps, butterflies and neuropteran insects. Because the Most region has a relatively warm and dry climate, woody species have a rather low cover (up to 30%), even in late successional stages. After about 20 years of succession, anthropogenic (or semi-natural) forest steppe is formed, which obviously persists for a relatively long period. In that time, the vegetation is relatively well stabilised and includes *Sambucus nigra*, *Salix caprea*, *Populus* spp., and especially *Betula pendula*, occasionally *Acer pseudoplatanus*, *Fraxinus excelsior*, *Rosa canina*, *Crataegus* spp. and other shrubs and trees.

Wetlands develop quickly in depressions inside or along the edges of the heaps. Usually a large number of small pools are found here, which are crucial for amphibians, for which spoil heaps are highly important even at the national level (Vojar 2006).

Reclaimed heaps host a much lower number of species than those spontaneously re-vegetated (Fig. 3), as shown for higher plants by Hodačová & Prach (2003) and by Hendrychová et al. (2011) for some invertebrates. In total, about 400 vascular plant species were found on spoil heaps of the Most district, which is approximately 15% of the Czech flora.

Conclusions

Most of the spoil heaps can potentially be restored by spontaneous succession, which is sufficiently fast and provides ecologically much more valuable habitats than reclamation (Prach et al. 2011). In terms of landscape restoration, reclamation is a negative and expensive activity except at sites which are endangered by erosion, close to the vicinity of settlements, and in case recreation and sport activities are planned. In many cases, reclamation destroys valuable habitats and negatively impacts populations of endangered and rare species. Moreover, spontaneous succession runs without any cost.

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Restoration of spoil heaps by spontaneous succession in the Sokolov coal mining area

Ondřej Mudrák & Jan Frouz

Location	Surrounding of the town of Sokolov, west Czech Republic 50°09'–50°16' N, 12°30'–12°46' E; altitude 500–650 m
Protection status	Regional biocentre (part)
Ecosystem types	Various successional stages from initial ones up to secondary forests
Restored area	300 ha
Financial support	Sokolovská uhelná coal mining company, ENKI o.p.s.
Costs	Reclaimed sites €20,000–60,000/ha, sites overgrown by succession €1,000–3,000/ha (despite the fact that the overall cost of spontaneous succession is an order of magnitude lower than that of classical reclamation, it should be admitted that project preparation, preceding research and monitoring of spontaneous succession may be more expensive than the preparation of reclamation)

Initial conditions

Surface mining of brown coal has been carried out in the Sokolov district since the 1950s (Frouz et al. 2007). In this process a large amount of substrate above the coal (layers more than 100 m thick) has to be removed and deposited aside. The original ecosystems are either excavated or overlain by material from coal overburden. Restoration of natural values thus starts here on bare spoil substrate, which has continuously been deposited on the heaps since the mining began.

The spoil heaps in the Sokolov district can potentially well be re-vegetated by means of spontaneous succession, as is apparent from several unreclaimed sites, but most of the heap area is reclaimed by means of traditional afforestation, whereby various tree species (both exotic and native) are planted directly into a spoil substrate which is not improved.

Abiotic conditions

The substrate forming the heaps is Miocene alkaline clay of the so-called *Cypris* formation (Rojík 2004). The pH (H_2O) of the freshly deposited material is between 8 and 9, but decreases during the succession to 5 to 6 (Frouz et al. 2008). The total amount of phosphorus in the substrate is relatively high (around 1200 $mg.kg^{-1}$), but due to the high pH it is hardly available to plants. The availability of phosphorus increases with site age. The amount of nitrogen is rather low after substrate heaping, but later increases to 1000–2500 $mg.kg^{-1}$ depending on site conditions (Frouz et al. 2008, Šourková et al. 2005). The substrate is dumped as solid mudstones, which disintegrate during weathering into smaller lamelloid fragments and finally (20–30 years after heaping) become amorphous clay (Frouz et al. 2001). This process strongly affects the water regime of the substrate, because water is adhesively

Fig. 1. Unreclaimed site of 18 years old with a mosaic of bare substrate and dense vegetation (mostly dominated by *Calamagrostis epigejos*). The first established trees increase the heterogeneity of the site and are an important source of seeds for further succession towards woodland. (O. Mudrák).

bound to amorphous clay and is thus less accessible to plants. Earlier in the succession, when lamelloid fragments are abundant in the substrate, and later, when soil structures are formed in the pedogenic process, the water regime becomes more favourable for plants (Cejpek & Frouz, unpubl.).

Objectives

The objective of this project is to protect rare and endangered species of plants, animals and fungi occurring on spoil heaps, but also to preserve the successional processes capable of reinstating many non-productive functions of reclaimed sites. These include resoiling, erosion control, and water regime improvement. Protection of unreclaimed sites also has high educative and scientific values, since they enable studying succession on the landscape scale.

Soil development

Several studies have demonstrated that restoration success is clearly linked with the process of soil formation, which occurs spontaneously at unreclaimed re-vegetated sites as well as in tree plantations (Frouz et al. 2008, 2009). Many processes take place in soil formation, but on the spoil heaps the activity of soil macrofauna, namely earthworms, was found to be particularly important. Earthworms (*Aporrectodea caliginosa*, *A. rosea*, *Dendrobaena octaedra*, *Dendrodrilus rubidus*, *Lumbricus rubellus*, and *Octolasion lacteum*; Pižl 2001) colonise the heaps mostly without deliberate human intervention. They are probably most often introduced on the heaps with the soil on the roots of planted tree saplings. Earthworms mix plant litter with the spoil, form stable soil aggregates and stabilise the organic matter in the soil by consumption of a large amount of substrate, which improves water regime and plant nutrition (Frouz et al. 2008). The composition of earthworm communities substantially differs between sites dominated by different tree species (Frouz et al. 2009). Especially the quality of litter produced by trees seems to be important here, as litter is a significant source of nutrition for earthworms, and structure, chemical composition and also palatability of the litter are species-specific (Frouz 2008, Lavelle et al. 1997). Soil formation is relatively fast under particular tree species. In the soil profile on sites with *Alnus* plantations (*A. glutinosa* and *A. incana*) a layer of mull humus (A horizon) of 93 mm thick on average is formed within 28 years. At unreclaimed sites the process of soil formation is slower. Within 28 years only a 27 mm thick layer of A horizon is formed here (Frouz et al. 2009, Mudrák et al. 2010), but the difference disappears with time and sites of 40 years old have a similar A horizon thickness.

Results

Both in the forest plantations and at the unreclaimed sites, soil conditions were found to be important for plant communities. Shortly after the heaping, unreclaimed sites are colonised by mainly ruderal species such as *Poa compressa*, *Tanacetum vulgare* and *Tussilago farfara*, but also tree seedlings of Goat Willow (*Salix caprea*), Birch (*Betula pendula*) and Aspen (*Populus tremula*) establish and later dominate the plant community. Around the 20th year of succession, *Salix caprea* prevails in the vegetation, which is later outcompeted by *Betula pendula* and *Populus tremula*. Between the 20th and 30th year of succession the unreclaimed sites are colonised by earthworms. The subsequent changes in the soil profile support establishment of species native to meadow and forest communities. After more than 40 years the succession leads to a development of sparse birch and aspen woodland with a species-rich understorey (up to 49 species per 25 m^2) mainly dominated by meadow species such as *Arrhenatherum elatius*, *Festuca rubra*, *Plantago lanceolata*, and *Lotus corniculatus*. In these stages, however, also the competitively strong grass *Calamagrostis epigejos* increases in dominance and often suppresses other species (Frouz et al. 2008).

Fig. 2. Unreclaimed spoil heap seven years after heaping. (O. Mudrák)

Fig. 3. Unreclaimed spoil heap 21 years after heaping. (O. Mudrák)

Fig. 4. Unreclaimed spoil heap 45 years after heaping. (O. Mudrák)

At the reclaimed afforested sites the effect of soil conditions coincides rather with the productivity of understorey species than with their diversity. Sites with the best developed soil profile have the highest total cover and highest total understorey biomass. However, this

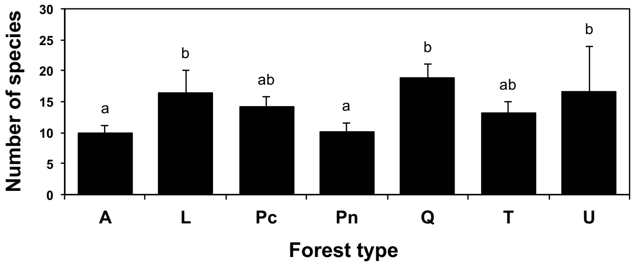

Fig. 5. Mean number of vascular plant species per 25 m² in the understorey of 7 forest types. Six were plantations dominated by *Alnus* (A), *Larix* (L), *Picea* (Pc), *Pinus* (Pn), *Quercus* (Q), and *Tilia* (T) planted as a reclamation measure and one grew spontaneously on unreclaimed sites (U) dominated by *Salix caprea*, *Betula pendula* and *Populus tremula*. All forest types were observed in 4 replicates and had a similar age (20–33 years). The error bar indicates the standard error of the mean. The statistically significant difference (one-way ANOVA with Fisher LSD test in post hoc comparison) is marked by different letters above the column (Mudrák et al. 2010).

Fig. 6. Forest reclamation in the Sokolov district – in the foreground a one-year old tree plantation of *Larix decidua*, in the background a 35-year old stand of the same species (O. Mudrák).

is mainly due to one species – *Calamagrostis epigejos*, whose cover negatively correlates with the number of other plant species. In a comparison of six forest types (planted in reclamation measures and aged 20–33 years) each dominated by a different tree genus (*Alnus*, *Larix*, *Picea*, *Pinus*, *Quercus*, *Tilia*) with unreclaimed sites spontaneously colonised by *Salix caprea*, *Betula pendula* and *Populus tremula*, the highest number of species was found in the stands dominated by *Quercus* (19 per 25 m²), which was comparable with the number observed in spontaneous succession plots (17 per 25 m²). The lowest number of species was observed in the *Alnus* plots (10 per 25 m²) (Fig. 5).

Spoil heaps and mainly unreclaimed sites host large numbers of rare and endangered species. They are for example inhabited by the largest stable population of the toad *Bufo calamita* in the Czech Republic. Other amphibians living here include *Bufo viridis*, *Pelobates fuscus*, *Triturus cristatus*, *T. vulgaris*, *T. alpestris*, *Rana lessonae*, *R. ridibunda*, and *Hyla arborea*. Rare birds to be mentioned are *Rallus aquaticus*, *Luscinia svecica*, *Oenanthe oenanthe*, and *Remiz pendulinus* (Frouz et al. 2007).

Other lessons learned and future prospects

Including spontaneously developing sites into the new post-mining landscape substantially increases diversity (on the level of both species and communities), improves the scenery and last but not least has a high educational value. Moreover, spontaneous processes can relatively quickly restore soil conditions in the spoil substrate. Expensive overlaying of the spoil by an organic horizon (as is often done in other coal mining districts) is therefore unnecessary.

An important threat to the ecological restoration of spoil heaps is the spread of the competitive grass *Calamagrostis epigejos*.

Public support

The local public as well as the coal mining company are interested in improving the scenery and ecosystem functions and services.

Acknowledgements

The study was supported by the Ministry of Education, Youth and Sports of the Czech Republic (LC06066, 2B80023), the Agency of the Academy of Sciences of the Czech Republic (grants nos. S600660505 and P505/11/0256), the Research Plan of the Institute of Soil Biology (AV0Z60660521), the Research Plan of the Institute of Botany (AV0Z60050516), and Sokolovská uhelná a.s. Coal Mining Company.

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Restoration of dry grassland vegetation in the abandoned Hády limestone quarry near Brno

Lubomír Tichý

Location	NE of the city of Brno, southeast Czech Republic 49°12'58"–49°13'18" N, 16°40'03"–16°40'35" E; altitude 310–410 m
Protection status	SCI
Ecosystem types	The main habitat types in the surroundings of the restored area are semi-natural semi-dry grasslands (*Cirsio-Brachypodion pinnati*) and open thermophilous oak forests (*Quercion pubescenti-petraeae*)
Restored area	6 ha mosaic in an area of 20 ha
Financial support	Českomoravský cement, a.s., nástupnická společnost (1998–2003), European Commission (LIFE Nature, 2004–2007), Czech Ministry of the Environment (grants for NGOs, 2000–2009)
Costs	Approximately €80,000

Initial conditions

The Hády quarry borders the Moravian Karst (Moravský kras) PLA. The close surroundings of the quarry are home to many rare thermophilous insects and 79 red-listed plant species (Holub & Procházka 2000, Tichý 2000; categories C1–C3). Archaeological evidence of limestone burning in the quarry goes back to the Middle Ages, but the recent history of the quarry started in 1907. Between 1965 and 1997, up to 300,000 tonnes of limestone were mined annually. Excavation stopped 90 years after it started, in 1997. The quarry location and surviving remnants of species-rich forest-steppe vegetation in the close vicinity were ideal to start a unique restoration project aimed at creating a mosaic of species-rich habitats.

Fig. 1. Combination of thin topsoil layer and bedrock gravel, sown with collected seeds and covered with hay. (L. Tichý)

Abiotic conditions

The entire locality has basic and nutrient-poor soils based on limestone. The dry conditions of the south-facing rocky slopes and terraces contrast with the large scree areas and the quarry bottom with artificial lakes surrounded by a small marsh spontaneously developed on mining deposits.

Restoration measures

1998–2009	Seeds of about 70 thermophilous plant species of Pannonian grassland vegetation were manually collected from natural vegetation in the close surroundings of the quarry.
1998, 2001, 2005–2006	A thin topsoil layer was artificially created in selected places of limestone terraces as a basis for the following restoration.
1998–2010	Hay was taken from steppe grasslands and distributed over recently sown localities to support seed germination.
2005–2008	Alien species (*Robinia pseudacacia*, *Amorpha fruticosa*, genetically introgressed populations of *Populus nigra*, *Solidago canadensis*, etc.) from newly established communities were widely removed (mowing, manual eradication, cutting incl. herbicide application) from the entire area of the former quarry.
1999–2006	Scattered planting of native shrubs (*Quercus pubescens*, *Q. petraea*, *Cornus mas*, *C. sanguinea*, *Crataegus monogyna*, *Ligustrum vulgare*).

Objectives

Restoration of dry grassland vegetation in a previously mined area with a minimum of technical restoration; increasing biodiversity; improving scenery.

Results

During 12 years, a total area of about 6 hectares was reclaimed in a mosaic of separate areas (0.1–0.5 ha) step-by-step. This strategy appeared to be speeded up by additional introduction of some species to the quarry area (Fig. 2). Various restoration techniques were used: (A) addition of thin topsoil layer, (B) sowing seeds of thermophilous species, (C) addition of a thin hay layer with maturing grass seeds, and locally also (D) planting of thermophilous trees and shrubs. Altogether, 17 endangered species of vascular plants were successfully sown and planted in the area of the quarry, after which some of them formed large populations of hundreds and thousands of individuals:

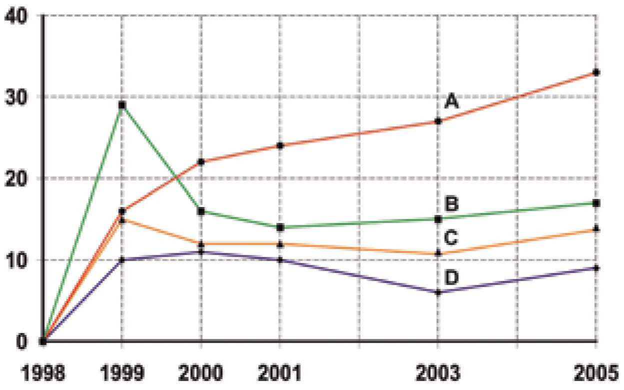

Fig. 2. Number of (A) thermophilous species, (B) archaeophytes, (C) nitrophytes, and (D) neophytes in a dry part of the bottom of Hády quarry (area of about 3 ha) during the years 1998–2005 (Tichý 2006).

e.g. *Arabis auriculata*, *Aster amellus*, *A. linosyris*, *Centaurium pulchellum*, *Crepis foetida* subsp. *rhoeadifolia*, *Epipactis palustris*, *Inula ensifolia*, *Linum tenuifolium*, *Melica ciliata*, *Onobrychis arenaria*, *Polygala major*, *Rosa spinosissima*, and *Thymus pannonicus*. The current environmental importance of the Hády quarry is fully comparable with other protected natural areas in the vicinity of Brno.

Other lessons learned and future prospects

Separate application of each of the above-mentioned restoration methods had limited success. However, their combination (thin topsoil layer addition, additional sowing of thermophilous species, covering with a thin layer of hay) resulted into sparse, but sufficiently species-rich grassland communities within 5–7 years. Such a new environment has several advantages for dry grassland species. It is relatively nutrient-poor, drier than natural habitats, the surface is usually flat, and the succession is blocked by the shallow soils. In such extreme conditions the newly established vegetation remains rather sparse and includes hardly any ruderal species. The new grasslands are relatively stable and need not be regularly grazed or mown.

Public support

The main part of the quarry is currently owned by a local environmental NGO. Even though the establishment of new communities needs a longer time with this type of restoration, the final vegetation cover is more stable, valuable for its biodiversity and not susceptible to ruderalisation. It should be supported by mining companies and local authorities as a relatively cheap and environmentally-friendly alternative of landscape restoration and environmental recovery.

Acknowledgements

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Fig. 3. Upper part of Hády quarry in 2001. (L. Tichý)

Fig. 4. The same part of the quarry as in Fig. 3, seen from the opposite side, in 2010. (L. Tichý)

Experimental restoration of species-rich deciduous forest on mining deposits in Mokrá limestone quarry

Lubomír Tichý & Roman Donocik

Location 	E of the city of Brno, east Czech Republic 49°13'36" N, 16°45'44" E; altitude 370–380 m
Ecosystem types	Oak-hornbeam forests (*Carpinion*) and open thermophilous oak forests (*Quercion pubescenti-petraeae*) as target communities
Restored area	0.06 ha
Financial support	Českomoravský cement, a.s., nástupnická společnost (2008–2011)
Costs	Approximately €8,000

Initial conditions

Mokrá quarry is one the largest limestone quarries in the Czech Republic. Mining started here in 1968 and the current quarry area is more than 1.2 km^2 in size. The quarry borders the southern part of the Moravian Karst (Moravský kras) PLA. Most of the quarry is surrounded by relatively species-rich oak-hornbeam forests and some remnants of thermophilous oak woodland. Animal and plant diversity is supported by the limestone bedrock and includes many endangered species of forests and forest-steppes (Holub & Procházka 2000).

The destruction of valuable forest habitats was the reason to establish a small experimental area here to test methods which could enable forest restoration on mining deposits. The project was initiated and supported by the Českomoravský cement mining company in co-operation with local environmental NGOs.

Abiotic conditions

The two experimental areas are covered by basic soils with pH ranging from 7.7 to 8.0. Three plots (A) are situated on steep west-facing slopes, while the other three plots (B) occupy steep east-facing slopes. The mean annual temperature is approximately 8.4 °C and the annual rainfall 509 mm (Airport Brno-Tuřany; http://www.airport-brno.cz).

Objectives

Creation of species-rich deciduous forests with typical forest species, increasing biodiversity, acceleration of forest ecosystem restoration, diversification of forest vegetation structure, improving of scenery.

Fig. 1. Overall view of the mining deposits covered by tree plantations as seen from the southwest; October 2007. (L. Tichý)

Methods

A 14-year old tree plantation of *Acer pseudoplatanus*, *Tilia cordata* and *Pinus nigra* on a reclaimed area of mining deposits was selected for the experiment. Six 100 m^2 permanent plots were divided into two groups. In area A, the first three plots, each with a 5-metre broad buffer zone, were protected with a 1.5 m tall fence. The other three plots in area B remained unprotected. Only newly planted trees in that area were fenced individually. The vegetation structure of the permanent plots was first recorded in September 2008. Then one plot from the first and one plot from the other group were covered with a thin layer of soil removed from an old semi-natural oak-hornbeam forest (dispersed over the area), containing roots, stems and seeds of many forest species. The second pair of plots was covered with forest litter (mostly dead leaves) collected and transported manually in large bags. The third pair of plots remained unaffected as a control. The tree canopy of the first four plots was opened (for about 20–40%) and young individuals of *Cornus mas*, *Carpinus betulus* and *Crataegus monogyna* were additionally planted in the openings.

Restoration measures

2008	Soil and litter were removed from a semi-natural oak-hornbeam forest and transported to the experimental plots.
2008–2011	Former tree plantations were gradually opened by cutting about 20–40% of the trees. Bottom branches of other trees were trimmed.
2009	New shrubs and trees were planted to increase the diversity of the future forest. One part of experimental area A was fenced. Young trees in experimental area B were fenced individually.

Results

At the beginning of the experiment, the herb layer of all plots consisted of mostly ruderal and heliophilous species. Three years later, we observed a significant increase in species in both plots covered with new soil, while the diversity and species structure of the other ones remained rather similar (Fig. 2). Even though some ruderal species persisted, many new species of semi-natural deciduous forests appeared in these plots: *Campanula persicifolia*, *Carex digitata*, *Convallaria majalis*, *Fragaria vesca*, *Galium odoratum*, *G. sylvaticum*, *Hieracium maculatum*, *H. murorum*, *H. sabaudum*, *Lathyrus niger*, *L. vernus*, *Luzula luzuloides*, *Scrophularia nodosa*, *Viola reichenbachiana*, *V. riviniana*.

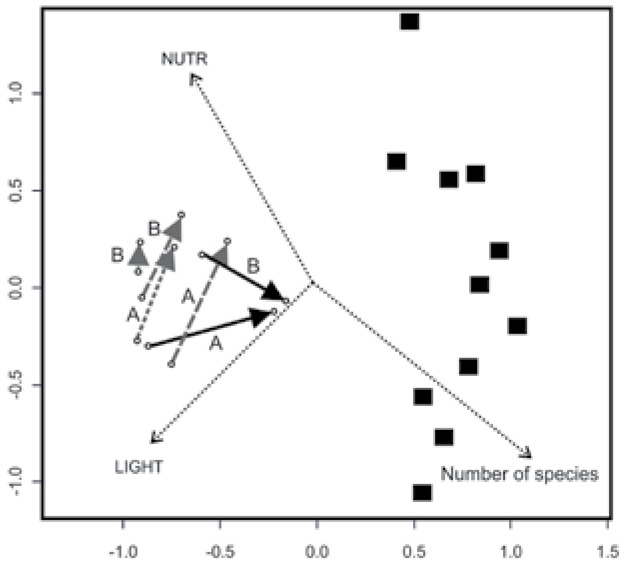

Fig. 2. Non-metric dimensional scaling (NMDS) ordination diagram with six permanent plots sampled in 2008 and 2011 (the same plots are connected by arrows) and with 11 plots of natural deciduous forests sampled in the close surrounding (black squares; source: Czech National Phytosociological Database – Chytrý & Rafajová 2003). Plots A were fenced while trees in plots B were protected individually. At the start of this experiment, two plots were covered with a thin soil layer (including litter) which had been removed from an old oak-hornbeam forest (black arrows). The surface of two plots was covered with litter from the same forest type (dashed grey arrows). Two plots were left as control (dotted grey arrows). Arrows NUTR and LIGHT represent Ellenberg indicator values for light and nutrients (Ellenberg et al. 1992).

Fig. 3. One of the permanent plots where trees of the plantation were partly cut and other trees and shrubs planted in the created openings; September 2011. (L. Tichý)

Other lessons learned and future prospects

Even if this small preliminary experiment was started just three years ago, the presented results clearly show that forest ecosystem restoration can be accelerated. The increasing mining area in large quarries sometimes repeatedly results in destruction of areas with semi-natural deciduous forest. The soil transferred from such forest vegetation before tree cutting and mining may be a good source of typical forest vascular plants and probably also of soil organisms, fungi and anthropods. The tree plantation intended for biodiversity increase must be at least 10 years old and its establishment should already count with an additional supplement of fresh soil from areas prepared for mining. The tree canopy must be well developed to protect the new soil against direct sunlight. For optimal restoration of this vegetation type, an appropriate and long-term vision of quarry exploitation and subsequent reclamation is necessary. This sort of reclamation is best applied in larger quarries owned by companies with a highly developed environmental liability.

Public support

The area is fully private, owned by the Českomoravský cement mining company, without free public access. The results of this experiment are available to serve forest restoration of other mining deposits.

Acknowledgements

The study was supported by the Ministry of Education of the Czech Republic (MSM 0021622416).

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Experimental acceleration of primary succession on abandoned tailings: role of surface biological crust

Pavel Kovář, Ota Rauch & Veronika Dlouhá

Location	Elbe river lowland near Chvaletice, East Bohemia, Czech Republic 50°02' N, 15°26' E; altitude 200 m
Ecosystem types	Initial successional stages
Restored area	40 ha

Initial conditions

The industrial deposit system at Chvaletice consists of three tailings (ore-washery basins) as a result of former pyrite ore mining.

In 1952 a surface mine was opened here. Sulphidic gneisses and carbonate Fe-Mn ore deposits were the main waste material originating as a by-product of sulphuric acid production. This material was transported as sludge (mixed with water) to sedimentation basins. After a basin had been filled up, dikes were built around it to fill the artificial basin with more sludge. This was repeated several times thus creating a final body of industrial deposits 18 m high (Kovář 2004).

The quarry at Chvaletice was finally closed in the mid-1970s, after which the two older tailings were reclaimed in a conventional way (partly agriculturally, partly by tree planting; Kovář 1979). The third, youngest basin has never been filled in completely and its surface has remained unreclaimed since the early 1980s and has become an important experimental site for the monitoring and testing of spontaneous colonisation of the substrate (Kovář et al. 2011).

The ecotoxicological character of the site plays an important role in its reclamation. The high heavy metal concentrations, extreme pH values, and high sulphur and phenol content of the substrate complicate spontaneous processes which would lead to natural recovery (Kovář 1990, Vos & Opdam 1993). The soil surface is moderately consolidated by salt efflorescences (from gypsum and jarosite). Soil development greatly varies over the basin, according to the microtopography determined by oxidation of sulphides and leaching of salts. Secondary salt accumulation is determined by the length of dry periods in the growing season. A strongly cemented horizon with red ferric oxides and gypsum has developed at lower depths of soil profiles (Rauch in Kovář 2004: 45–58).

The non-reclaimed basin has therefore remained largely treeless and non-vegetated, and no manipulations were carried out after abandonment. In the genesis of acid sulphate soils, chemical processes prevail over the role of vegetation, which is reflected in major adverse characteristics of the soil profiles. The vascular plant diversity

Fig. 1. In the abandoned sedimentation basin at Chvaletice, vascular plants (*Calamagrostis epigejos* and *Betula pendula*) establish using crevices in the deposit surface. (P. Kovář)

Fig. 2. The surface mosaic on ore-washery tailings, created by the moss *Ceratodon purpureus* and lichens of the genus *Cladonia*, are the result of alternating wet and dry microsites. (P. Kovář)

Fig. 3. View of one of the paired plots in a tailing with an experiment (left) and control (right) quadrat, two years after mulching the bare surface, which clearly supports a grass stand (left). (V. Dlouhá)

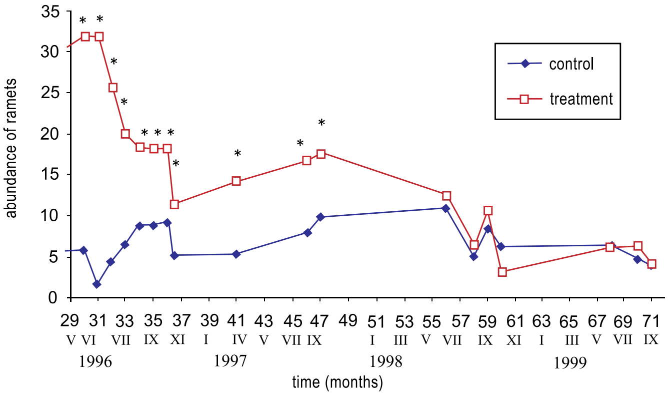

Fig. 4. Changes in abundance of *Calamagrostis epigejos* ramets after mulching the bare substrate surface. Asterisks indicate the pairs of samplings (experiment/control) with differences significant at level $P < 0.01$. (V. Dlouhá)

is usually low in this toxic environment. In such places, the surface is often covered with biological soil crusts, originating spontaneously and analogous to similar crusts frequent in semi-arid and desert environments (Evans & Johansen 1999, Hroudová & Zákravský in Kovář 2004: 235–247, Neustupa et al. 2009). Both types of crust are usually composed of fungal mycelia, cyanobacteria, algae, lichens, mosses and liverworts (Kovář 2004, Neustupa et al. 2009). The initial state of the substrate surface resists colonisation by vascular plants (Palice & Soldán in Kovář 2004: 200–221, Pohlová in Kovář 2004: 222–234) because its roughness is insufficient (extremely low interception and retention capacity for plant seeds transported by wind) and a humus soil layer is missing (absence of biotic nitrogen and carbon fixation).

Objectives

Investigating the effectiveness of introducing dead plant biomass added to the bare surface of a non-reclaimed tailing in terms of plant colonisation and speed of vegetation succession, species diversity and the facilitation of natural processes.

Methods

Experimental plots were designed (1993) as paired quadrats (one treatment, one control) with eight replicates (i.e. 16 squares of 1.5 × 1.5 m). The bare substrate surface was covered with a 10–15 cm thick layer of dry local plant biomass. All plots were divided into 15 × 15 cm squares for recording vegetation features (Dlouhá 2000). Abundance of the aboveground biomass was assessed (1995–1999) by means of using a nine-point scale (0–8).

Results

The addition of dry plant biomass resulted in a very rapid appearance of numerous seedlings, predominantly of *Calamagrostis epigejos*. This resistant pioneer grass species exhibits both anemochorous and zoochorous (myrmecochorous) dispersal strategies depending on the properties of the tailing substrate (Bryndová & Kovář in Kovář 2004: 267–276, Jiráčková & Dostál in Kovář 2004: 59–76). Establishment of the light seeds depends on surface roughness (retention and fixation) and microhabitat conditions. The introduced plant litter moderates extremes of salinity and microclimate (Fig. 4).

The initial stage is dominated by *Calamagrostis epigejos* due to its high abundance in the surroundings. After initial large differences between treatment and control plots, the abundance of this grass showed convergence, suggesting that the development does not necessarily indicate a negative trend towards a blocked successional stage with solely this clonal grass (e.g. Prach & Pyšek 1994). In these extreme ecological conditions, *Calamagrostis epigejos* plays a positive role, in contrast to its behaviour in other habitats such as spoil heaps after coal mining. In the second year of our experiment, seedlings of the following plant species were recorded: *Cerastium holosteoides*, *Conyza canadensis*, *Epilobium* sp., *Puccinellia distans*, *Sonchus oleraceus*, *Taraxacum* sect. *Ruderalia*, *Tanacetum vulgare*, *Betula pendula* and *Populus tremula* (Dlouhá 2000).

The increase in species number continued during the following years reaching a stage in which the local stand has become similar to that of the species pool in the surrounding. The tree layer has reached a height of ca. 5 m (for details, see Kovář et al. 2011).

The revegetation was significantly enhanced by the organic litter cover, which protected the rhizosphere against heat, drought and salt incrustation (Rauch in Kovář 2004: 45–58, Vaňková & Kovář in Kovář 2004: 30–45). This creation of a biological crust was based on a synergy of two effects of the added organic material: nutrient enrichment by decomposition of dead matter (Kovářová & Frantík in Kovář 2004: 153–175) and creating a vital environment for ants as distributors of zoochoric plants (Jarešová & Kovář in Kovář 2004: 300–310).

Conclusions

Addition of dry local aboveground plant biomass to the surface of an abandoned tailing suggests the following functions in assisted restoration of ecologically extreme sites:

— it provides substrate roughness and retention of seeds transported by wind,

— it protects the rhizosphere against extreme heat, drought and salt incrustation,

Fig. 5. Local salt incrustations on the substrate surface are an environmental limitation to plant growth. (P. Kovář)

Fig. 6. Present state of tree stands and open areas in the abandoned ore-washery tailing at Chvaletice, 17 years after the described restoration measures. (P. Vojtíšek)

— it positively modifies the hydrological regime of microsites,
— it commences the creation of a humus soil layer and enrichment of the substrate with nutrients,
— it facilitates colonisation by plant seedlings from seeds transported by anemochorous or zoochorous mechanisms,
— generally speaking, it is the essential factor in creating an effective biological crust enhancing and accelerating species diversity during succession.

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Abandoned military areas

Species-rich grassland in active military training area, Dolany shooting range, Boletice, June 2010. (A. Pavlíčko)

Introduction

Pavel Marhoul & Jaroslav Zámečník

Both active and abandoned military areas have recently begun to be perceived as areas with high species diversity, hosting many protected and endangered species. Biologists have gradually discovered that they serve as refuges for organisms which are rare or vanishing from the countryside (Reif et al. 2011). Research shows that these sites are of the same, and for some taxa even of greater importance than nature reserves with similar types of habitats (Cizek et al. submitted). Areas influenced by military activities are of key importance especially to organisms requiring disturbed and early successional stages, which have practically disappeared from the landscape in the past decades.

Biodiversity and military activity

How have these sites become biodiversity hotspots of the Czech landscape and what is the reason for such a large number of species living here? In military areas several factors, to which we owe the preservation of their species richness, have come together. Most training areas and shooting ranges were established in the 1950s or even before. They were established in an agricultural landscape, in those days still markedly heterogeneous, composed of a mosaic of small fields, pastures and open forests and therefore on average rather species-rich. Moreover, the training areas were established on large areas, including a wide range of habitats in various successional stages and thus also a large number of species. The actual military activities subsequently produced a sufficiently dense mosaic of habitats allowing survival of viable populations at a smaller scale than the surrounding landscape. Experience has shown that agricultural areas of a similar size would not be able to sustain a sufficiently structured mosaic of habitats. Impacts of military activities are naturally not equally convenient for all species, but support especially the creation of early successional stages and organisms associated with these. It is the permanent or repeated disturbance that is essential for the survival of many endangered species (e.g. White & Jentsch 2004, Jentsch 2007). Another important factor influencing species diversity of areas used by the military is the fact that these sites have escaped from eutrophication.

Fig. 1. The character of military areas has, besides mechanical disturbance, often been modelled by fires. At their demonstrations, military history associations simulate training conditions in many ways. (Archive Hutur)

Fig. 2. Military training on Načeratický kopec near Znojmo, 1985. (Archive Hutur)

Fig. 3. View from the same position, 2010. Twenty years after military activity stopped, succession has markedly progressed. (J. Koptík)

Nature conservation

In many aspects, the development of the nature conservationist's view of military areas has been similar to that of other sites created by human activities, such as quarries, dumps, waste ash dumps, and sludge lagoons. Also their view of military areas went through a stage of comparison to a moon landscape and weeping over destroyed nature. Finally we have realised that on the contrary we have created, or more precisely, assisted in making, biologically interesting areas where the species diversity is high not despite military activities, but thanks to them. Unfortunately we are still failing in applying this finding more broadly in practice and in abandoning classical methods when designing the management of these areas.

Military training activities are heterogeneous in space and time, which leads to formation and maintenance of a mosaic of variously changing habitats. It is the dynamics of army activities including strong disturbances that is the essential factor for maintenance of diversity. Impacts of military activities thus open up a living space even for less competitive, mostly endangered species. This is a substantially different approach from the usual management of open habitat communities, which are currently restored by grazing or mowing, with the objective to preserve a more or less stable state. This sometimes gardening-like maintenance of a successional stage of a certain habitat, however, is only convenient for some target species. Disturbances have not yet been fully appreciated in common conservation practice and are mostly understood as a factor blocking succession.

At the beginning of the 1990s, the areas used by the army underwent a considerable transformation. After departure of the Soviet army and reduction of the Czech (Czechoslovak) army at most of the training grounds and shooting ranges, military activities were inhibited. Three training areas, Milovice–Mladá, Mimoň (near Ralsko), and Dobrá Voda in the Šumava range, were even abandoned completely. Some sites have been used commercially, others changed into arable land or homogenous grasslands, and some were afforested, supported by subsidies. Several of them were designated as nature reserves, e.g. Bzenec Training Area, Na Plachtě 2 (Hradec Králové), Tankodrom (Rakovník), and Pod Benáteckým vrchem (Milovice). Most of the areas have however remained unnoticed by both investors and nature conservation authorities.

Development since 1990

Twenty years after military training activities ended, bare soil has disappeared due to succession, grasslands have grown dense, and shrub and tree vegetation has expanded massively. Some training areas or parts of them have become practically impassable. It may be clear which negative influence these changes have had to the species composition of these sites. Unfortunately, not even the designated nature reserves have been managed optimally during that period. Some have remained practically without management (e.g. Tankodrom), at others inappropriate management was implemented (e.g. homogenous mechanical mowing at Pod Benáteckým vrchem), and elsewhere management with the ambition to preserve selected habitats (Na Plachtě 2) was applied. Designating abandoned military areas as nature reserves unfortunately meant exclusion of motocross riders and off-roaders, which actually helped avoiding the worst in some unprotected areas of this type.

Over the past few years there has been a lot of agitation about military areas. At many sites various business projects are being planned or have been realised, e.g. solar power plants (Stříbro, Ralsko) and amusement centres (Ralsko). Also nature conservation was active and designated more than 20 sites as SCIs. However more importantly, the management interventions at these sites have changed and the first projects simulating or using military activities have appeared. Activities at Milovice–Mladá and Na Plachtě are definitely noteworthy; for details, see the case studies.

Desired management

Especially simulation or maximum use of military activities which have produced such species-rich places are the key to preserving the biological qualities of the sites. No data are yet available to support this argument, but monitoring is being carried out on the impact of particular activities and combinations of them. There is, nevertheless, one unquestionable argument for the approach of simulating military activities. The army-used areas were usually established in a landscape of moderate quality at the time (the 1940s and 1950s). Military activities have not only preserved the local species to date, but the conditions at these sites were so favourable that the species have survived even 20 years without management and are only vanishing now.

It therefore seems logical to continue the methods influencing and maintaining the areas for decades. It would definitely be unfortunate to introduce uniform types of management such as mowing large

Fig. 4. Grazed plots in the commercial tankodrome at Milovice. In combination with another kind of disturbance this is an appropriate type of management. (Archive Hutur)

Fig. 5. Grazing is a possibly way of maintaining abandoned military areas, but this alone cannot offer sufficient bare substrate. Abandoned military area Malhostovice near Brno, 2010. (P. Marhoul)

areas, which cannot provide a heterogeneous mosaic of habitats with sufficient representation of open substrate and sparse grassland vegetation. The first results of interventions at Milovice and Na Plachtě show that we are heading in the right direction. These confirm that it is necessary to incorporate a wide range of disturbances simulating the impact of driving with tracked and wheeled vehicles in these areas, and to restore minor variations in the soil horizon formed while making trenches and dugouts or by explosives. It is also essential to include burning in the management. These activities have of course to be combined randomly in space and time.

We have to point out here that these methods do not only concern non-forest habitats. Most of all the sites Milovice–Mladá and Ralsko also include large forest stands, which are often rather atypical in character compared to common economically exploited forests, especially around shooting ranges and tank training areas which have been formed by fire, explosions or disturbances by heavy equipment. The result is strongly differentiated stands in terms of age and structure, with a large proportion of pioneer trees. In some places we can see forests comparable to savannahs in their tree density. Forest stands influenced by military activities are characterised by a large proportion of dead and decaying wood, a high rate of insolated trees and undergrowth, and by a considerable proportion of open soil. They are also a refuge of many protected and endangered organisms (cf. Vitner et al. 2001). These stands are unique in the Czech Republic and are rapidly disappearing due to succession and introduction of standard forestry management.

Introducing management in abandoned military areas and conserving them also has another substantial benefit for nature conservation. Proper care of military areas requires the presence and activity of people. Nature conservation can thus offer the public places to spend their leisure time, places practically missing from the current Czech landscape, places where a nearly unlimited scale of activities can be performed. Off-roaders, quad-bikers, horse riders, and paintballers are all welcome. At many sites various meetings, musical and other events could be organised, because what is the difference between trampling of hundreds of soldiers and hundreds of techno dancers? Thanks to this approach nature conservation will have a chance to step a little out of their often unjustly understood position of a prohibiting institution and an enemy of people who do not stay on the marked trails in nature reserves.

Military areas also provide a sufficiently large area for the return of large mammals, especially the European Bison, to our landscape. The first knowledge is collected by the Military Forests and Estates, Milovice, which is considering introduction of the European Bison in the Doupov Mountains in collaboration with Nature Conservation Authority of the Czech Republic. Restoring populations of native herbivore species could be a good opportunity to restore and maintain naturally open forest and open vegetation in these and other selected areas in a cost-effective way.

Military areas are also important in offering an example of management in non-military protected areas. The species composition in the areas influenced by the army, where we can encounter combinations of e.g. steppe and ruderal plants, shows us on a small scale how the landscape used to function in the past. Knowledge of this principle makes us understand why a lot of – especially insect – species are dying out despite well-targeted management and why the landscape structure, particularly its current division into e.g. meadows, forests and steppes, does not correspond with the requirements of a range of (most of all animal) species. We would be able to support a large number of endangered and protected species this way, including those preferring early successional stages, just by diversifying the current management practice and adjusting its objectives.

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Disturbance management, a way to preserve species-rich communities in abandoned military areas

Jaroslav Zámečník & Pavel Marhoul

Location 	Milovice–Mladá, 40 km NE of Prague, central Czech Republic 50°16' N, 14°53' E; altitude 190–260 m
Protection status	NR (Pod Benáteckým vrchem), SCI (Milovice-Mladá – 1250 ha)
Ecosystem types	Approximately half of the SCI consists of non-forest ecosystems with dominant xerothermic, mostly dense grassland vegetation (predominantly *Bromion erecti* and *Arrhenatherion elatioris*) and adjacent semi-ruderal and ruderal vegetation; the other half is covered by forest stands with prevailing *Quercus robur* and *Betula pendula* (predominantly *Genisto germanicae-Quercion*), still noticeable influenced by the military activities which have formed them (Čížek & Zámečník 2007)
Restored area	135 ha: Pod Benáteckým vrchem NR 69 ha, Pozorovatelna ca. 60 ha, Traviny ca. 6 ha
Financial support	Landscape management programmes, Operational Programme Environment, Agri-environmental schemes, Regional Authority of the Central Bohemian Region, Hutur NGO, Daphne CZ – Institute of Applied Ecology
Costs	€300–500/year (management simulating military activities)

Initial conditions

The history of Milovice-Mladá Military Training Area dates back to 1904, making it one of our oldest areas reserved for military training. Since the beginning it was planned for training of various troops and until 1950 even artillery fire was practised in the area. From the 1950s to 1991, when the army abandoned the area, tank training prevailed.

After abandonment of the 59 km^2 area, Pod Benáteckým vrchem NR was designated on an area of 70 ha. However, unsuitable management was applied, consisting of partial mechanical mowing of the area. The remaining non-forest habitats of the training area were left without management and the forests were managed in an economic way.

Most habitats are currently biologically degraded and show a large proportion of expansive grass and shrub species. Long-term absence of interventions has led to a dense sward and reduced proportion of dicotyledonous plants. The originally mostly open forest stands have lost their character due to the cessation of military activities, subse-

Fig. 1. One of the methods used for mechanical vegetation disturbances. A set of rails can only be dragged with a tank. (P. Vaňhát)

quent significant expansion of shrub and most of all by introducing traditional forestry management. These changes have already led to the extinction of animals: many species associated with early successional stages are currently missing from the site, e.g. the butterflies Dusky Meadow Brown (*Hyponephele lycaon*), and Grayling (*Hipparchia semele*), and Woodlark (*Lullula arborea*), a rare bird.

Abiotic conditions

The mineral bedrock consists of Turonian marly siltstones and sandstones of the Czech Cretaceous basin, in places covered with fluvial sand and gravel sediments. Average annual temperature is 8 °C, average annual rainfall is 578 mm.

Objectives

The objective of the management is to simulate impacts of army activities, first of all by repeated initiation of succession.

Restoration measures

The interventions are currently limited to the non-forest part of the Military Training Area.

2010–2011	Management simulating military activities was carried out on 69 ha (Pod Benáteckým vrchem NR): driving with wheeled and tracked vehicles, dragging a set of rails, removing the sward and topsoil with an excavator and a tracked bulldozer, annual burning of parts of grasslands, restoration and creation of new depressions simulating craters after ammunition disposal and dugouts for equipment. All activities were distributed randomly, thus creating a changing mosaic of habitats differently disturbed and in various stages of succession. Disturbances were also carried out by off-road riders and cyclists. Sheep and goat grazing is planned.
2010–present	Regular monitoring of the abundance of plants and selected animal groups.
2011	Burning, sheep grazing and mowing on approx. 60 ha (Pozorovatelna). In the next years disturbances by military equipment should be added to the management. Elimination of shrub and introduction of grazing on approx. 6 ha (Traviny).

Monitoring the impact of management

The objective of the research is to find out how the implemented activities lead to (a) denudation of the soil, (b) changes in grassland density, and (c) changes in the proportion of dicotyledonous plants, and what changes then occur in species composition and abundance of invertebrates and vertebrates. Results of the research should allow us to adjust possible negative influence of the management to the species composition and abundance of particular species, and to minimise financial costs.

The following methods were used.

1. A series of permanent transects were marked out in the area, where data are collected on vegetation, selected groups of invertebrates (butterflies, ground beetles, ants, spiders) and birds.
2. In thermophilous *Bromion erecti* and *Cirsio-Brachypodion pinnati* grasslands a small-scale experiment was set up in order to obtain basic data on the progress of succession after various types of one-time disturbance: (a) driving with tracked vehicles, (b) removing the top soil layer with the sward, and (c) application of a graminicide to eliminate competitive, dominant grasses (cf. Hurst & John 1999).

Results

Three studies have been carried out in the area for three years and 1.5 year, respectively. The results have not been analysed in detail yet and so the following provides a verbal description of the main trends.

The management implemented in Pod Benáteckým vrchem NR has led to a substantial increase in the proportion of dicotyledonous plants (see Fig. 3) in structurally homogenous vegetation with dominant *Bromus erectus* or *Brachypodium pinnatum*. The total increase in proportion and number of dicotyledonous plant species, including semi-ruderal and ruderal ones, has caused an increase in nectar. An interesting finding is the fact that the same management interventions has led to a stronger increase in the number of xerothermic species and their fertility in (ruderal) habitats richer in nutrients and humidity than in typical steppe vegetation, which is most likely a reflection of the ecological requirements of these species.

Fig. 2. Management measures simulating military activities (2010): besides members of the Military History Club, Milovice, also volunteer firemen participated. (P. Marhoul)

Long-term preservation of xerothermic species in semi-ruderal habitats is thus often obtained by a suitable arrangement of interventions limiting succession and leading to its repeated permanent initiation (cf. Konvička et al. 2005). This has been one of the basic reasons allowing an increase in abundance and further expansion of many (but not only) protected and endangered invertebrate species. This can be illustrated by e.g. increasing numbers of the critically endangered butterflies *Phengaris alcon* and *Nemophora violellus*. After introduction of measures which are drastic at first glance, the dense semi-ruderal vegetation, in which *Gentiana cruciata* plants regenerate well, has substantially opened up, the number and size of flowering shoots have increased and many seedlings have been found around the plants. Also butterfly species such as *Polyommatus daphnis*, *P. amandus*, *Zygaena ephialtes*, and *Z. angelicae* have increased in abundance. These species have rapidly settled areas with open, tall-sward grassland vegetation. There are however many invertebrate species preferring low-sward xerothermic grasslands, which do not settle in semi-ruderal vegetation even though it is open vegetation. According to observations these are *Spialia sertorius*, *Zygaena carniolica* and *Jordanita globulariae*. In xerothermic grasslands, however, even these species prefer disturbed spots with sparse vegetation.

Preliminary analyses have demonstrated differences in the course of succession after using different types of disturbance. All types of basic disturbance show an increase in proportion of dicotyledonous plants, but there are differences in species composition. Mechanical disturbance, unlike graminicide use, suppresses *Thymus* spp., *Prunella* spp., *Dianthus* spp., and *Tetragonolobus maritimus*.

Fig. 3. Removed strip of topsoil where a herb-rich semi-ruderal habitat developed with a rich offer of nectar for invertebrates, one year after the intervention. (Archive Hutur)

Other lessons learned and future prospects

Designation of the area as a SCI protects it against strong pressures of economic utilisation (urban expansion, solar power plants, an airport, etc.). On the other hand, implementation of suitable management which is quite unusual in Czech nature conservation is hard to enforce. Moreover, any management is very costly due to the large size of the area. Restoration of non-forest habitats and reintroduction of disturbances has therefore raised conflicts between representatives of NGOs and state nature conservation authorities.

Out of the total area of 600 ha of open vegetation, quality management has been implemented on only 70 ha (Pod Benáteckým vrchem NR). On another approx. 70 ha (Pozorovatelna and Traviny shooting ranges) efforts are being made to adjust the management appropriately. In contrast, there is no activity on 600 ha of forest stands and, for various administrative and financial reasons, no conservation measures are planned either. A greater effort of nature conservation authorities could therefore be aimed at using cost-free management offered by e.g. off-roaders and similar interest groups.

Public support

Two military associations, seated in the neighbouring villages have joined the project. One of them is currently using its equipment (tanks and infantry combat vehicles), the other one is expected to do the same in the future.

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Restoring disturbance and open vegetation in the former military training area Na Plachtě

Martin Hanousek

Location	Na Plachtě NR, SE outskirts of Hradec Králové, northeast Bohemia 50°11'18" N, 15°51'35" E; altitude 230–250 m
Protection status	NR, SCI
Ecosystem types	Temporary and permanent pools, open-sand vegetation (*Koelerio-Corynephoretea*), dry and moist grasslands (*Violion caninae*, *Molinion caeruleae*, *Bromion erecti*, and *Trifolion medii*), dry lowland heaths (*Euphorbio cyparissiae-Callunion vulgaris*), moist heathland (*Genisto pilosae-Vaccinion*)
Restored area	12 ha
Financial support	Landscape management programmes, Hradec Králové Region Authority, volunteers (public, NGOs, East Bohemian Friends of Military Equipment Club)
Costs	Traversing by military vehicles €2000/ha, 85% financed by the East Bohemian Friends of Military Equipment Club; restoration of pools €2000 per year (ca. €12/m^3); mowing €800/ha; elimination of scrub €0 (sold as firewood and wood chips); rotational sheep and goat grazing incl. supervision €2800/ha

Initial conditions

The northern half of the area of interest was communal property for centuries and used for grazing. In 1897 the area became a military training area (until 2000) and was expanded by felling forest in the other part of the area. In the first half of the 20th century the northern part was also used as an airport.

Military activity repeatedly disturbed the surface of the training ground with heavy vehicles, and digging trenches created marshes. Sometimes fires occurred, which had a positive impact on species living on the former pastures.

Termination of military training and consequently cessation of the regular disturbance have led to encroachment of the area with shrubs and trees (in 2008 over ca. 80% of the area). In the northern part even a dump of construction waste, and partly also domestic waste, have appeared. Part of the area has been built up.

These changes have led to a loss of early successional habitats and therefore also to a decline or disappearance of populations of a range of important species. For example, the last European Ground Squirrel (*Spermophilus citellus*) population in the Hradec Králové Region has gone extinct (Mikátová 1997).

The biological value of the area was first reported in the 1970s. To date, approximately 720 plant, 69 moss, 107 mushroom and more than 2300 animal species have been recorded in the former training area, including 900 beetles, 50 dragonflies, 750 butterflies, 220 Hymenoptera, 114 Diptera, 40 molluscs, 16 amphibians, 5 reptiles, 140 birds, and 14 mammals (Mikát et al. 2004).

Fig. 1. One of the 20 pools, where a 30 cm thick layer of soil was removed after cutting scrub (see Fig. 2); April 2011. (M. Hanousek)

Fig. 2. Reconstructed marsh at the start of restoration in October 2010, i.e. ca. 25 years after the decline of military activity. (M. Hanousek)

Abiotic conditions

The bedrock is marlstone with protruding marl, gravel and sand at the top. The groundwater table is strongly influenced by rainfall, thickness of the sand layer and depth of the impermeable marl layer (mostly 0–2 m). Thus shallow temporary pools filled by rainwater as well as deeper pools influenced by the groundwater table occur. Annual precipitation is 590–630 mm and mean annual air temperature is 8.5 °C.

Objectives

Restoration and expansion of open vegetation habitats, i.e. grassland, heathland, open sand, pools and groups of insolated trees (exposed to sunlight).

Fig. 3. Restoring early succession stages of pools using military vehicles. (M. Hanousek)

Restoration measures

Up to the late 1970s	First conservation attempts, at first limited to safeguarding territorial protection and preventing dumping.
Since the 1990s	Mowing by volunteers, and cleanup of small plots.
Around 2005	Termination of encroachment of plots with preserved open vegetation, introduction of systematic management of marshes and heaths, mowing and maintenance of pools not overgrown by trees and large shrubs. Despite these activities, 85% of the former training area remained unmanaged.
2009	Part of the area tenured by the Nature Conservation Agency of the Czech Republic, start of expanding the open vegetation in collaboration with experts of the Museum of Eastern Bohemia, NGOs, etc.
2009–2012	Cutting of ca. 7 ha of 25 to 30-year old shrubs and trees, restoration of 20 temporary and permanent pools where amphibians reproduce, introduction of experimental sheep and goat grazing in part of the area. Solitary trees and tree fragments were left and tall stubs were purposely created in the restored open vegetation in order to obtain weakened, insolated trees, in which hollows easily appear.
October 2010 and 2011	Traversing with tracked vehicles in an area of 4 ha and on 6 km of paths.

Results

Already in the second year after traversing and disturbance by vehicles transporting cut wood, dozens of temporary pools with populations of the Tadpole Shrimp (*Triops cancriformis*) and Fairy Shrimp (*Branchipus schaefferi*) reappeared.

In 2011, the Skimmer (*Leucorrhinia pectoralis*) and Northern Crested Newt (*Triturus cristatus*), both Natura 2000 species for which the SCI was designated, were repeatedly observed in reconstructed marshes. After traversing in 2010, the *Triops cancriformis* population increased from a few dozen (2008–2010) to at least a few hundred individuals (2011), and *Branchipus schaefferi* increased from dozens to thousands of individuals. Also the population of European Green Toad (*Bufo viridis*) increased and the critically endangered Natterjack Toad (*B. calamita*) was recorded for the first time in 17 years.

The military vehicles have restored thousands of square metres of habitat for insects confined to open sands on heathland, e.g. *Coniocleonus* weevils, solitary wasps and bees, and the parasitic bees and beetles associated with them.

The retained solitary trees appeared to be suitable for the *Ovalisia dives* and *Agrilus* jewel beetles, the Longhorn Beetle *Xylotrechus pantherinus*, mycophagous insects, etc.

As the management measures were carried out recently, their impact on insects cannot yet be assessed in detail. However the suppression of Wood Small-reed (*Calamagrostis epigejos*) by traversing with military vehicles in swards weakened by mowing was surprisingly successful.

The restoration of open vegetation repeatedly met with rather inadequate attempts of some nature conservation authorities to protect and replace trees as compensation for ecological loss due to restoration of open habitats.

Other lessons learned and future prospects

Realisation of the project has shown that there is a potential for collaboration with non-environmental organisations when conserving nature. Active intervention in the area enabled us to verify practical ways of managing a former training area, its results, and costs of various approaches.

The conservation of the area has unfortunately evoked conflicts between conservationists and developers. The greatest barrier in restoring open vegetation is currently however formed by the unjustified and groundless fear of these measures among some conservationists.

To safeguard continuation of the project it is important that the public and professionals are informed sufficiently and are willing to listen to professional arguments. The will to realise unusual measures and to try them out in practice is no less important.

Public support

The project could not have been realised without support of the East Bohemian Friends of Military Equipment Club. Part of the measures was carried out with the help of volunteers recruited from the public and non-profit organisations.

Thanks to its location on the outskirts of the town, the site is extensively used by schools to educate pupils and by residents of the nearby housing estates for recreation. Amateur and expert documentation is a source of important data on the occurrence of particular species. The very high visit rate is basically a positive factor (disturbance), but increases the costs of maintaining facilities such as nature trails and fences, and of management work requiring surveillance (e.g. grazing).

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Fig. 4. Dry heath where management is being realised; August 2010. (M. Hanousek)

Landscapes

Anemone sylvestris in Křéby NR near Kroměříž. (Z. Patzelt)

Introduction

Alena Salašová

The Czech Republic holds an exceptional position in European geography, being determined by four geological units meeting here (Hercynian, Carpathian, Polonian, and Pannonian). Its specific geological history is responsible for a great natural diversity. The Forecarpathian lowland at the foot of the Western Carpathians has created a natural migration route through Silesia and Moravia since the Palaeolithic, used by plant and animal species as well as human populations. The landscape of the Czech Republic, situated in the imaginary centre of Europe, has thus become an important crossroads, a place of transit and exchange of information between the Baltic, Mediterranean, Danubian lowlands, and western Europe. The variety of natural conditions and cultures has influenced the overall character of the cultural landscape – remarkably diverse despite its small size – made up of various river, mountain, karst, and other ecological features, elements, and habitats, which is the basis for the development of structural and biological diversity of our landscape (Fanta 2011).

Development of the cultural landscape

For many centuries, the Czech landscape has been shaped by agriculture, forestry, and fish farming. Since the Middle Ages transport, mining of mineral resources, building, and power engineering have been added. Despite the significant influence of industrial and urban development, the landscapes of Bohemia, Moravia and Silesia have remained predominantly rural. The settlement structure of the Czech Republic is still characterised by a high number of villages and small settlements. More than 90% of villages have less than 2,000 inhabitants and 28% of all settlements in the Czech Republic are communities with less than 200 inhabitants (Anonymus 2009), whereby 26.2% of the population lives in the country (Střeleček & Zdeněk 2006).

Although humans have influenced the landscape since the Bronze Age, it was the spatial diversity of the landscape that determined settlement structure and character until the early Middle Ages. Land use followed from man's natural respect for the small-scale character of the local landscape for centuries.

Significant changes in the landscape structure were caused by the industrial development of the 19th century. Technical opportunities and uncontrolled human activity took large areas to the edge of an ecological crisis.

The time of land nationalisation and collectivisation of agriculture in the second half of the 20th century exerted excessive pressure on the landscape. Never before had the Czech farmland gone through such vast destruction of its structural and biological diversity. The environment became so unfavourable for over 70% of plant and animal species, that they have remained endangered and required special protection ever since (Fanta 2011).

The 'leitmotiv' of the socialist era (1948–1989) was self-sufficiency in agricultural production at any cost. Soviet farming methods were an imposed directive without respect for substantial differences in natural conditions. All farming activities were targeted at achieving maximum yields. One of the consequences of this policy was consolidation of land plots into very large agricultural units. The high species and ecosystem diversity of the landscape, which was typical of small-scale farming in the past, significantly declined, erosion risk of the soils increased, soils degraded, landscape accessibility was reduced, residential values decreased, and the ecological equilibrium of farmland was disturbed.

The Czech Republic lost about 20% of its grassland, 800,000 km (about 145,000 ha) of baulks, 120,000 km of rural roads, 35,000 ha of small woodlands and hedges during the post-war era. Moreover, most marshes and floodplain forests were drained and many river and stream courses channelised and reinforced (Weber & Hrochová 1992, Fanta 2011). Farmland changed into a uniform space with only one function – production. Devastation of the farming landscape affected almost all regions of the country, although not in the same intensity.

In the early 1990s the following landscape problems were found to be the main ones caused by insensitive farming in the past:

- strong simplification of the landscape pattern and overall unification of forest and agricultural land with prevailing large-scale monoculture cropland;
- reduced accessibility of the intensively exploited landscape for man and other organisms;
- heavily polluted soils and waters caused by eutrophication and pollutants (pesticide residues, oil products, heavy metals, nitrates, phosphorus and potassium compounds);
- soils seriously affected and threatened by wind and water erosion;
- disturbed water regime by strong drainage, regulation, and reduced retention capacity of watersheds;

Fig. 1. Cultural landscape of Moravské Kopanice, Bílé Karpaty PLA. The orchards and numerous fruit trees are characteristic of the Czech Republic. Old and regional fruit cultivars are an important cultural heritage and component of the local landscape. (A. Salašová)

Fig. 2. The Czech Republic loses nearly 11 ha of agricultural land daily due to urban sprawl. (A. Salašová)

— forests damaged by intensive management (preference of spruce plantations) and air pollution;
— degradation of a significant area by underground and open-cast coal mining;
— disturbance of the landscape character and aesthetic values of the landscape scenery;
— loss of people's relation to their land, mainly caused by forced ownership changes (transfer of private to state or co-operative ownership).

Regeneration of the cultural landscape

The political changes started in 1989 opened a wide public discussion on the state of the environment and started a long-term process of reclamation and regeneration of the cultural landscape in the Czech Republic. In the 1990s new national legislation was created. No landscape regeneration would have been possible without e.g. the Environmental Act, the modern Act on Nature and Landscape Conservation, the Environmental Impact Assessment Act (all from 1992), which first brought EIA and SEA processes into practice, the 1991 Act on Land Consolidation and Land Registries, which created conditions for land restitution and restoration of the agricultural landscape, as well as amendments of the 1976 Building Act, which introduced the obligation of including ecological networks into land planning.

Parallel with the preparation of new legislation, the Czech government announced several grant schemes to support landscape restoration and reconstruction. It is quite remarkable that most of them still exist, although in amended form. The most important grant schemes are the Rural Restoration Programme (1991), the Landscape Management Programme (1994), and the River System Revitalisation Programme (1991, replaced by a broader scheme, the Programme for the Restoration of Natural Landscape Functions, in 2009). However, it has to be stated that the implementation of these schemes has not always been fully successful in meeting all the environmental demands, hence some of the results are rather poor.

The leading programme is the Landscape Management Programme, which has significantly supported the implementation of specific measures across the Czech Republic. Its purpose is to protect and enhance important non-productive landscape functions, based on sustainable management – especially ecological and water management functions. The programme supports a broad range of restoration activities, such as managing nature reserves, controlling invasive plant and animal species, establishing environmental networks, and restoring wetlands, permanent grasslands, extensive fruit orchards, lines of tree, but also historic parks and gardens. Several examples are given in the case studies on the following pages.

In order to realise landscape restoration, first of all new regional plans had to be elaborated and land ownership rearranged by means of land consolidation. These are all very costly and time-consuming operations, which the state has performed since 1989, but which have not yet been completed everywhere. Thanks to comprehensive land consolidation, measures to control erosion, water management adaptations, facilities to improve accessibility to the landscape, ecological network elements and other measures improving the landscape have been realised. At the same time farmland plots have been more efficiently arranged.

In 1992–2002 a total of 21,000 simple land consolidation projects were carried out (rearrangement and regeneration of part of a municipal territory) and 146 complex land consolidation projects. Until 2011, a total of 1,146 complex land consolidation projects were realised, slightly less than 11% of the country's total area. Progress is hampered by a lack of finances which the state can allocate (Podhrázská 2011). Another problem with land consolidation projects is a lack of interest by landowners.

Current situation and problems of the landscape

The Czech landscape has significantly changed over the past twenty years. The degradation of the landscape, started in the communist period, has continued until the present day. It has not only affected the natural and spatial aspects of the Czech landscape, but also the cultural identity of man with respect to his landscape, reflected in the loss of relation to the land and lack of sense of landscape scale. This is proved by the decreasing importance of cultural and historic values of the landscape and its structures, elimination of old orchards and lines of trees, development of historic spaces, and by damaging small religious objects including the trees accompanying them. The landscape is definitely losing its historic memory and cultural content.

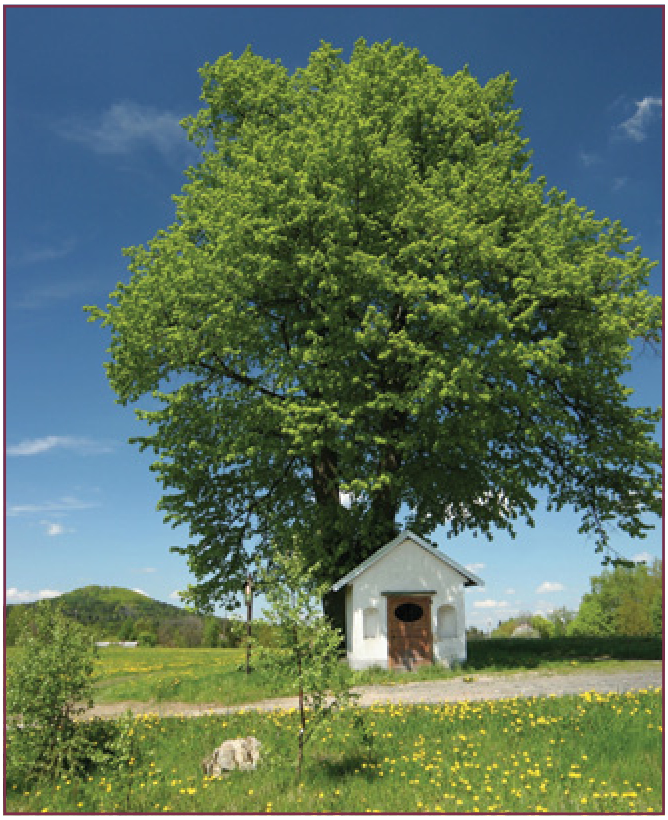

Fig. 3. Solitary trees also belong to the landscape and deserve protection and care. An example is this monumental lime tree with a chapel at a junction near Krásná Lípa. (Z. Patzelt)

It is becoming just a space purposely exploited to produce marketable commodities, a space we only pass through.

Differences between regions increase depending on their socio-economic and natural conditions. The main processes in productive and prominent regions are: a) urban sprawl taking up land and disqualifying it from meeting its ecological and production functions, b) intensive farming oriented to a small number of crop species (cereal crops, maize, oilseed rape). Economically marginal areas are nowadays characterised by extensification, most often afforestation and establishment of grassland, or complete farmland abandonment. These trends will lead to a permanent loss of some types of landscape (often environmentally valuable, such as Wallachia) or will be irreversibly altered (Miko & Hošek 2009).

However, the same trend also has positive effects: it supports natural processes better, and many new habitats are formed, often with interesting succession (e.g. the case study 'Restoration of semi-natural vegetation in old fields in the Bohemian Karst').

A positive trend seen in the past two decades is that agriculture does not merely focus on food production for the population and raw materials for food and light industries. More often, although not yet enough, it acts as a landscape 'nurturer', emphasising its non-productive functions. This trend is reflected in the ever-increasing public interest in organic production methods, subsidised by governmental grant policies and the EU Common Agriculture Policy, especially through so-called Agri-environmental schemes. Introduction of alternative farming methods in the Czech Republic is however problematic (insufficient legislative and political support, inadequate economic environment), which substantially limit farmers and inhibits development of organic agriculture.

The largest volume of funds from the Agri-environmental schemes is currently provided to grassland maintenance (approximately 60% of all farmland), organic farming (currently 8% of farmland, but further increase is expected), intercropping, and establishing of grasslands on arable land. The impact of these schemes on nature and landscape is however often controversial. This counts mainly for grassland maintenance, where inappropriate uniform methods still prevail.

The greatest current problems in the landscape of the Czech Republic are urban and suburban sprawl along with development of infrastructures. Developed areas are increasing in an unprecedented way, mainly to the detriment of farmland. Almost 11 hectares of farmland are developed every day, leading to a rapid growth in urbanised areas: since 1990 they have increased by 245 km^2, i.e. 5%. This is almost half of the farmland lost between 1990 and 2006, which accounted for 537 km^2. If the current rate of urban development continues until 2050, this number will grow by another 1,350 km^2 (Miko & Hošek 2009).

Globalisation versus protection of the cultural landscape identity

Globalisation trends are influencing the landscape in the Czech Republic more and more markedly. They change the layout of urban areas (suburban development) and the architecture of buildings, and increase the concentration of unified infrastructures. Moreover, aggressive billboards visually degrade the landscape. Globalisation also continues to affect the open landscape. Typical examples of this are

Figs. 4, 5. Planting of various autochthonous trees in the Osoblaha region, N Moravia. Since 1997, scattered trees and shrubs have been planted on large areas of arable land. In total 7 km of strips of trees (4–)15 m broad and biocorridors 20–36 m broad have been planted in this agricultural landscape. The planting is financed by the Bruntál Land Registry and from landscape management programmes. Complete realisation has cost ca. €12,000/ha. (L. Bureš) the increasing production of oilseed rape grown as a fuel crop and the current boom of solar power plants on farmland.

Land use is changing, mainly determined by market mechanisms and fast profit. The economically less attractive small-scale landscape with a varied crop structure is gradually disappearing, along with old terraced fields and open enclaves within forests. Abandoned land is encroached by woodland or is developed.

The Czech Republic, similarly to other countries of the EU (e.g. Swanwick 2002, Salašová 2000), has included landscape protection into its legislation. Protecting the identity of the cultural landscape has become even more important after the Czech Republic ratified the European Landscape Convention in 2005 and consequently implemented it in the new Building Act (2006). Assessment of the landscape character became part of planning documents and regional development policies. Preventive landscape character assessments, including principles and recommendations on development of the area in question and on conservation and restoration of valuable landscape features, have been elaborated in most protected landscape areas and a range of districts, towns and villages. Thanks to an active approach of communities, non-governmental organisations and interest groups, measures to preserve characteristic landscape features are being gradually realised. On the other hand, landscape protection faces massive opposition by investors, developers, and local authorities preferring landscape changes yielding fast profits.

In areas where local people identify themselves with the idea of restoring a certain site, attention is mainly paid to the restoration of characteristic lines of trees along roads and extensive orchards with historic and regional fruit cultivars, the conservation and sanitation of solitary trees, the restoration of stone heaps, scattered greenery, small religious objects, wells and waterholes, and the maintenance of memorable sites.

Landscape character assessment plays especially an important role in discussions with local people about the natural, cultural, historic, and aesthetic value of the landscape in which they live. So far, people have not been used to thinking about the landscape and its values, and hence they do not actively perceive and understand the landscape, and do not participate in its conservation. Dialogues which occasionally take place between state authorities, experts and the public may help create better conditions for protection of the traditional cultural landscape values and their development in the full sense of the European Landscape Convention.

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Fig. 6. Historical park-like landscape with scattered settlements, meadows, pastures, fields, woods, and solitary trees; Křečovice, N Bohemia. (A. Salašová)

Reclamation of rural landscapes at Velké Bílovice

Alena Salašová

Location	Surroundings of Velké Bílovice, southeast Czech Republic 48°51'–48°53' N, 16°50'–16°53' E; altitude 162–210 m
Protection status	NR (Trkmanec), SCI, most of the area however unprotected
Ecosystem types	Areas A–B: originally arable land; area C (Trkmanec): waterlogged terrain depressions in fields with halophyte and subhalophyte communities dominated by reed beds of eutrophic still waters with patches of halophilous reed and sedge beds and tall-sedge vegetation (*Phragmito-Magno-Caricetea*); fragments include salt marshes (*Juncion gerardii*), in irregularly ploughed banks of waterlogged depressions (which dry up in periods of drought) also vegetation of exposed pond bottoms (*Verbenion supinae* and *Bidentetea tripartitae*)
Restored area	150 ha (10 sites)
Financial support	Landscape management programmes, Land Fund of the Czech Republic
Costs	Area A: €25,500, area B: €37,500 (establishment and 3-year maintenance, prices on the level of the period 1997–2000), area C: €32,000 (plantings), €212,000 (construction of polders and modifications of other plots)

Initial conditions

Rural landscapes in the former Czechoslovakia underwent a series of substantial reorganisations in the second half of the 20th century, changing the scenery of the entire landscape. Socialist land management led to consolidation of farmland into large blocks for monoculture crop production and significant reduction of dispersed vegetation elements (avenues, linear vegetation accompanying watercourses, field boundaries and hedges, grassland areas). The increasing production intensity resulted in a high anthropogenic pressure on the land, and land consolidation caused a significant decrease in species and ecosystem diversity of the agricultural landscape, and thus a decline of its overall ecological stability.

After 1989, reclamation of farmland and restoration of ownership rights and relationships to land have become one of the main political tasks. To support this aim, comprehensive land arrangement schemes have been introduced, including erosion-control measures, environmental network components, water management facilities, roads, and other measures improving the landscape. South Moravia has already seen many reclamation projects, such as the creation of biocentres and biocorridors, wetlands, and polders; grassland restoration, etc. This project at Velké Bílovice is one of many examples of this type of landscape restoration (Salašová 1996, 1998).

Abiotic conditions and land use

The area is situated on the boundary of the Central Moravian Carpathians and the Vienna Basin in a warm and dry climate. Typical weather features include storm rainfalls and very dry and hot summers. The bedrock consists of Carpathian flysch covered with fluvial

Fig. 1. Trkmanec-Rybníčky NR. The diversity of habitats, including surface water, abandoned arable land, waterlogged depressions with reed vegetation and the planted wood in the E part, is obvious. (A. Salašová)

sediments. As for soils, chernozems prevail, whereas solonchak phaeozems occur at Trkmanec.

The Velké Bílovice territory (1999) is 2,572 ha in size and its forest rate is 0.046%, whereas farmland covers 89%.

Objectives

Increasing biodiversity, reducing soil erosion and flood risk, improving the scenery, enhancing the residential function of the landscape, restoring marshes.

Restoration measures

The system of vegetation elements described below was established gradually, according to available finances. In all cases plants of certified origin produced at local nurseries were used. As an example only the three largest elements have been selected. The municipality of Velké Bílovice was investor and executor of all plantings and is currently responsible for their maintenance.

A. Járek

Linear vegetation accompanying the Trkmanka water course. Area 1.11 ha, grassland area 0.89 ha, area of plantings 0.23 ha. Proposed species composition: *Acer campestre*, *Alnus glutinosa*, *Fraxinus excelsior*, *Populus nigra*, *P. tremula*, *Quercus robur*, *Salix alba*, *S. fragilis*, *Tilia cordata*, *Corylus avellana*, *Euonymus europaea*, *Prunus padus*, *Rhamnus cathartica*, *Cornus sanguinea*, *Viburnum opulus*.

1995	Project preparation.
1996–1997	Planting in two stages – autumn and spring. The plantings were carried out in five sections of various nature (Type 1: trees and shrubs, Type 2: trees only, Type 3: shrubs only). Shrubs were planted as space-fillers or a commercial grass seed mixture was sown. Grassless areas were mulched with a 5 cm thick layer of crushed bark.
1997–1998	Basic maintenance.
1999	Planting check-up, cutting for weed suppression, recording phytosociological relevés.
2000–present	Annual check-up of the planting, continuous thinning of dense growths where required.

B. Úlehle

Two erosion-control measures on the slope (5 × 550 m each). The slope is shaped as a parabolic grassy contour furrow with shrubs and loosely spaced trees.

1997	Project preparation. Originally presumed length of the linear feature 3.74 km, width 3 m, proposed planting of 2000 shrub and 1000 tree saplings of the following composition: *Acer campestre*, *Sorbus aria*, *S. torminalis*, *Prunus padus*, *P. avium*, *Quercus petraea*, *Cornus mas*, *C. sanguinea*, *Crataegus monogyna*, *C. laevigata*, *Prunus spinosa*, *Rosa canina*.
Spring 1998	Linear plantings of the shrubs and trees.
1998–1999	Basic maintenance.
1999	Planting check-up, recording phytosociological relevés.
2000–present	Annual check-up of the plantings, cutting for weed suppression while leaving the biomass at the site.

C. Trkmanec

Marsh and baulk at an inundation polder. Total area 12 ha. The project involved the construction of an inundation polder for flood control. Planting was divided into three areas – two of 0.3 ha in contact with the polder water designed as a lowland willow-poplar alluvial forest (*Salicion albae*), one of 0.6 ha planned as a lowland hardwood alluvial forest (*Ulmenion*). The established area connects to woodland planted south of the polder, which is also part of the Trkmanec-Rybníčky NR.

1997	Project preparation. Proposed species composition: *Quercus robur*, *Fraxinus excelsior*, *Ulmus laevis*, *Acer campestre*, *A. platanoides*, *Carpinus betulus*, *Tilia cordata*; in marshy depressions: *Alnus glutinosa*; shrubs: *Cornus sanguinea*, *Ligustrum vulgare*, *Rhamnus cathartica*, *Salix viminalis*, *Euonymus europaea*, *Corylus avellana*. The shrubs were planted around the area on request of the local hunters society.
1998	Extensive terrain work, construction of inundation polder.
1999	Ploughing of littoral zones, planting work. Bare root saplings were used. Part of the reed beds in the area was preserved.
2000–2001	Planting of water plants in the polder. Basic maintenance after planting, recording phytosociological relevés.
2001–present	Area left to succession, occasional reed bed reduction in the plantings.
2006	Designation of Trkmanec-Rybníčky NR 44.59 ha in size.

Fig. 2. Trkmanec. Planted wood around the inundation polder as a buffer zone against negative impacts of intensive farming. (A. Salašová)

Fig. 3. Trkmanec. The inundation polder, originally built as part of flood control measures, currently serves mainly as a refugium for water fowl. (A. Salašová)

Management measures after planting

— Cutting weeds at least once per year for 3–5 years.
— Application of repellents against browsing by game.
— Mowing grass plots twice per year.
— Removing plants in too dense plantings.
— Occasional mowing of reed beds in marshes.

Results

The saplings took root successfully and had a very good vitality. Die-back was negligible thanks to the good care and the plantings were hardly damaged by game.

In 2011 the cover of the tree layer at Járek was 80%, the shrub layer had a cover of 15% and the herb layer 10%. The most dominant plants were *Fraxinus excelsior*, *Populus tremula*, *Acer campestre* and *Cornus sanguinea*. At Úlehle, the tree layer had a cover of 40%, the shrub layer 50%, and herbs 20%. Here, the dominants were *Rosa canina*, *Sambucus nigra* and *Crataegus monogyna* agg. At Trkmanec the tree, shrub and herb layers had covers of 60%, 20%, and 70%, respectively, and the planted *Fraxinus excelsior*, *Quercus robur* and *Corylus avellana* were the dominants. The oak growth figures for this site are quite interesting: over a 12-year period the oaks have grown from the original 1.5 m to a height of 6–7 m.

A general problem was the protection of the plantings against drought and competitive ruderal species, especially *Convolvulus arvensis*, *Elytrigia repens*, *Rumex crispus*, *Calamagrostis epigejos* and *Artemisia vulgaris*. The plots need to be maintained for the following 10–15 years. It is appropriate to periodically cut dense reed beds, which are able to overgrow shallow marshes in a short time.

However, particular competitive species (*Sambucus nigra*, *Cornus alba*, *Robinia pseudacacia*, *Amorpha fruticosa*) invading from the surrounding caused a problem at the beginning (Salašová 1999). The most effective measure appeared to be cutting of the stands and leaving the cut biomass at the site to serve as mulch.

At Trkmanec, six protected plant species were recorded after seven years, along with 13 plant species included in the Czech red list (e.g. *Cirsium brachycephalum*, *Carex secalina*, *Thalictrum flavum*, *Rumex stenophyllus*, *Lycopus exaltatus*, *Melilotus dentatus*). In a survey, the significant amphibians *Bombina bombina*, *Pelobates fuscus*, *Hyla arborea*, and *Bufo viridis* were recorded in the area. The marsh serves as a stop for migrant bird species. A total of 41 bird species have been recorded, e.g. Hen Harrier (*Circus cyaneus*), Western Marsh-harrier (*C. aeruginosus*), Eurasian Hobby (*Falco subbuteo*), Greylag Goose (*Anser anser*), Black-crowned Night Heron (*Nycticorax nycticorax*), Black Stork (*Ciconia nigra*), Common Sandpiper (*Actitis hypoleucos*), Spotted Crake (*Porzana porzana*), and Little Crake (*P. parva*). Since 2000 the area has been inhabited by the beaver (*Castor fiber*).

Other lessons learned and future prospects

The plantings were realised by local residents. The advantage of this process was cheap workforce and personal relationship of the local people to the plantings. Although performed by lay people (supervised by professionals) the plantings were very successful.

At present reduction of especially *Fraxinus excelsior*, *Populus tremula*, and *Corylus avellana* is needed.

The plantings have become significant refuges for a large number of bird, insect, and small mammal species, and are good examples of landscape restoration for other municipalities.

Public support

Active help with maintenance of the plantings by local interest groups (firemen, hunters society). Interest in the quality of the plantings by landowners in the surrounding.

Acknowledgements

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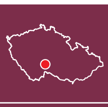
Fig. 4. Járek, between Trkmanka stream and road. Tree plantings here have increased the amenity value of the landscape – the place is today used for walks in the landscape. (A. Salašová)

Restoration of the Včelnička stream catchment, Bohemian-Moravian Uplands

Miroslav Šrůtek & Jaromír Čašek

Location 	Benešov near Kamenice nad Lipou, SW margin of the Bohemian-Moravian Uplands, south Czech Republic, 93 km SSE of Prague; 49°20' N, 15°00' E; altitude 629–657 m
Ecosystem types	Agricultural land and abandoned mesic and wet meadows (*Molinio-Arrhenatheretea*), total area ca. 180 ha; in 1995: arable land 135 ha (75%), mesic and wet meadows and pastures 45 ha (25%); in 2011: arable land 99.7 ha (55.4%), mesic and wet meadows and pastures 80.3 ha (44.6%)
Restored area	Territory of Benešov and a 6-km section of the Včelnička stream and the upper part of its catchment area (16.2 km^2)
Financial support	Landscape management programmes, Agri-environmental schemes
Costs	a) Conversion of part of arable land (30 ha) to mesic meadows and pastures with high species diversity: €20,000; b) Revitalisation of Včelnička stream and its pond system: septic tank and wastewater treatment plant – €18,000; settling pond for the waste water treatment plant – €12,000; fishpond – €24,000; revitalisation of upper part of Včelnička stream – €70,000; c) Restoration of wet meadows, incl. construction of three pools: €64,000; d) Reconstruction of bio-corridors – shrub and tree plantings: €80,000

Initial conditions

Since the 1950s, the Benešov area has suffered from intensification of agriculture and forestry. During collectivisation in 1950s small fields and meadows were combined to form larger units. Trees were cut and hedges removed. Outside forests, the Včelnička stream and its tributaries were regulated to form open channels without naturally meandering courses (Šrůtek & Čašek 1995). The wet meadows in the stream floodplain were mostly drained. During the 20th century, native fir-beech forest (*Abies alba*, *Fagus sylvatica*) was replaced by Norway spruce (*Picea abies*) plantations.

In 1992 the Šrůtek family's local farm commenced organic agriculture on about 40 ha of arable land and meadows, which they considered a first step to restore the landscape. After the farm buildings were reconstructed, conventional agriculture was stepwise converted to organic farming (for definition of organic farming, see Šrůtek & Urban 2008).

The current organically run farm area is 220 ha, the main product of the farm is raw organic milk from 40 dairy cows. The herd includes another 35 calves and heifers (Fig. 1).

The mean annual flow rate of the Včelnička stream is ca. 200 l.s^{-1}.

Fig. 1. Part of herd of dry cows and a heifer on mesic and wet pasture along Včelnička stream. (M. Faltus)

Abiotic conditions

The mean annual temperature is 6.4 °C (Černovice station), mean annual precipitation 677 mm (Kamenice nad Lipou station) (Vesecký 1961), but 775 mm according to private standard measurements in Benešov from 1997 to 2010; the geological substrate is biotitic gneiss.

Soil chemical analyses for the Benešov District have indicated acidic soils: pH 4.90–5.50, Ca 907–2140 $mg.kg^{-1}$, Mg 62–189 $mg.kg^{-1}$, P 8–112 $mg.kg^{-1}$, K 132–377 $mg.kg^{-1}$ (www.eagri.cz, farmer portal, 2007).

Objectives

Slowing down the mineralisation rate of organic matter in the soil, to be achieved by a rise of the groundwater level and development of a rich and dense root zone in mesic meadows (cf. Ripl et al. 1994).

Restoration measures

1993	A concrete septic tank, wastewater treatment plant and settling pond (Fig. 7) were built for the village with a population of almost 100 people; a fish pond 1,500 m^2 in size on the Včelnička stream was reconstructed.
1992–1993	Conversion of part of the arable land to mesic meadows and pastures commenced (Fig. 6) as well as restoration of wet meadows (regular mowing of ca. 12 ha).
1993–1994	Construction and reconstruction of private farm buildings; the first 20 dairy cows were purchased and milk production started.
1996	Revitalisation of the Včelnička stream: creation of meanders over ca. 950 m (Fig. 2); stone constrictions prolonging the water course over ca. 1,300 m (Fig. 3); ca. 4,000 m of line plantings of trees (*Alnus glutinosa*, *Salix fragilis*) and shrubs (*Salix aurita*, *S. triandra*); construction of three water pools of ca. 3,200 m^2 in total. Reconstruction of biocorridors: planting of three game refuges ca. 1,700 m^2 in total (Fig. 5) with locally indigenous trees and shrubs such as *Sorbus aucuparia*, *Acer pseudoplatanus*, *A. platanoides*, *Fraxinus excelsior*, *Crataegus* spp., *Rosa* spp., *Prunus avium*, *Salix aurita*, *S. caprea*, *Populus tremula*, *Betula pendula*, *Quercus robur*, *Prunus spinosa*, and *Tilia cordata*; ca. 5,000 m of line plantings of selected fruit trees (*Prunus avium*, *P. domestica*, *Malus domestica*, *Pyrus communis*) and woody plants mentioned above.
1997–2008	Monitoring of the chemistry of running waters to reveal effects of changes made in the Benešov District.
1994–present	Monitoring of secondary succession of mesic meadows on former arable land (van der Putten at al. 2000, Hedlund et al. 2003, Lepš et al. 2001, 2007, Pakeman et al. 2008, Fortunel et al. 2009).

Results

The rules of organic farming are applied strictly on the farmland, e.g. inorganic fertilisers and pesticides are avoided. One of the most positive results is that organic matter in the soil increases.

Preliminary monitoring of the wastewater treatment system has revealed its effectiveness in removing contaminants from wastewater. The mean maximum removal rates of NH_4^+ nitrogen, NO_3^- nitrogen and PO_4^{3-} phosphorus were 67.0, 58.3 and 37.4%, respectively, from the sewage plant beds with *Phragmites australis*, and 61.8, 42.4 and 79.8%, respectively, from the beds with *Glyceria maxima* (Riemersma et al. 1997).

New mesic meadows and pastures on the arable land created by means of conventional seed mixtures have since 1992 gradually been occupied by native plant species from the surrounding landscape (e.g. *Leucanthemum vulgare* agg., *Bistorta major*, *Lychnis flos-cuculi*, *Scorzonera humilis*, *Lotus corniculatus*, etc.).

In the man-made meanders in the Včelnička stream natural erosion and accumulation zones are spontaneously being created, both contributing to an increase in algae and bacteria, which increase the self-purification capacity of the stream. A streambed adapted this way provides at the same time a better refugium for aquatic fauna. For example, the occurrence of Common Minnow (*Phoxinus phoxinus*) and European Bullhead (*Cottus gobio*) has been observed here.

The constructed pools and the managed wet meadows support amphibians such as Common Frog (*Rana temporaria*), Edible Frog (*Rana* kl. *esculenta*), European Toad (*Bufo bufo*), European Tree Frog (*Hyla arborea*) and Smooth Newt (*Triturus vulgaris*) recorded in the area (Pechová 1996).

Although the planted trees and shrubs in the biocorridors have been damaged and/or destroyed especially by European Roe Deer (*Capreolus capreolus*) and European Hare (*Lepus europaeus*), there are still good refugia for many birds and other animals to be found.

Fig. 2. Autumnal aspect of artificial meanders in Včelnička stream with planted alder (*Alnus glutinosa*) and willows (*Salix* spp.). (J. Urban)

Fig. 3. Stone constrictions prolonging the water course. (M. Šrůtek)

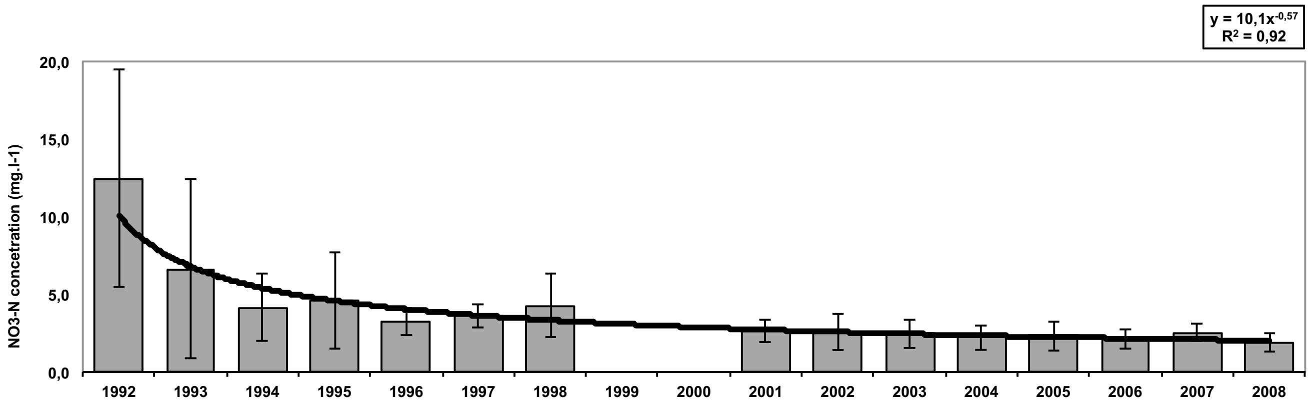


Fig. 4. NO_3-N concentrations in water samples collected in the upper part of the Včelnička stream from 1992 to 2008. The vertical bars indicate seasonal minima and maxima. (O. Simon)

Long-term monitoring (1992–2008) of NO_3^- nitrogen concentration in the running waters revealed a gradual decrease of this component in the landscape (Fig. 4).

The study of secondary succession in experimental mesic meadows on former arable land revealed current dominance of *Trisetum flavescens*, *Lathyrus pratensis* and *Lotus corniculatus*, indicating a significant effect of high nutrient doses after fertilising was ceased 15 years ago. This limits their development into species-rich mesophilous grasslands (cf. Pavlů et al. 2011).

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Fig. 5. Line planting of trees and shrubs between pasture and path. (M. Faltus)

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Fig. 6. Newly established mesic pasture. (M. Šrůtek)

Fig. 7. Part of waste water treatment system: settling pond with two crosswise belts covered by *Typha angustifolia* and *Phragmites australis*. The water surface is covered by *Lemna minor*. (M. Faltus)

Restoration of greenery elements in the Podblanicko region

Karel Kříž & Pavel Pešout

Location 	Benešov District, southeast Central Bohemian Region 49°25'–50°03' N, 14°24'–15°13' E; altitude 280–630 m
Protection status	PLA (Blaník – 7 lines of trees), general protection of greenery according to the Nature Conservation Act
Ecosystem types	Mostly formerly arable land, to a lesser extent eutrophic grassland (*Arrhenatherion elatioris*)
Restored area	417.2 ha (295 sites)
Financial support	Landscape management programmes (80%), own resources (20%), voluntary work
Costs	Initial costs: fruit tree planting av. €2,000/km, deciduous tree planting av. €3,200/km, planting of orchards €2,000/ha, planting of hedges €10,000/ha; annual costs: repair of netting against browsing, mowing €4–100/km, grazing in orchards av. €800/ha, hedges practically costless (occasional checking of fences, no management)

Initial conditions

The landscape of the Podblanicko region has gone through strongly negative changes as a result of land consolidation due to agricultural collectivisation, elimination of baulks, cart tracks, walls, wayside shrines etc. in the 1950s and 60s, and due to reclamation mostly in the 1970s and 80s. All these changes have led to biodiversity loss, extensive water and wind erosion and water regime alterations.

Since 1998, the Czech Union for Nature Conservation has therefore been realising a programme for the restoration of small landscape elements, mostly lines of trees and hedges as "first aid" for the agricultural landscape of Podblanicko (Kříž 2003, 2006, Kříž & Pešout 2004). Most sites are located on intensively farmed and strongly eutrophicated farmland, where these plantings significantly contribute to biodiversity increase as well as reduction of wind and water erosion. Local communities, the owners of most cart tracks and local roads as well as enlightened landowners have been important partners.

Fig. 1. Newly planted lines of lime trees near Přestavlky. (Archive Czech Union for Nature Conservation, Vlašim)

Objectives

- Restoration of landscape structures, particularly greenery elements, on farmland.
- Re-accession of the landscape.

Restoration measures

The measures consist of two types: restoration of declining greenery elements (e.g. stabilisation of disintegrating lines of trees and hedges, usually with a conserved herb or shrub layer) and renewal of defunct and ploughed elements (mostly on arable land). In the latter case it is necessary to reduce ruderal species, prepare the soil and sow an appropriate grass mixture (or at least winter grain) before the element can be established. In the case of plantings of lines of trees mowing has to follow.

1998–1999	Restoration of still existing old lines of trees (cutting self-seeded shrubs, treatment of old trees, planting new trees).
1998–2006	Phase 1: Restoration of the first 100 km of lines of trees, hedge planting, restoration of two extensive orchards.
2007–2011	Phase 2: Maintenance of restored elements in collaboration with landowners, restoration of another 61.3 km of lines of trees, hedge planting.

Results

Lines of fruit trees with a length of 86.63 km have been planted and restored to date (Tab. 1), mostly consisting of tall-trunk apple, pear, plum, cherry and walnut trees. In one case a line of mulberry trees was planted. Also lines of deciduous trees with a length of 74.67 km have been realised. These mostly consist of *Tilia cordata*, *T. platyphyllos*, *Acer pseudoplatanus*, *A. platanoides*, *Fraxinus excelsior*, *Quercus robur*, and admixed *Ulmus glabra*.

The species compositions of hedges differ according to the function they have. In linear hedges, shrubs prevail and trees are scattered,

Tab. 1. Restored and newly planted lines of trees, hedges and orchards.

Elements	Lines of fruit trees		Lines of non-fruit trees		Hedges	Extensive orchards	Total
	Newly planted	Restored	Newly planted	Restored			
Number	122	24	101	4	42	2	295
Area (ha)	132	41	212	10	13	9	417

Fig. 2. Planting of a hedge upstream of the Chocholouš pond. (Archive Czech Union for Nature Conservation, Vlašim)

whereas in wide hedges mainly trees are planted and shrubs only create a fringe. Species used in hedges are *Prunus spinosa*, *P. avium*, *Rosa canina*, *Crataegus* sp., *Viburnum opulus*, *Cornus sanguinea*, *Corylus avellana*, *Lonicera xylosteum*, *Quercus robur*, *Q. petraea*, *Carpinus betulus*, *Sorbus aucuparia*, *Malus sylvestris*, and *Pyrus pyraster*.

It can be concluded that over 80% of the restored lines of trees are currently viable and the remainder (where in most cases the subsequent maintenance has not been realised) is gradually supplemented with new saplings. Hedges have successfully been realised in 100% of the cases (also due to conceiving them as non-managed).

Other lessons learned and future prospects

In the 14 years the programme has been running we have gained some essential experience thanks to which the plantings have not only been realised but also maintained for a longer period of time.

— When planning landscape element restoration, the easiest way is to use registered old (ploughed up) tracks and baulks.

— It is advised to make appointments with the person who is in charge of the land use. Leaving enough passage space prevents intentional damage or destruction.

— Conversely, in the case of intentional damage it is good to repair the damaged parts relentlessly. In most cases the damaging stops after a few years.

— Adequate saplings should be used for planting: deciduous trees up to 150–200 cm tall, best with clod, and tall-trunk fruit trees. Taller trees do not survive in the landscape, since they cannot receive as much care as in a town or village. Moreover, they are unnecessarily expensive. In hedges, it is better to plant saplings used in forestry practice (30–50 cm tall). It is good to combine bare-rooting saplings for two thirds and saplings with clods for one third, which offers very good rooting at a yet acceptable price.

— Planting in the open must be carried out in autumn. Spring is often followed by spells of drought, which demands intensive watering. Otherwise the saplings die.

— Saplings have to be protected against browsing by game. The netting must be checked regularly, especially before and during winter. If this task is neglected, one winter night can ruin the whole work.

— The sward under the lines of trees must not be mown. Saplings (particularly shrubs) are poorly visible among weeds, so that a large number of them may be cut off. Within 3–5 years the saplings will outgrow the weeds.

— Aftercare should not be neglected, especially checking the netting against game browsing and pruning tree crowns (mainly cutting away co-dominant shoots).

Public support

Introducing new elements into the landscape, especially lines of trees, is very much appreciated by the public, just as increasing the accessibility of the landscape is: along lines of trees or linear hedges a path is formed after some time. Generally, if somewhere new landscape elements (especially lines of trees) appear, also interest in these works from adjacent villages can be expected.

Acknowledgements

Our thanks go most of all out to representatives of the communities involved and enlightened landowners, without whom such a number of landscape elements would not have been realised on the territory of the Podblanicko region.

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Fig. 3. Newly planted hedge (right) and plum-trees (left) near Chotýšany. (Archive Czech Union for Nature Conservation, Vlašim)

Restoration of standard orchard at Habrůvka

Stanislav Boček

Location 	SW of the village of Habrůvka (see Fig. 2), N of Brno, southeast Czech Republic 49°18' N, 16°43' E; altitude 490 m
Protection status	PLA (Moravský kras)
Restored area	3 ha
Financial support	Landscape management programmes, South Moravian Region
Costs	€1900/ha (removal of invasive species with a brushcutter, mowing of the grassland and subsequent removal of the biomass, planting of 10 young standard apple trees)

Initial conditions

Around 1932, an orchard was established on the "Na stání" commons and named Tyrš Orchard in honour of the founder of the Sokol sport organisation. It was gradually expanded to a size of 3.8 ha. The former maintenance included gradual replacement of old trees, planting of new trees, grass mowing and fruit harvesting by local citizens. In 1982–1995 the management was carried out by members of the local gardeners society.

After 1995, the orchard was not systematically managed and became gradually overgrown by self-seeded and invasive shrubs and trees (mostly *Robinia pseudacacia* and *Rosa canina*) and suckers from the rootstock (*Prunus cerasifera*) of planted plum trees. Some old trees (especially cherries) are instable, their trunks damaged, branches broken and crowns desiccated. The orchard has also been negatively affected by the presence of an illegal waste dump nearby.

In 2010 a new non-governmental organisation called Habrůvka – Traditional Village was founded. It set the main target of its activities to restoring Tyrš Orchard, and a management plan was drawn up in cooperation with Biosférická rezervace Dolní Morava, o.p.s. (Biosphere Reserve Authority) and Mendel University, Brno.

Fig. 1. Fruits of the rare 'The Queen' cultivar discovered during the inventory of the orchard. (S. Boček)

Objectives

Restoration and creation of an extensively managed, species- and variety-rich orchard, formation of a gene bank, increasing biodiversity, creating a meeting point for local citizens.

Fig. 2. Location of the site.

Restoration measures

2011	— Inventory of the fruit trees including assessment of their health and general value. — Removal of self-seeded and invasive woody species, especially Black Locust (*Robinia pseudacacia*). — Removal of remnants of illegal waste dump, terrain levelling. — Summer pruning of stone fruit trees (cherries) – removal of diseased and dead branches (while retaining dying and dead trees in the orchards if they are not a risk to people's safety). — Mowing grass with a brushcutter including subsequent biomass removal. — Planting 30 apple trees of different historical varieties (e.g. 'Oranienapfel', 'Wesener', 'Graham's Royal Jubilee', 'Coulon's Renette') and landraces (e.g. 'Granatapfel aus Třiblice', 'Korbapfel', 'Sudeten Renette', 'Vlk's Seedling', 'Himbeerapfel von Holowaus').

Management measures

— Maintenance of fruit trees by pruning.
— Mosaic mowing of the grass twice a year with subsequent biomass removal (grazing by domestic animals could be an alternative).
— Planting new trees, mainly pome fruit (apple, pear).
— Subsequent maintenance of newly planted trees (improvement cutting of young trees and hoeing the soil around the trees for at least 3 years after planting).

Fig. 3. The orchard before restoration, autumn 2010. (S. Boček)

Fig. 4. The orchard after restoration, autumn 2011. (S. Boček)

Methods

In 2011 a detailed inventory of the fruit trees in the orchard was conducted in order to identify the fruit cultivars present. For each tree, we assessed the following features on a five-point scale (excluding the rate of crown desiccation):

— General value of the tree (1 – high value; 5 – low value) (Pejchal & Šimek 2011).
— General state of health (1 – completely healthy individual; 5 – heavily damaged individual).
— Trunk damage (1 – none; 5 – extensively damaged).
— Rate of crown desiccation (0–100%).

Results

The orchard comprises a total of 416 planted fruit trees: 9 pear trees (cv. 'Hardy'), 33 apple trees (cv. 'Gascoyne's Scarlet Seedling', 'Kuhländer Gulderling', 'The Queen', 'Roter Böhmischer Jungfernapfel', 'Winter Goldparmäne', 'Sudeten Renette'), 37 Persian walnut trees (saplings), 127 plum trees (cv. 'Common Prune', 'Durancie', 'Wangenheim'), and 210 cherry trees (cv. 'Annonay', 'Hedelfingern', 'Kaštánka', 'Karešova', 'Libějovická', 'Napoleon', 'Früheste der Mark', 'Skalka'). Tyrš Orchard is not significant from the viewpoint of gene pool conservation. Except for the relatively rare varieties 'The Queen' and 'Skalka', the orchard includes a range of common, old standard fruit trees.

The average values of the assessed features were as follows: overall state of health 2.8, trunk damage 1.9, crown desiccation 30.8%. The general value of all assessed trees reached a mean score of 3.0, which indicates moderately valuable trees supposed to live long, possibly with reduced vitality and health. The trees can be utilised for fruit production as well as ornamental or compositional vegetation elements.

Other lessons learned and future prospects

Long-neglected extensive orchards can be restored relatively quickly using appropriate agrotechnical operations including special pruning for tree improvement and maintenance, cleaning the area from unwanted vegetation (self-seeded trees, rootstocks), and planting new trees. Retaining dead or unviable trees creates suitable habitats for xylophagous insects and other organisms.

Traditional extensive orcharding seems to be the optimal way of conserving on farm genetic resources of vegetatively propagated species (Holubec & Paprštein 2005), especially old and regional cultivars found in a particular area (Paprštein & Kloutvor 2006, Boček & Tetera 2008).

Public support

Local citizens are interested in actively participating in the management of Tyrš Orchard. The orchard is suitable for educational seminars (pruning trees, biological fruit crop control, etc.).

Acknowledgements

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Restoration of semi-natural vegetation in old fields in the Bohemian Karst

Alena Jírová

Location 	Bohemian Karst (Český kras) PLA, SW of Prague, Czech Republic 49°52'–50°00' N, 14°03'–14°21' E; altitude 251–488 m
Protection status	PLA
Ecosystem types	Deciduous woodland (dominated by mesophilous oak-hornbeam and thermophilous oak woods), mesic meadows, shrubland, dry grasslands
Restored area	91.7 ha (110 original old fields dating from 1975), 18 ha (46 still existing, spontaneously developed fields)
Costs	€0

Initial conditions

Arable land in the Czech Republic, just as in other central and eastern European countries, was extensively abandoned in the 1990s as a result of political and economic changes (Brouwer & van der Straaten 2002). However, abandonment of arable land had also earlier been practised for various reasons.

Altogether 110 abandoned arable fields were recorded in the mid-1970s, covering 0.7% of the karst area (Osbornová et al. 1990). This case study focused only on those with spontaneous succession.

Abiotic conditions

It is a relatively warm and dry region, with mild winters; a mean annual temperature of 8–9 °C and a mean annual precipitation of 530 mm. Limestone is the bedrock in most of the area.

Objectives

The following main questions were asked:

— Do target stages, identified as shrubby grassland (SG) and semi-natural deciduous woodland (W), develop and, if so, which species are involved?

— Are the target stages predictable?

— What is the influence of the surrounding vegetation on the target species composition of the old fields?

Data collection

1975	Klaudisová (1976) sampled 58 of 110 old fields in the area.
2008–2009	A total of 28 of them were re-sampled (Jírová et al. 2011).
2009–2011	Complete lists of vascular plant species were recorded for 46 fields and their surroundings up to 100 m from their margin.

Results

Late successional stages

The spontaneous succession in old fields proceeded towards target stages, either deciduous woodland or shrubby grassland (Fig. 2). Their establishment can be tentatively predicted by soil pH and early occurrence of grassland species. Moreover, shrubby grasslands develop on the shallower soils.

Influence of surrounding vegetation on the succession

In total, 589 vascular plant species were recorded in the studied old fields and their surroundings, 154 of which were classified as target species (belonging to the *Querco-Fagetea*, *Festuco-Brometea* and

Fig. 1. Late shrubby grassland stage (58 years old) of an old field by the Berounka river near Srbsko. (A. Jírová)

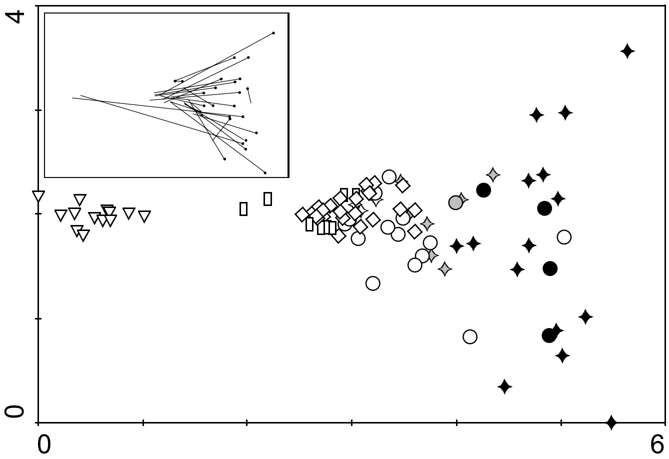

Fig. 2. Ordination (DCA) of original (1975, empty symbols) and repeated (2008–2009, full symbols) vegetation records of old fields. The latter are represented by either shrubby grassland (grey) or woodland (black). Particular symbols represent the age of fields after abandonment in years: triangles 1–6, boxes 7–16, diamonds 17–30, circles 31–50, stars >50 yrs. The first axis explains 6.4% of variability in species composition. Arrows in the inset diagram connect the vegetation records obtained in 1975 and 2008–2009 in the same field. Source: Jírová et al. (2012).

Trifolio-Geranietea classes in the European classification system), the remainder being either weeds, common and widespread species or species typical of mesic grasslands. Forty-four target species were not recorded in the fields, but most of them, except for 13 species, occurred in the surrounding area once or twice. Target and native species were generally successful in the late successional stages. This result is important from the viewpoint of nature conservation. The four most successful establishing taxa were *Aster amellus*, *Crataegus* sp., *Rosa canina* agg. and *Cornus sanguinea*. Some rare species spontaneously arrived at the restored sites, e.g. *Orchis purpurea*, *Lithospermum purpurocaeruleum*, *Gentianopsis ciliata*, and *Anthericum ramosum*.

Fig. 3. *Orchis purpurea*. (A. Jírová)

Other lessons learned and future prospects

Spontaneous succession can be considered a suitable restoration measure in old fields. Shrubby grassland and deciduous woodland as target vegetation have developed in this case without any intervention. However, in some cases of shrubby grassland a reduction of woody species is desirable to support and maintain rare heliophilous species. Shrubby grassland, resembling natural steppe-like communities typical of the region, is valuable from the restoration point of view. Landowners can save money by replacing expensive reclamation by spontaneous succession at suitable sites.

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Conclusions

This publication reflects the state-of-the art of restoration ecology and practical ecological restoration in the Czech Republic, although only selected examples are presented. Many valuable restoration projects have been conducted or are in progress, however more needs to be done. We believe that our country will comply with the Strategic Plan of the Convention on Biological Diversity for the post-2010 period, which recommends restoration of at least 15 per cent of degraded ecosystems by 2020.

We can draw especially the following conclusions:

1. Our landscape is traditionally based on a diverse fine-scale mosaic of natural, semi-natural and anthropogenic habitats, which should be respected by restoration projects. Sometimes even less traditional measures, such as prescribed fire, topsoil scraping, off-road activities, etc., can be integrated into restoration projects to diversify their output. Heterogenous restoration in space and time seems to be most desirable. Uniform, large-scale projects, such as many of those under the present Agri-environmental schemes, can be detrimental to many biota if not appropriately modified.

2. Restoration projects should not target just one group of organisms or one ecosystem service. If the various interests cannot be balanced, mosaic management can be an appropriate solution.

3. Collaboration across scientific disciplines and between practical restorationists, decision-makers and the public must be improved. Even during the preparation of this publication we came across some very narrow views of the problem of habitat restoration and biodiversity conservation, which we hope this publication will help to overcome.

4. Natural processes, usually manifested in spontaneous succession, are often effective and cheap tools of restoration. Frequently, habitats valuable from the nature conservation point of view are formed. Succession often needs arresting or even reversing, because early successional stages may be more appreciated for their biodiversity. This could be easily financed by a fragment of the huge amount of money invested into often useless technical reclamation.

5. We have rather good scientific and practical knowledge of how to restore various disturbed habitats preferably in near-natural ways. However, there are still many obstacles to applying this knowledge in practice, often due to low interest by target companies, officials, decision-makers, and sometimes due to inconvenient legislation.

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Nature Conservation Agency of the Czech Republic

The Nature Conservation Agency of the Czech Republic (NCACR) is a state institution preparing and performing nature and landscape management in the country.

NCACR manages all significant protected areas in the Czech Republic except for National Parks. It maintains these areas, for which it also provides civil service administration and prepares management plans. Protected areas under the auspices of NCACR, making up approx. 15% of the area of the Czech Republic, include:
— 24 Protected Landscape Areas
— 213 National Nature Reserves and Monuments
— 537 Nature Reserves and Monuments

NCACR monitors the state of Czech biodiversity by:
— managing the Nature Conservation Finds Database containing 9 million data
— supporting decision-making by public administration institutions
— prepares documents for the Natura 2000 network and recommended principles for the management of 41 Important Bird Areas and 1087 Sites of Community Importance
— delimiting and managing the National System of Ecological Stability of the Landscape
— representing the state in nature conservation matters at the European Commission

NCACR prepares and realises action plans for endangered species.

NCACR supports, from various financial sources, landscape measures such as:
— tree planting, anti-erosion measures
— stream and wetland restoration
— management of valuable habitats
— improvement of species composition and spatial arrangement of forests

NCACR informs the public about the beauty of Czech nature by means of:
— 91 nature trails in a range of protected areas
— the 'House of Nature' programme aimed at building visitor centres
— the impacted Příroda journal, the Ochrana přírody magazine, and other publications.

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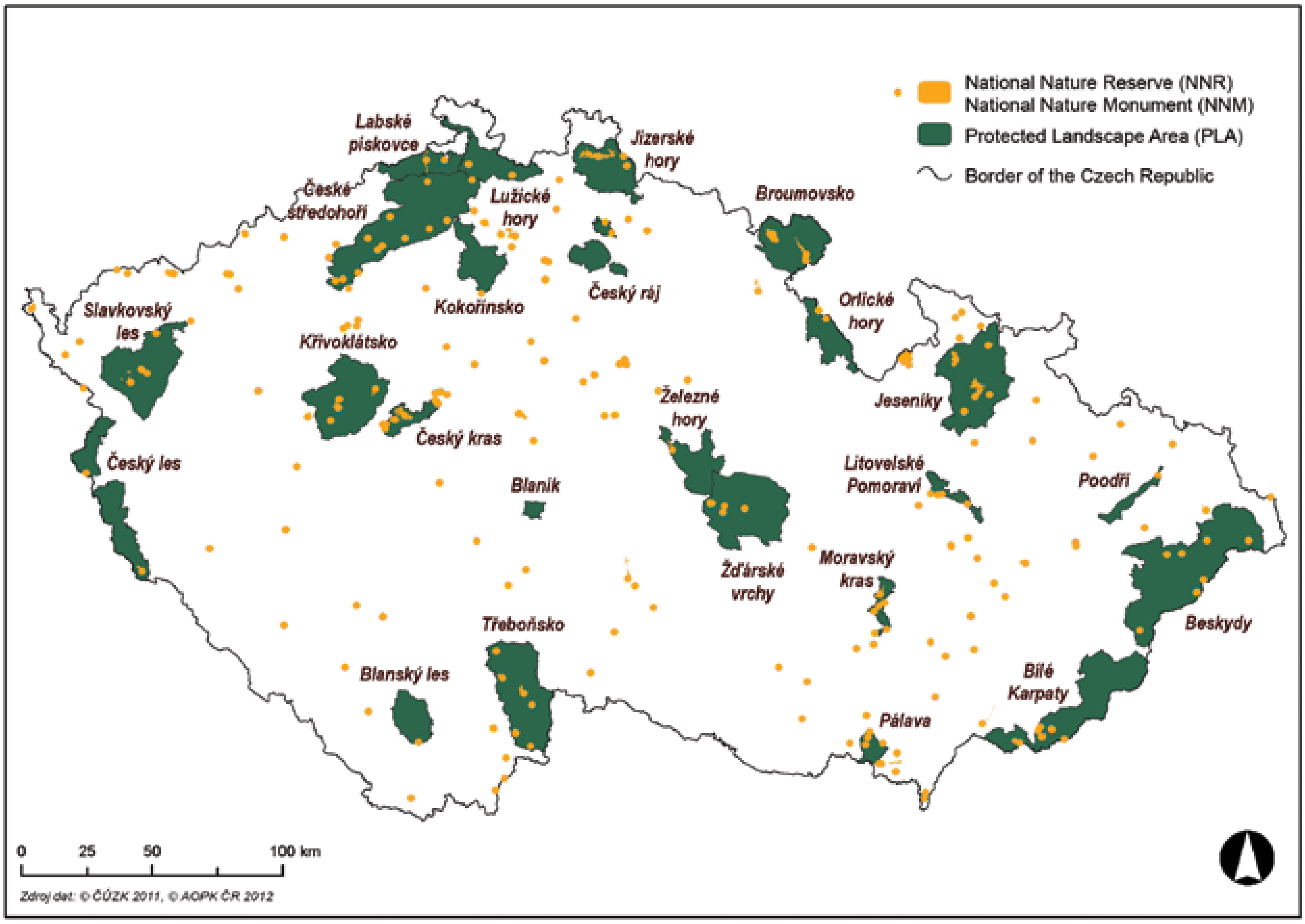

Society for Ecological Restoration (SER)

The 8th European Conference on Ecological Restoration is a regular, biennial event of the Society for Ecological Restoration, European branch. The Society was established in 1987 in the USA and has gradually grown into a worldwide network. Nowadays, it has about 2,500 members from 40 countries. The members include scientists, practitioners, volunteers, decision-makers and even some politicians. Since 1993, the Society has published Restoration Ecology as the main journal in the field. Besides, the Society issues a practically oriented journal under the name Ecological Restoration and the electronic weekly bulletin RESTORE. The European branch of the Society was officially established in 2001, but the European conferences have been organised since 1996. All relevant information, including that about membership, can be found at www.ser.org. For more about the European branch, simply add /europe.

SER SOCIETY FOR ECOLOGICAL RESTORATION

Working Group for Restoration Ecology, České Budějovice, Czech Republic

The Working Group for Restoration Ecology is a part of the Department of Botany, Faculty of Science, University of South Bohemia, České Budějovice (Budweis). This informal group includes, under the leadership of Prof. Karel Prach, not only botanists but also specialists from other fields and departments of the faculty, as well as several institutes of the Academy of Sciences of the Czech Republic. The members are especially interested in using ecological succession in the restoration of various human-disturbed sites (such as mining sites), ecosystems on ex-arable land, and various neglected and wrongly managed grasslands, as well as the restoration of natural species composition and functioning of degraded forests, especially plantations. Results are published in top ecological journals as well as popular publications. Emphasis is placed on spreading the ideas of restoration ecology to the public.

The working group is the main organiser of the 8th European Conference on Ecological Restoration, 2012. For details about the group, see http://botanika.prf.jcu.cz/restoration.

Brief reviews

A useful publication in the field of modern nature conservation, demonstrating experience and results, but also problems, gained in the Czech Republic in practical applications of restoration ecology. A wide range of case studies in different types of ecosystem is documented, including conditions for the use of particular approaches, financial demands, and the degree of public support for the illustrated projects. Even though restoration ecology is a relatively recent ecological discipline, the publication clearly shows it is quite a respectable tradition in the Czech Republic. Individual case studies indicate that under certain conditions a restored ecosystem can be left or led to natural processes, preserving desirable dynamics and without risk of degradation, while in other cases systematic, suitably applied management is needed, dependent on the availability of the necessary human and financial resources.

All the presented knowledge, including the documented problems and identified future challenges, is of great value for practical conservation of nature, individual natural phenomena or the landscape as a whole. At the same time, it also meets the Czech Republic's international commitments, for example the implementation of the European Natura 2000 network, the requirements of the European nature conservation directives, and the commitment to restore 15% of degraded ecosystems in this country by 2020.

Conciseness, a clear and simple structure and photographs and diagrams documenting the case studies are the great advantages of this publication. It also provides contacts to the authors, who may on demand pass on further detailed knowledge to whoever interested.

Ladislav Miko

This collection of papers is above all a synoptic summary of a whole range of nature conservation activities started in the past, which now provide us with essential information on the management of species, habitats and large areas. It deals systematically with the issue of so-called conservation and restoration management, both at the ecosystem level and on a spatial scale, and documents various activities, from forest conversion through traditional grassland management to wetland restoration and rehabilitation of natural streams.

Considerable attention is paid to areas disturbed by draining (peat bogs) and mining, into the disputable reclamation of which still huge sums of money are invested. However, the presented studies demonstrate that nature at these sites (sand pits, quarries, spoil heaps, tailings) can also be restored by spontaneous succession.

The chapter on abandoned military areas presents the principles of sustainable management of these areas. This happens at a time when the military is planning massive withdrawal from these areas and it is high time to know how to manage these areas and maintain the very specific biota which have been created here during decades of military activity. The communities here are initial successional stages and their conservation requires so-called disturbance management.

The final chapter summarises the issue of landscape restoration.

The editors have managed to unify the various contributions in a way which enables comparison of the data, including financial support. This provides extremely valuable information, complementing our ideas about the "price of nature". Also worth mentioning are the chronological tables of restoration measures, showing that the ecological restoration of habitats and ecosystem functions is a long-term affair and well exceeds the time length of relevant subsidy programmes.

This publication will undoubtedly become a popular handbook on ecological restoration, not only in common conservation practice, but also among students a pedagogues.

Tomáš Kučera