# Ecological restoration in the Czech Republic II

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Drone view of landscape below Oblík hill, Lounské středohoří Uplands. (J. Bělohoubek)

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# Contents

# Preface

Jordi Cortina-Segarra, chair of the European Chapter of the Society for Ecological Restoration

The technological progress and accessibility to technological resources in environmental sciences is overwhelming. In 2018, we can browse through the latest information on the extent and dynamics of forest cover in Europe (www.geo-informatie.nl) or help monitoring the hydrological and ecological quality of our backyard river (riunet.net) by simply switching on our mobile phones. Unfortunately, the quality of European nature is not yet advancing at the same pace. Reports from the European Environmental Agency show that the progress towards achieving the European Biodiversity targets (2020) is largely insufficient to non-significant. In relation to Target 2 (Maintain and restore ecosystems and their services), despite the restoration activities going on, the trend towards degradation of ecosystem services has not been halted, and national and regional frameworks to promote restoration and green infrastructure still must be developed and implemented. This situation is particularly severe outside the Natura 2000 network.

To reverse this trend, we need financial support, social engagement and political commitment. In this respect, we are looking forward to the opportunities created by the EU Action Plan for Nature, People and the Economy (4/2017). We must also generate and deliver the knowledge needed to improve the efficiency and success of restoration actions. In other words, we need to develop tools to diagnose the syndromes of our damaged landscapes, and design suitable cures to restore their capacity to provide services and preserve the biodiversity that sustains them.

In 2012, Ivana Jongepierová, Pavel Pešout, Jan Willem Jongepier and Karel Prach made a significant step forward in this area by publishing the first monograph summarising the state of the art of ecological restoration in the Czech Republic. They described the main problems affecting Czech landscapes, providing many examples of actions reversing land degradation.

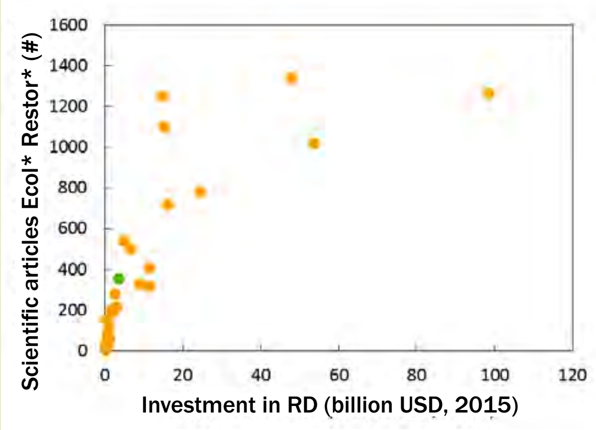



**Fig. 1.** *Number of scientific articles containing the terms Ecol*, Restor* and country names in 28 European Union countries concerning their investment in research and development. The green dot represents the Czech Republic. Source: WOS (1864–2018) and Eurostat (http://ec.europa.eu/eurostat).*

Six years later, Karel Prach, Ivana Jongepierová and Pavel Pešout have assembled 33 new stories providing new insights into the composition and function of Czech forests, alpine vegetation, grasslands, heathlands, marshes, streams and highly anthropic landscapes, and the way natural processes can be driven towards restoring Czech nature. The volume reflects the increasing involvement of Czech researchers and managers in ecological restoration as well their ability to disseminate their approaches and the results of their interventions. This should increase the awareness of Czech society of the need to restore damaged ecosystems and facilitate the adoption of sound restoration techniques in this country. We are delighted that the Czech texts have been translated into English, which makes the information accessible also to non-Czech researchers and practitioners.

Involved in ecological restoration myself for some time, I can testify of the high quality of Czech research in this topic and its impact worldwide (Fig. 1). Indeed, my first experience in ecological restoration back in the 1980s, showed me that restoration success was not directly related to the intensity of the intervention. I wish I had read Karel Prach's advocacy of natural processes earlier. As current chair of the European Chapter of the Society for Ecological Restoration, I welcome the second volume of Ecological Restoration in the Czech Republic, being convinced of its relevance and impact and hoping we will have the opportunity to enjoy further volumes of this series.

**Fig. 2.** Grazing by large herbivores, including European bison (*Bison bonasus*), as a tool for the restoration of open formations at the former military base of Milovice. (K. Prach)

# Introduction

Karel Prach, Ivana Jongepierová & Pavel Pešout

In 2012, the Ecological Restoration Group at the Faculty of Science of the University of South Bohemia organised the 8th European Conference on Ecological Restoration. On the occasion of this conference the edited volume Ecological Restoration in the Czech Republic (Jongepierová et al. 2012) was published. Since that time six years have passed and also our knowledge of ecological restoration has advanced. A range of older restoration projects (scientific as well as practical ones) is continuing, some have been successfully completed, others have started, legislation has changed somewhat, and also the general awareness of the discipline of restoration ecology has expanded in the country. We have therefore decided to compile a follow-up of the previous volume, Ecological Restoration in the Czech Republic II. We do not want to repeat what has already been written, but have focused on new projects and findings and on new results of older continuing projects and their interpretation. Since scientific knowledge from the restoration ecology discipline is the basis of every high-quality ecological restoration, we start with a brief selection of scientific works related to ecological restoration in the country from the past five years. More detailed information can be found in the cited publications.

## New scientific insights into ecological restoration in the Czech Republic

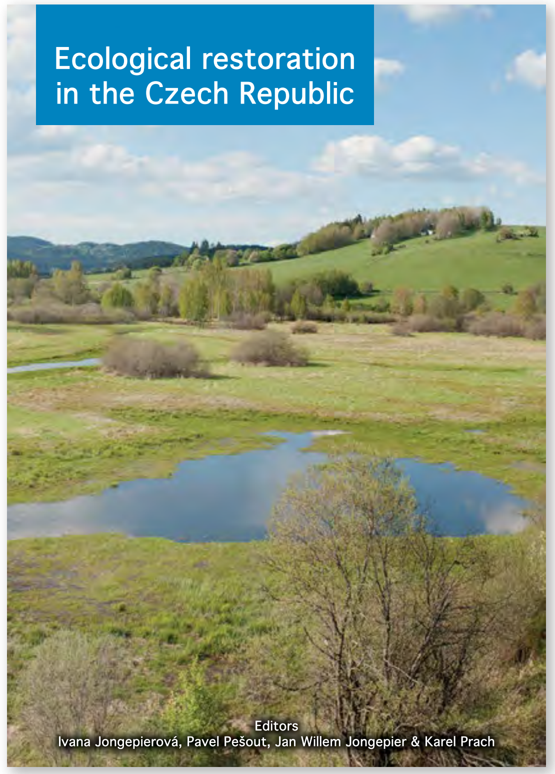
The mentioned conference has produced two international synoptic publications to which also Czech authors have contributed considerably. A special issue of Applied Vegetation Science was published, including studies summarising the progression of spontaneous succession (so-called passive restoration) at various disturbed sites in the Czech Republic (Prach et al. 2014b). It has unequivocally been demonstrated that spontaneous succession is a very appropriate (and cheap) ecological restoration instrument also at strongly disturbed sites. In most cases near-natural vegetation or ecosystems are restored during two decades, sometimes even markedly sooner. Another paper (Mudrák et al. 2014) presents findings with respect to the use of hemiparasitic *Rhinanthus* species to reduce grass dominance. Artificial sowing of these species can, among others, considerably reduce the cover of the unpleasant expansive *Calamagrostis epigejos*.

Another output was the book Guidelines for Native Seed Production and Grassland Restoration (Kiehl et al. 2014), to which Czech authors have contributed with a chapter on the ecological restoration of species-rich meadows on arable land (Jongepierová & Prach 2014).

Czech authors have also markedly participated in the output of the subsequent 9th European Conference on Ecological Restoration, which took place in Oulu, Finland in 2014. In a special issue of the Environmental Science and Pollution Research journal (Prach & Tolvanen 2016) a total of three papers dedicated to the ecological restoration of Czech sand quarries were included (Horáčková et al. 2015, Šebelíková et al. 2016, Řehounková et al. 2016). These articles demonstrated, among others, that young, often initial succession stages, occupied by the most protected and endangered species of not only plants but particularly insects, are the most valuable. Also an article presenting the results of a study into different groups of invertebrates on fly ash deposits (Tropek et al. 2016) was included. It showed that these sites, particularly early successional stages occurring at them, are exceptionally valuable substitutional habitats for many species threatened with extinction.

A range of scientific insights has been provided by research into spoil heaps in the area around the town of Sokolov since 2012. Not only a synoptic book (Frouz 2013) was published, but other, specialised papers (Frouz et al. 2015, Mudrák et al. 2016 and others) as well. Also research into spoil heaps around the town of Most (Šálek 2012, Harabiš et al. 2013, Kabrna et al. 2014, Vojar et al. 2016) has provided new information. The study of other mining sites such as peatbogs (Konvalinková & Prach 2014) and quarries has continued. A considerable number of successional series regarding ecological restoration from different mining sites have been compared in Prach et al. (2013). Further, attention has been paid to long researched fly ash deposits (Kovář et al. 2013).

Besides mining sites and other industrial sites, research into the restoration of White Carpathian meadows has continued (e.g. Mitchley et al. 2012). Among others the importance of the surrounding landscape has been demonstrated, particularly the number of target species growing here. If a sufficient



number of species-rich meadows are preserved in the surrounding, also arable fields sown with a species-poor grass mixture have a good chance of restoring with time (Prach et al. 2015b). A recently popular specific grassland restoration method is sowing hemiparasites in degraded grasslands dominated by competitive grasses, as already mentioned above (Mudrák et al. 2014, Těšitel et al. 2017). Possibilities of restoring degraded heathland have been demonstrated by Dostálek & Frantík (2015). In 2014, the Czech Botanical Society organised a conference titled Restoration and Management of Grassland Ecosystems, the results of which have been published in the conference proceedings (Prach et al. 2015a). After the restoration of sites disturbed by mining, grassland restoration is the most frequent subject of ecological restoration research in the Czech Republic. The traditional study of succession on abandoned arable fields has been expanded to cover the entire Czech Republic (Prach et al. 2014a).

In addition, new information has been provided by research into the assisted restoration of forests towards a more natural composition (Vrška et al. 2017) and into spontaneous restoration of forests disturbed by fires (Adámek et al. 2016, Bogush et al. 2014) or bark beetles (Kopecký et al. 2014). Further, the roles of coppicing (Müllerová et al. 2015, Hédl et al. 2017) and reintroduction of litter raking in the restoration of the species composition of lowland forests (Vild et al. 2015) have been verified.

The cited works are not more than a selection. Other ones can be found in the studies included in the References.

## Realisation of Czech ecological restoration projects

The realisation of ecological restoration projects on a larger scale started in the first half of the 1990s thanks to the adoption of landscape management and restoration programmes of the Ministry of the Environment. Annually an amount of approx. €5.8 mil. has been spent on restoration projects, especially on wetland restoration (Pešout & Fišer 2012). In 2007, a fundamental shift took place with the launch of the Operational Programme Environment (OPE), into which the cessation of biodiversity loss and improvement of the water retention capacity of the landscape were included as global objectives.

In the first OPE planning period, a total of 4,493 projects improving the state of nature and landscape were supported. Until 2015, €77 mil. was spent on the restoration of landscape structures, €231 mil. on water regime optimisation and €81 mil. on regeneration of urbanised landscapes. This way the establishment of 2,724 interactive elements and structural components (e.g. biocentres, biocorridors) under the Territorial System of Ecological Stability (TSES) was financed on a total area of 20,335 ha. The total length of these elements amounts to 1,046 km. Restoration management for biodiversity support was realised on an area of 16,149 ha. In the same period also 238 km of watercourses were restored and the accumulation volume of new or restored water reservoirs was increased by 24,899,071 $m^3$. In vast urban areas, greenery was restored, which included the


**Fig. 1.** Participants of the international ECER conference in České Budějovice, 2012. (J. Řehounek)

**FIg. 2.** Botanical monitoring in experimental plots at the site of Výzkum in the White Carpathians, 2015. (I. Jongepierová)

**Fig. 3.** Analysis of seedling establishment in a reclaimed sand quarry in the Třeboň area. (K. Prach)

planting of 403 km of allees (Limrová 2015, Anon. 2016). Even though these are all good deeds, the expert documents were not always respected and some projects ended up as mere technical solutions.

Since the OPE took over the task of financing most restoration projects, national programmes were redefined and have since then particularly concentrated on supporting the management of valuable areas and financing minor restoration projects (Dobrovský et al. 2009). The amount of available finances has unfortunately been declining for many years. This trend can be illustrated on the development of the volume of finances in the Landscape Management Programme (LMP), the most fundamental national subsidy instrument. Since the year 2000, the programme has seen a fall in finances of 25% (inflation taken into account). Moreover, especially because of the expansion of protected areas, the demands for securing management of the most valuable Czech nature are constantly increasing. The result is a lack of finances for the realisation of small ecological restoration measures in the open landscape.

In the new OPE planning period (projects to be realised by 2023) also support for ecological restoration projects has been included. For projects improving the water regime, establishing TSES structural elements, improving species and spatial forest composition, reducing landscape fragmentation and improving its permeability for organisms alone, an amount of €160 mil. has been allocated. A barrier in using this financial resource is however its exceptional administrative demandingness.

## Education, methodology and popularisation

Besides the traditional tuition of the discipline at the Faculty of Science in České Budějovice, regular and still expanding courses are being organised at the Faculty of Science of Charles University in Prague and at the Faculty of Environmental Sciences of the Czech University of Life Sciences at Suchdol, lately also at the Faculty of Science of the University of Hradec Králové. Incidental courses also run at other faculties of various universities. Ecological restoration has once been the main topic of the so-called Ecological Olympics competition and has also been presented at the Biological Olympics competition at secondary schools. We consider finding motivated students very important for the future of the discipline. Concerning education, the situation in the Czech Republic is certainly better than seven years ago. Thanks to this, restoration ecology is becoming better known and – as we believe – also popular, mainly for its immediate practical applications and perspectives. Thematic conferences of the Czech Botanical Society (recent ones: Prach et al. 2015b) have hopefully also contributed to this.

Lectures aimed at introducing the discipline and showing mainly Czech examples are also requested by enlightened mining companies (Českomoravský štěrk), the Chamber of Garden and Landscape Architects, etc. for their conferences or seminars. Popularised articles on ecological restoration have become common in specialised magazines (Příroda, Ochrana přírody, Fórum ochrany přírody, Zahrada-Park-Krajina, Veronica, etc.).

Exchanging experience from the field of restoration ecology has been a basic item at annual conferences titled Selected Nature and Landscape Conservation Questions organised by the Nature Conservation Agency in collaboration with the Czech University of Life Sciences since 2015. In 2016 it was concentrated on the question of grazing in protected areas, in 2017 on forest ecosystems and in 2018 on landscape fragmentation.

Ecological restoration experience and knowledge are reflected in some professional methodologies. The most significant act in this field was the initiation of creating standards for nature and landscape management in 2012 (Pešout & Šterba 2013). Standards for grassland restoration by means of regional seed mixtures, for measures improving the species composition of forests, for functional planting of fruit trees in agricultural landscapes, and for the creation and restoration of pools and ponds have already been published.

Despite all this it must be stated that ecological restoration (and the discipline of restoration ecology) are still badly known to the public. In terms of public awareness of the discipline we lag behind the most developed countries, although we belong to the world top in the level of scientific knowledge of ecological restoration processes. We believe that works like this publication may improve this awareness.

## Conclusion

It should be reminded here that also the Czech Republic is bound to the recommendation of the European Commission to restore at least 15% of disturbed ecosystems by 2020 (see http://ec.europa.eu/environment/nature/biodiversity/

**Fig. 4.** Recording phytosociological relevés in permanent research plots in Cep II sand quarry, Třeboň area. (J. Řehounek)

comm2006/2020.htm). As almost all ecosystems in our country are more or less disturbed, there is certainly much to restore. The authorities have however taken an active position to this recommendation only in the past few years, with the effects of disturbed water retention of the landscape, soil degradation, and deterioration of forest structure and functioning becoming more and more apparent. The need to restore disturbed ecosystems and meet the recommendation of the European Commission appears in today's strategies (e.g. Strategic Framework of the Czech Republic 2030) and is also included as a priority in most landscape subsidy programmes of state and municipalities.

Restoration in the Czech Republic can be divided into five main categories: restoration at anthropogenic sites (e.g. after mining or on arable land), restoration of wetlands and river ecosystems, restoration of degraded secondary grassland ecosystems, restoration of species and spatial forest composition, and restoration of entire landscapes. In the present volume, further a separate chapter is dedicated to hitherto slightly neglected alpine ecosystems, on the restoration of which a range of new facts have been collected. In contrast, we encountered a lack of results from the monitoring of the effectivity of landscape restoration projects when compiling this publication, even though a number of projects are realised every year. Restoration of landscapes is an urgent requirement with regards to the poor water retention of the landscape, the high rate of water and wind erosion, general soil degradation, fragmentation and isolation of natural habitats, decline of threatened species, spread of invasive alien and expansive indigenous species, etc. Realisation of measures on the landscape scale and monitoring of their effectivity are therefore a great challenge for state institutions as well as non-governmental organisations. The appraisal of ecosystem services, also developed in the Czech Republic, as well as the completion of methods for habitat assessment and their subsequent application give some hope in this regard.

Details of the above-mentioned ecological restoration items can be found in the respective chapters of this volume. We wish and are convinced that the publication will be useful and raise the interest and awareness of the restoration ecology discipline and its practical applications in ecological restoration.

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# Nomenclature, acronyms and glossary

The nomenclature of plants is according to Danihelka et al. (2012), that of plant communities follow the Czech vegetation compendium (Chytrý 2007, 2011, 2013) and the Habitat Catalogue of the Czech Republic (Chytrý et al. 2010).

The nomenclature of butterflies is according to the Checklist of Lepidoptera of the Czech Republic (Laštůvka & Liška 2005), names of other invertebrate and vertebrate species follow national Red Lists (Farkač et al. 2005, Plesník et al. 2003). Where necessary, special nomenclature is used.


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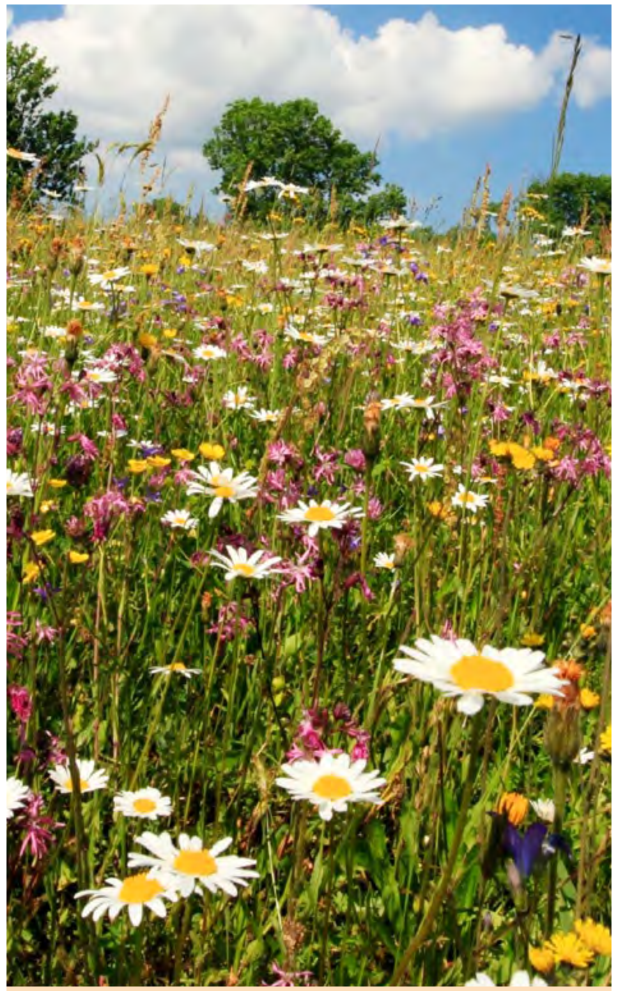

**Fig. 1.** Flower-rich meadows in Králický Sněžník NNR. (Z. Růžičková)

**AS** – Academy of Sciences

**CSF** – Czech Science Foundation

**CUNC** – Czech Union for Nature Conservation

**LC** – Local Chapter

**LČR** – Lesy České republiky, s.p. (Czech national forestry enterprise)

**ME** – Ministry of the Environment

**ME Landscape Management and Restoration Programmes** – subsidy titles financed by the Ministry of the Environment (Landscape Management Programme, River System Revitalisation Programme, etc.)

**MEYS** – Ministry of Education, Youth and Sports

**NCA** – Nature Conservation Agency

**NM** – Nature Monument

**NNM** – National Nature Monument

**NNR** – National Nature Reserve

**NP** – National Park

**NR** – Nature Reserve

**OPE** – Operational Programme Environment

**PLA** – Protected Landscape Area

**SAC** – Special Area of Conservation (area protected under the Natura 2000 network)

**SPA** – Special Protection Area (area designated under European Council Directive 79/409/EEC on the conservation of wild birds)



# FORESTS

Herb layer with *Lunaria rediviva* in Líska NM. (J. Šmucar)

# Introduction

Radim Hédl

## Forests and their restoration

Forests are, from the perspective of ecological restoration, a rather special case among the various types of ecosystems. In Central Europe, a forest is perceived as a potential vegetation cover (Bohn et al. 2000). To put it bluntly, one may say that without the human influence, nearly the entire Czech Republic would be covered with more or less dense tree formations.[1] This provides a specific dimension to the restoration of forest ecosystems, because a forest expands and sustains itself in the long run. This textbook knowledge is based on many theoretical and field studies dealing with ecological succession (e.g. Shugart 1984, Walker et al. 2010, Meiners et al. 2015, Prach et al. 2016).[2]

Forest restoration may therefore mainly concern revitalisation of stands destroyed by e.g. industrial pollution or insect outbreaks.[3] This theme strongly resonates in society because it combines the elements of disaster and efforts spent to return forests to a natural state. “Forest dieback” (*Waldsterben*) was a particularly important environmental issue in the period of massive industrial pollution in the 1980s (e.g. Kandler & Inness 1995). Official statistics indicated 100% of forest being damaged in some regions of former Czechoslovakia (cited in Kubíková 1991). Foresters perceive forest land which incidentally becomes treeless as a depressive matter, regardless of the cause. The ideal forest is simply understood as a stand possessing beautifully straight trunks with a tidy undergrowth and, if possible, no major clearings. Forest stages preceding mature stands, either after planned harvest or as the result of a calamity, are seen as a state which needs to be overcome as quickly as possible. The number of dead trees must be limited to make, so to say, a good impression in reserves.

Any larger departures from the ‘optimal’ state are undesirable.[4] Most foresters and the public tend to see them as dysfunctional and unstable extremes which need to be carefully monitored and corrected without delay. This logic is obviously governed by forestry legislation with its main goal to maintain forest sustainability and long-term timber production.[5] Forest, understood as a set of trees, is literally cultivated and tended with the best belief (Polanský 1947). Knowledge of the ecological variability of forest ecosystems is also mainly applied to cultivate a forest as a stand of trees more efficiently (Průša 2001, Poleno et al. 2007).

In the modern understanding of nature management (nature conservation in a broad sense), a forest has a wider meaning than was briefly stated above. The utility aspect steps back more or less pronouncedly, and natural phenomena with their long history of interactions between nature and humans are regarded as the main values of a forest (e.g. Sutherland & Hill 1995). These may be the coexistence of different species of organisms, natural dynamics or aesthetic values. Of course, many other concepts and ideas, which can be defended or even accurately measured and subsequently justified, may be considered for a forest. It should however be emphasised that they are basically backed by

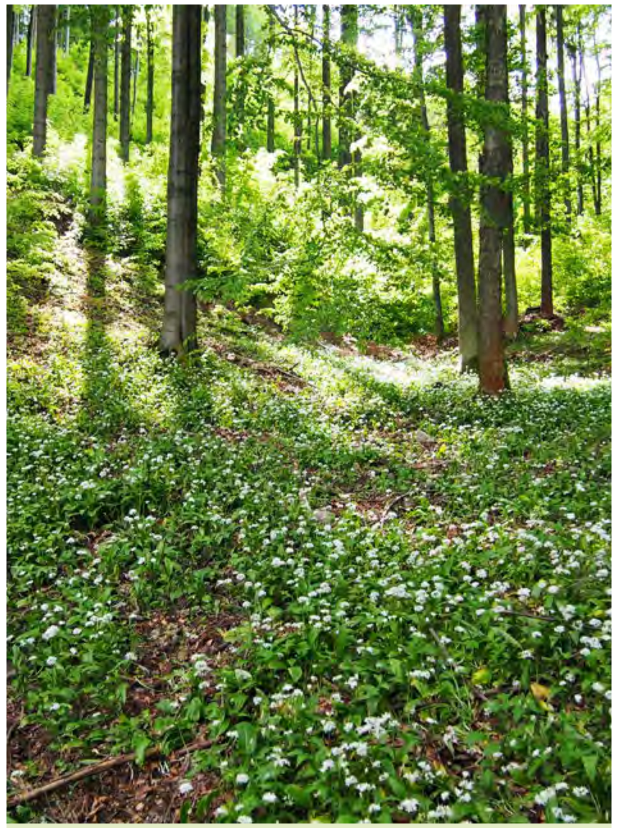

**Fig. 1.** Central European deciduous forests typically have a conspicuous undergrowth. Flowering *Allium ursinum* in the spring aspect of a montane forest by a stream. Horní Lipová, Rychlebské hory Mts. (R. Hédl)

subjective attitudes motivated by what we consider valuable and important. It is necessary to see the current trends in forest restoration in this light. Diversification of approaches to forest management is essential, because diversified forests as a whole maintain basic ecological functions, such as the protection of soil, water regime and biodiversity, much better than artificially cultivated forests. Diversification should be the primary goal of present forest ecosystem restoration.

The current scope of restoration ecology includes almost any natural environment in which we want to restore its state and functions. We restore something of the past which has gradually diminished or even disappeared. In addition to elements and functions, of which we have direct evidence (from e.g. natural or written archives), we can also restore what we assume only hypothetically. It is good to have at least a basic idea of the succession dynamics of our ecosystem (Pickett et al. 2009), in which an element of history is always implicitly present. The history of an ecosystem is usually not uniform but shows variability at different spatiotemporal scales (Szabó & Hédl 2011). Establishing the ‘historical range of variability’ (Swetnam et al. 1999) of our ecosystem is one of the keys to its successful restoration.

## Two or many approaches?

Two new, distinct concepts have recently been discussed in the Czech Republic as complementary to the approaches to ecological forest ecosystem restoration. The first concept is not all that new: it accentuates leaving the forests to natural development, i.e. non-intervention. This actually coincides

**Fig. 2.** The biodiversity of valuable lowland forests suffers from encroachment by scrub, which is the result of a change in management regime. This is also the case in the open subcontinental oak forests in Hodonínská Dúbrava NNM, which hosts very species-rich plant communities. It is one of the largest complexes or former wood pasture in the country, but the required traditional management forms have not been resumed here to date. (R. Hédl)

with the classical doctrine of nature conservation based on the premise that nature is most valuable without humans. The second concept seeks to restore traditional forms of management, so again generally nothing new. Only the acceptance of active, historically learned ecosystem management has extended to forests where it had previously not been considered (e.g. Petříček & Míchal 1999). In the Czech Republic, the increased attention to both concepts dates back to around the turn of the millennium.

We will not go too deep into describing both concepts here. An idea of the mentioned views on the restoration of forest ecosystems can be obtained by reading relevant chapters of the first edition of this publication (Čížek 2012, Vrška 2012). Nowadays, the debate has proceeded so far that in certain situations both modes are commonly accepted as meaningful alternatives to conventional forest management. However, they are usually presented as mutually incompatible, although the reality is not that simple.[6]

It should be stressed that both approaches can be combined quite well with conventional forest management. Combining biodiversity conservation and forest management is not only possible, it is even a prerequisite for sustainable forest management (e.g. Bunnell & Dunsworth 2010). Sustainability is strongly linked with ecological restoration anyway, because one of the main reasons for ecosystem restoration is to achieve a more or less long-term stable state. Forest stability was, in the concept of certain forest ecologists (e.g. Míchal 1992, somewhat more critically Zlatník 1976), associated with a near-natural state – a climax in the sense of Clements (1936).[7] The climax has been disrupted by human interventions and should be restored again in order to regain ecological forest stability. This is obviously the source of the inclination of many ecologically oriented foresters to the concept of non-intervention. Practically oriented foresters perceive the stability of a forest mainly as the absence of destructive impacts such as windbreak or bark-beetle.

In principle, it is well possible to perform management of various intensity including non-intervention at one location such as a forest property or a reserve. The author is aware that there are currently quite different views on this subject, so we cannot consider the discussion to be concluded. However, as far as the range of options is concerned, the reality is definitely not black and white. For example, the concept of near-natural management (Košulič 2010) builds on the natural ability of tree stands to regenerate spontaneously, just as coppicing and certain clear-cut systems do. There is a whole spectrum of possible combinations, so it seems that the main limitation is our ability to accept and implement them in practice.

## What and why do we restore?

The following brief overview presents some approaches to the restoration of forest ecosystems presently used in the Czech Republic. A more detailed view of current approaches to the restoration of temperate forest ecosystems can be obtained from a review compiled by Götmark (2013). This introduction and the respective section with case studies deals with the restoration of existing forests. Forests, however, establish also spontaneously, often on abandoned agricultural land or on former mining land; the chapters of this section are devoted to these kinds of forests. The presented overview is certainly not exhaustive. Moreover, it accentuates conservation rather than forestry approaches, however closely linked they are. Concrete examples are described as case studies. It is apparent from the entire section how difficult it is to make generalisations and how important knowledge of the local situation is, including the history of particular ecosystems.

- In European forestry there is a long-term trend towards no-clearcut management, sometimes referred to as close-to-nature forestry management, although production-oriented clearcut management still persists and will probably exist for long.[8] This implies, among other things, efforts to improve the man-altered species composition of forest stands. Under the current natural conditions, deciduous trees would probably prevail in the Czech Republic, while conifers would form a minority. Nowadays, spruce constitutes about 51% of forests in the Czech Republic, 17% of which is pine; deciduous species make up only about 27% of the forests (Ministry of Agriculture 2016). The aim is therefore to gradually create forests with a higher proportion of deciduous tree species. This trend is shown in the official statistics (Ministry of Agriculture 2016). Examples from forestry practice show how long and complex this process can be (Tesař et al. 2004). It is however necessary to point at the regional differences, calling for great caution when applying generalised principles. Knowledge of the history of restored ecosystems is important here. For example, a historically higher proportion of spruce than previous reconstructions would suggest could be fairly commonplace in the Czech Republic (Rybníček & Rybníčková 1978, Abraham et al. 2016).
- Another tendency in forest ecosystem restoration places emphasis on biodiversity. This is usually expressed by various indices relating to the biotic community, or focuses on rare and endangered species. Although it may seem from the current debate that restoration of declining forest biodiversity is primarily a question of active management with an emphasis on restoring traditional forms of management, the reality is quite different. Restoration of biodiversity includes all forestry management approaches and intensities. For example, increase in deadwood to support the biodiversity of saproxylic organisms relates both to the restoration of traditional management and non-intervention, while it is probably the most significant in commercially managed forests (McGeoch et al. 2007). Opinions that it is necessary to either manage actively or, on the contrary, not to manage at all in order to support forest biodiversity, only reflect certain aspects of a multifaceted reality. Active management results in repeated suppression of competition by tree species, mainly benefiting not only herbs and heliophilous invertebrates, but also other groups like fungi and mammals (Fuller & Peterken 1995). Absence of management is an acute problem at sites where we observe a high biodiversity of various groups of organisms. The biodiversity of forest ecosystems appears to be, at least partly, the consequence of long-term management at the landscape level.
- Restoration of natural processes aims to support the natural dynamics of forest ecosystems both as a value of its own and a prerequisite for the restoration of many forest functions. The main advantage in terms of implementation is that the costs of restoration management are reduced or eliminated. A special case is non-intervention, which has to be defined arbitrarily, because external inferences cannot be excluded. For example, non-intervention may be considered to be absence of direct management in order to bring the species composition and biodiversity closer to the hypothetical natural state.[9] External anthropogenic influences such as nitrogen deposition, climate change and game management can virtually not be ruled out, so natural processes at the ecosystem level will always be influenced by man, albeit only indirectly. Resumption, or better introduction, of a non-intervention regime is probably the most discussed theme of ecosystem restoration in the current media coverage. It is mainly associated with wilderness, a value with a strong emotional content (Cronon 1996, Kotecký et al. 2010). Rewilding is a pan-European challenge (Martin et al. 2008). In the Czech Republic, this topic primarily concerns forests because of the long tradition in interest and connected research (http://pralesy.cz). From the perspective of biodiversity, we move to the landscape level, where the creation of undisturbed areas helps to restore the populations of large vertebrates hunted out in the past.

**Fig. 3.** Restoration of lost forms of traditional forest management often consists in a substantial thinning of the tree layer. This has been realised in e.g. Zahrady pod Hájem NNR, Bílé Karpaty PLA. Since 2013 a coppice-with-standards forest has been restored at two sites here, subsequently increasing the diversity of the herb layer by several times. In a plot of 100 $m^2$ up to more than 90 species are found here today. (R. Hédl)

- Traditional management forms, as we understand it here, are the approaches used before the introduction of modern forestry. The latter was introduced at the turn of the 18th and 19th centuries and continued until the second half of the 20th century, locally (including the Czech Republic) pertaining until today. Compared to modern forestry, traditional management was characterised by a large variation in the application of approaches due to the less centralised forestry on the one hand and a greater frequency of management interventions on the other. The forest stands were on average younger than the relatively old and gradually still aging present forests (Ministry of Agriculture 2016). The last 200 years saw a complete, professionally justified (e.g. Pelíšek 1957) extermination of several once widespread forms of traditional farming including coppicing.[10] The connection between the loss of biodiversity and former traditional forest ecosystem management is obvious (e.g. Konvička et al. 2004, Müllerová et al. 2015). Besides coppicing, other widespread forms of traditional forest management were litter raking and wood-pasturing (e.g. Krčmářová 2015). However, wood pastures have probably never been a significant element of the Czech landscape. The restoration of traditional management forms is dependent on the socio-economic situation. A perfect return to the past is hardly meaningful, and the restoration may not be realistic other than on a small scale (e.g. Hédl et al. 2017). In the current forestry practice, traditional management forms (especially coppicing) have a potential mainly for the category of special-purpose forests, which make up about 24% of the forests in the Czech Republic (Ministry of Agriculture 2016). Although the traditional management forms do generally not have economic benefit as the main goal, economic considerations are an obvious motivation especially for smaller forest owners (Kadavý et al. 2011).

## Conclusion

Restoration of forest ecosystems is a broad topic. It requires close cooperation between nature conservation and forest managers. It includes both already adopted approaches and concepts discussed only recently. For successful restoration, knowledge of the long history of restored ecosystems is important, which offers a relatively wider knowledge base in forests than in non-forest habitats. The main theme for the future is diversification of management approaches. These should include a wide spectrum from frequent operations resembling traditional forms of management to a complete non-intervention regime. Most of the forests will probably be managed in the conventional way, yet also increasingly implementing the restoration of ecological and other forest functions.

## Acknowledgements

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### FOOTNOTES

1 The influence of large herbivores, which were partly extirpated or practically eliminated in prehistory (European bison or wisent, aurochs, tarpan) and partly artificially supported (red deer, roe deer and the omnivorous wild boar), remains an open question; see Vera (2000) for details.

2 In terms of nature conservation, the gradual increase in woodland at the expense of non-forest habitats at the landscape level is one of the most serious problems in protecting the biodiversity of species and communities in Central and Western Europe.

**Fig. 4.** Montane forests are naturally formed by conifers. However, the main problem is the presence of artificial stands managed by means of clearings. View of Mt Orlík (1204 m) from Mt Medvědí vrch (1216 m), Jeseníky PLA. (R. Hédl)

**Fig. 5.** In Drbákov - Albertovy skály NNR, situated on the right bank of the Vltava river north of the village of Nalžovické Podhájí, tending interventions have been carried out, opening up the forest stands. Their aim was to support heliophilous plant species in the undergrowth and improve the living conditions of a *Hipparchia alcyone* population. The operations started in 2006 and have continued, according to need, until today. They are concentrated on felling of *Carpinus betulus* and *Tilia cordata*, which grow under the initial open *Quercus robur* stands, causing a decline in light conditions in the undergrowth. Thanks to the measure, two types of area are created: light, partly open sites serving as plots for caterpillars of the butterfly to feed on festues, separated by thinned, connecting 'migration' corridors in forest stands. (P. Kolibáč)

3 An example of successful restoration of a forest damaged by air pollution was described by Tesař et al. (2011).

4 On the global scale, however, the term forest is defined very freely. According to the FAO definition, a forest is an area larger than 0.5 ha covered by trees at least 5 m tall and with a ground cover of 10% or higher (FAO 2000).

5 Act No. 289/1995, on forests, and Decree No. 83/1996 of the Ministry of Agriculture, on the elaboration of regional forest development plans and on the delimitation of forest management forms. Downloadable at http://www.uhul.cz/ke-stazeni/legislativa.

6 Simplified concepts sometimes enter the nature conservation strategy; see e.g. the currently promoted division of small-scale protected areas into nature reserves and monuments according to the assumed management form. In the view of the author of this text, it would be more reasonable to approach each protected area individually, with a long-term conceptual vision, but with some flexibility reflecting the current level of knowledge in general as well as regarding the site.

7 With regard to climax and ecological stability it should be noted that today's view of the long-term dynamics of ecosystems, including the impact of global climate change, makes both closely linked concepts rather relative.

8 The purpose of close-to-nature forest management is not to mimic the structure of natural forests but to use the creative forces of nature as much as possible (and thus save input costs), in order to achieve the best economic result while respecting the basic principles of sustainability and balanced yield while maintaining or improving ecological conditions, in other words, the production capacity of the stands (Schütz et al. 2016). (Comment by T. Vrška.)

9 The comparative framework is rather broad and still under discussion even in the literature. Humans have had influence on the changing Central European nature since the last Ice Age, and it is practically impossible to separate natural and anthropic influences. The 'cultivation' of all European landscapes, which is not completely evident to us, was aptly described by famous anthropologist C. Lévi-Strauss (1966).

10 Historically, coppicing used to have considerable extent in Europe. In the Czech Republic, coppicing was dominant in the lowlands and its extent can be traced back to the Middle Ages (Szabó et al. 2015).

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# Litter raking as restoration management in an oak forest in Podyjí National Park

Ondřej Vild, Radim Hédl & Jesse M. Kalwij

| | |
|---|---|
| Location | Podyjí NP; 48°48’ N, 15°57’ E; elevation 370 m |
| Conservation status | NP, SPA, SAC |
| Restored area | 1 ha |
| Financial support | 0 |

## Abstract

Raking of leaf litter used to be a common activity in European forests. We employed an experimental method to evaluate the impact of this management on the forest understorey, and its potential for the restoration of forest vegetation biodiversity. We monitored 45 plots (7 × 7 m) for seven years. The most pronounced change was an increase in the diversity of annual plants, most of them considered ruderals. Continuation of the experiment will be needed to evaluate the long-term impact.

## Site description

The forest stand has a heterogeneous age structure (Fig. 1). It consists mostly of sessile oak (*Quercus petraea* agg.) admixed with *Pinus sylvestris*, *Carpinus betulus* and *Tilia cordata*. The dominating bedrock is granite. The soil type is oligotrophic cambisol with a pH of 4.0–5.5 (measured in water suspension). The relief is homogeneous, with slopes gently descending southwest. Grasses such as *Avenella flexuosa*, *Poa nemoralis*, *Festuca ovina* and *Melica uniflora* dominate the understorey. In more open places, *Trifolium alpestre*, *Galium verum* and *Lychnis viscaria* occur. We can rarely also find here some endangered species, e.g. *Platanthera bifolia*, *Fourraea alpina* and *Monotropa hypopitys*.

## Initial state

The entire region was formerly intensively managed by man. Grazing by domestic animals was very common until the 19th century, and trees were only scattered. Here, as well as in other open lowland forests in the region, the effects of eutrophication and vegetation succession are most obvious. These processes are partly driven by increased atmospheric deposition of nitrogen. Additionally, abandonment of traditional, nowadays banned management types is a contributing factor. Litter raking is one of such types of management. In the past, this management exported significant amounts of nutrients from the forest ecosystem (Sayer 2006). As a result, competitively strong species such as *Calamagrostis epigejos* and *Arrhenatherum elatius*, have expanded at the study site. Simultaneously, plants of oligotrophic habitats, including many endangered species, have disappeared.

**Fig. 1.** Sessile oak (*Quercus petraea* agg.) is the dominant tree species at the site. (O. Vild)


**Fig. 2.** Experimental plot. (O. Vild)

## Restoration objectives

The aim of litter removal is to decrease the eutrophication processes and ecological succession. It should lead to a decrease in competitively strong and expansive species, whereas competitively weak species of oligotrophic habitats should be supported by it.

## Measures applied

Leaf litter was removed with rakes in 30 permanent plots in 2010–2016.

## Monitoring methods

We established 45 permanent plots (7 × 7 m; Fig. 2) in 2010. One third of them are control plots, while litter is removed in the rest of the plots using rakes each year. In the middle of each plot, we recorded a relevé (5 × 5 m) consisting of a list of all plant species of the understorey with cover/abundance estimates using the modified Braun-Blanquet scale. The first survey was carried out before the experimental management started, and then repeated each following year.

## Results

An analysis of vegetation data in the R program (version 3.2.3, available at http://www.r-project.org/) showed that litter raking resulted in a significant increase in species per plot (repeated measures ANOVA, $F = 4.153$, $p = 0.0424$; Fig. 3). Differences between treatments started to be clear already in 2012.

It is worth noticing that the inter-annual fluctuations in species richness are considerable. Further analyses showed that these are mostly the result of inter-annual differences in precipitation and temperature in the winter season (Vild et al. 2015). When conditions are suitable, annual species are able to germinate. Many are typical of ruderal habitats, i.e. habitats strongly influenced by man. Germination of some species, such as *Moehringia trinervia*, *Geranium robertianum* and *Fallopia convolvulus*, was probably supported by mechanical disturbances (Baskin & Baskin 2014). The germination of other species, present only in the seed bank, was probably induced by the missing litter layer normally functioning as a mechanical barrier.

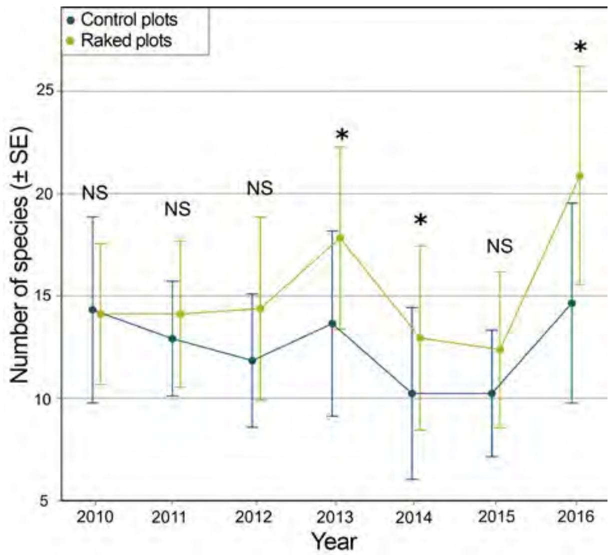


**Fig. 3.** Comparison of temporal changes in the number of species per plot between experimental treatments. The symbols mark significance of the difference between treatments: asterisk: $p < 0.05$.

## New insights and recommendations

Experimental removal of leaf litter had a positive impact on the species richness in the oak forest. Mostly ruderal species increased in the short term. This result can be partly attributed to the agricultural character of the region and history of the locality and its surroundings characterised by grazing until the 19th century. Many ruderal species have thus probably been able to survive in open places. However, these are mostly competitively weak annual species with a low cover, not able to pose a threat to other species of the herb layer.

The lack of effect of litter raking on other species can be attributed to (1) the fact that most of them are perennial species, and (2) the soil buffering capacity, which prevents soil chemistry from fast changes and thus from a decrease in eutrophication level. In order to be able to describe the impact of litter removal on these species and other, more resistant components of the ecosystem, the experiment is planned to continue. This will also help us to assess whether target species characteristic of the habitat in question are able to colonise the plots.

## Acknowledgements

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**Fig. 4.** Litter raking in autumn 2015. Approximately 20 kg of dry leaf mass is removed from each plot yearly. (O. Vild)

# Results of 20-year conversion of pine-dominated stands in Podyjí National Park

Tomáš Vrška, Jaroslav Ponikelský & Petra Pavlicová

| | |
|---|---|
| Location | Podyjí NP; 48°52'32" N, 15°53'25" E; elevation 375–430 m |
| Conservation status | NP, SPA, SCI |
| Restored area | Pyramida: 96 ha in total, representing ca 900 ha of NP stands under conversion |
| Financial support | Operational resources of NP Authority, ME Landscape Management and Restoration Programmes |

## Abstract

Active conversion of initially predominantly pine stands to mixed hardwood stands with a spatial structure of separate groups has been carried out in the buffer zone of Podyjí National Park since 1995. In order to assess the interventions and the methods used, forest stands in an experimental area named Pyramida (96 ha) were classified into five forest types from allochthonous Scots pine monocultures to mixed hardwood stands in the target state, for which forest management directives were compiled. The emphasised function of biodiversity conservation and support is secondarily combined with the production function, creating a local timber resource. These functions do not exclude each other.

After realising conversion measures for 20 years, the percentage of conifers has declined from 61 to 42% and that of hardwood trees conversely. In 36% of the experimental area, complete conversion towards the target forest type was realised during 20 years. From the observed process it is realistically expected that the conversion will be completed in 70% of the area 30 years after the start.

**Fig. 1.** In 1995, thickets of thin pines from the mid-1980s were disrupted by heavy snow. Microclimatic variation of sunlit and shaded places without routinely straightening of the boundaries was applied to introduce target hardwood species. Situation 15 years after planting. (P. Válek)

## Initial state

While after World War II the canyon-like Dyje valley in Podyjí National Park was saved from major exploitation measures thanks to its geomorphology, on the undulating plateau above the valley considerable areas of indigenous hardwood stands dominated by oaks (*Quercus* spp.) and hornbeam (*Carpinus betulus*) were transformed to spruce (*Picea abies*) and particularly pine (*Pinus sylvestris*) monocultures. At the time when the national park was established (1991) these represented high pine forest with undergrowth of hardwood trees or thickets to pole-stages with very poor or no admixture of hardwood trees. The horizontal structure (texture) was simple and large areas of stand groups (3–5 ha) with straight boundary lines often prevailed. The vertical structure generally showed a single layer, but in the case of a mixture of pine and hardwood trees two layers could be distinguished. Forests with a dominance of hardwood trees formed smaller stands, particularly at stony sites, where oak and hornbeam coppices had been preserved. Only scattered old trees of beech (*Fagus sylvatica*) were present. Also the amount of decaying wood was low, as it was used as firewood.

After the designation of Podyjí NP and its zonation, the basic principles of forest management in the buffer zone were defined (Škorpík 1993, update and additions: Reiterová & Škorpík 2012), based on the first management plan (1992–1993):

- creating a functional forest complex, buffering external influences on the unmanaged territory (infiltration of invasive species, farmland runoff, etc.);
- creating a functional forest complex, buffering influences of potential disturbance (wind, black ice and consequently insects) in the unmanaged zone, especially from the surrounding production forests;
- actively supporting and protecting valuable biodiversity elements in all groups of organisms by means of creating a heterogeneous forest structure, including traditional forest management (coppice and coppice-with-standards forest), a higher volume of decaying wood in the stands, leaving habitat trees for endangered species, etc.;
- enabling adequate timber production for the local community.

The conversion of mostly even-aged stands dominated by pine in the buffer zone had to respect nature conservation objectives and also the variation in management (sensu Bauhus et al. 2009, Decocq et al. 2004, Götmark 2007, 2013). It is thus a more fundamental change than conversion in a production forest. National Park priorities were: a) irregular spatial structure with clearings, b) use of exclusively autochthonous species, c) work with a higher rate of decaying wood, and d) work with habitat trees.

Basic forest conversion principles:

- no clear-cut logging as a forest restoration tool;
- using the entire potential of hardwood trees in pine stands, no planting of homogeneous stands on bare tracts;
- spatially dividing up large continuous tracts of former even-aged stands first;
- introducing missing beech (which cannot re-establish and spread naturally – except for single standards) by means of underplanting or sideways shaded groups;
- gradually introducing group selection management, modified for work with more light-demanding trees, through diameter and spatial differentiation;
- supporting and creating space for primarily oak admixed with hornbeam, lime (*Tilia cordata*), beech and other hardwood trees in thinnings.


**Fig. 2.** Spatial distribution of compartments for management of the Pyramida site. In the mosaic of mixed hardwood forests and conifer (mostly pine) monocultures, the latter are dark green, budding hardwoods are light green (hornbeam, lime, maples, etc.), and oak is as yet leafless. (Archive Podyjí NP Authority)

| | | 3- | 3+ | 2- | 2+ | 1 |
|---|---|---|---|---|---|---|
| Forest type | |  | | | | |
| Tree representation in % of basal area (m²/ha) | Conifers | 95+ | 60-90 | <60 | <5 | interspersed |
| | Hardwoods | <5 | 5-40 | 40-95 | 95+ | <100% |
| Stand spatial structure | | one-storeyed; minimal diameter differentiation | formation of second storey (undergrowth), mostly hardwood coppice | two (or up to 3) storeys; conifers prevailing in upper layer | multi-storeyed (in patches or singly); hardwood trees in all storeys; diameter structure formed | multi-storeyed; more diverse diameter structure created |
| Essential measures | | mild but more frequent thinning to support mechanical stability; support of interspersed hardwood trees | support of hardwood trees in lower layer; opening up conifer canopy (esp. *Pinus sylvestris*) aimed at stand structure differentiation | support of prospective hardwoods (future target trees); conifer felling – formation of new gaps for hardwood regeneration; first support of deadwood and habitat trees | transition to group selection silvicultural system; making space for target trees in parts with conifers; transition to increment checking | group selection silvicultural system; felling of target diameters; preserving habitat trees, retaining decaying wood to support biodiversity |
| Forest restoration | | gap reforestation and underplanting of beech and missing target trees | | gap reforestation and underplanting of beech and missing target trees + natural regeneration | natural regeneration only | |
| Silvicultural system | | compartment management in even-aged tracts | | | non-compartment management applying selection principles | |
| Applied Forest Management Planning method | | age-class method | | | control method (supporting statistical inventorying) | |

**Fig. 3.** Forest type classification system.

## Restoration objectives

Creating a functional forest complex, buffering external influences on the unmanaged territory and influences of potential disturbances from the surrounding cultural landscape; actively supporting and protecting valuable biodiversity elements by creating forests rich in structure and species.

## Measures applied

Since 1995, cleaning, thinning and restoration felling have been carried out according to the basic conversion principles. At the moment of conversion to Forest type 2- or 2+, selective management principles are gradually implemented.

## Monitoring methods

The mentioned measures concerned ca 900 ha of forest in Podyjí National Park. Therefore an experimental area named Pyramida 95 ha in size was selected (Fig. 2) with the aim of monitoring and assessing the conversion process, providing model examples of particular steps. To this aim, five forest types were distinguished reflecting the basic attributes: a) species composition and b) stand spatial structure (Fig. 3), with regards to their possible implementation in regular forestry practice:

3- pure coniferous
3+ prevailing coniferous
2- initial transitional
2+ advanced transitional
1 target stand

For each forest type, basic principles of tending and restoration as well as the forest system as a whole were defined, gradually leading to Forest type 1 (target) – see Fig. 3.

Surveying was performed in 1992, 2003, 2007 (Růžička 2008) and 2013 (Pavlicová 2014). Each monitoring round included:

a) statistical operational inventories of 34 round plots (each measuring 500 m²), aimed at assessing changes in species composition and diameter structure, dynamics of natural regeneration, and amount and structure of decaying wood;

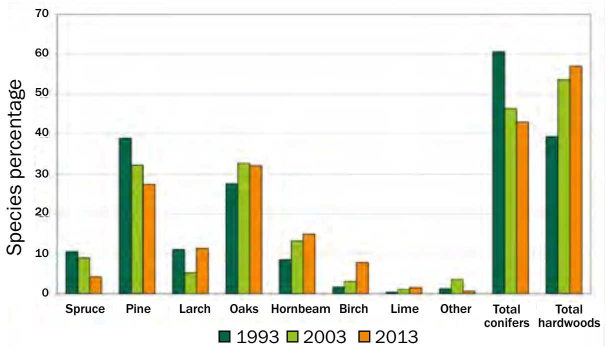


**Fig. 4.** Changes in species percentage according to basal area (circular areas at 1.30 m above the base) at Pyramida, 1992–2013.

b) surveys of horizontal structure (texture – spatial distribution of different growth stages) with orthorectified aerial photographs, aimed at monitoring the fragmentation of formerly large even-aged stands and size optimisation of plots for a group selection management;

c) appraisal of forest types, aimed at assessing the speed of conversion and effectivity of the performed measures (see Fig. 3).

## Results

### Changes in species composition

In the period 1992–2013 an important change occurred – hardwood trees became the prevailing category instead of conifers. The percentage of conifers declined from 61 to 42% and that of hardwood trees conversely (Fig. 4). The former main species *Pinus sylvestris* saw a significant decline: from 39 to 28%, spruce fell from 11 to 4%. In both cases this was the result of targeted support of admixed hardwood species. Calculated according to the number of trees, the decline was even higher. This is because robust pines in Forest types 2- and 2+ reacted to the cutting of adjacent ones by higher light increment and thus the percentage of pine according to basal area is not so pronounced. The increase in hornbeam from 9 to 15% reflects its dynamics as a former undergrowth species, which had never been a target species in the forest systems. This changed with the forest management concept in the buffer zone. We also interpret the growing percentage of birch (from less than 2 to 8%) this way, as the presence of pioneer species is a significant source of biodiversity in a forest. Although in the period 1992–2013 beech was plant-

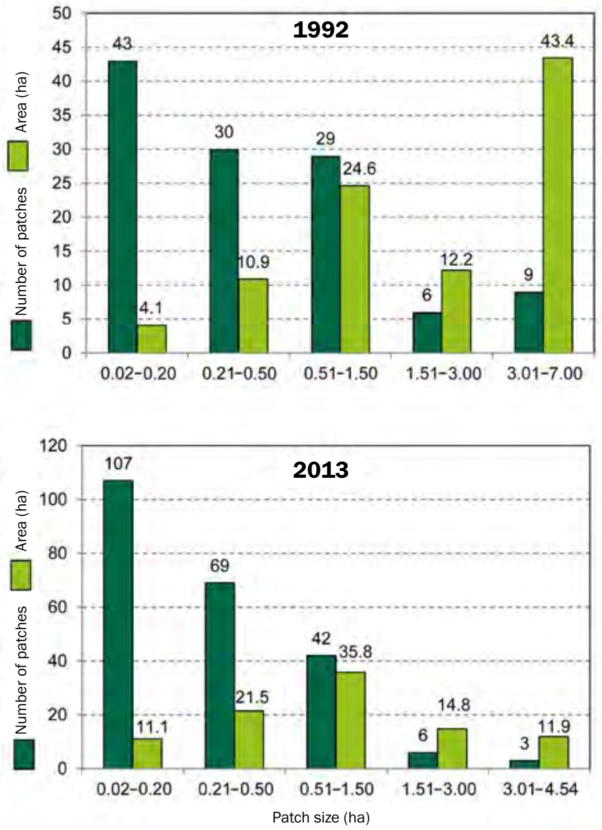


**Fig. 5.** Changes in number and size of forest types under the influence of active stand differentiation, 1992–2013.

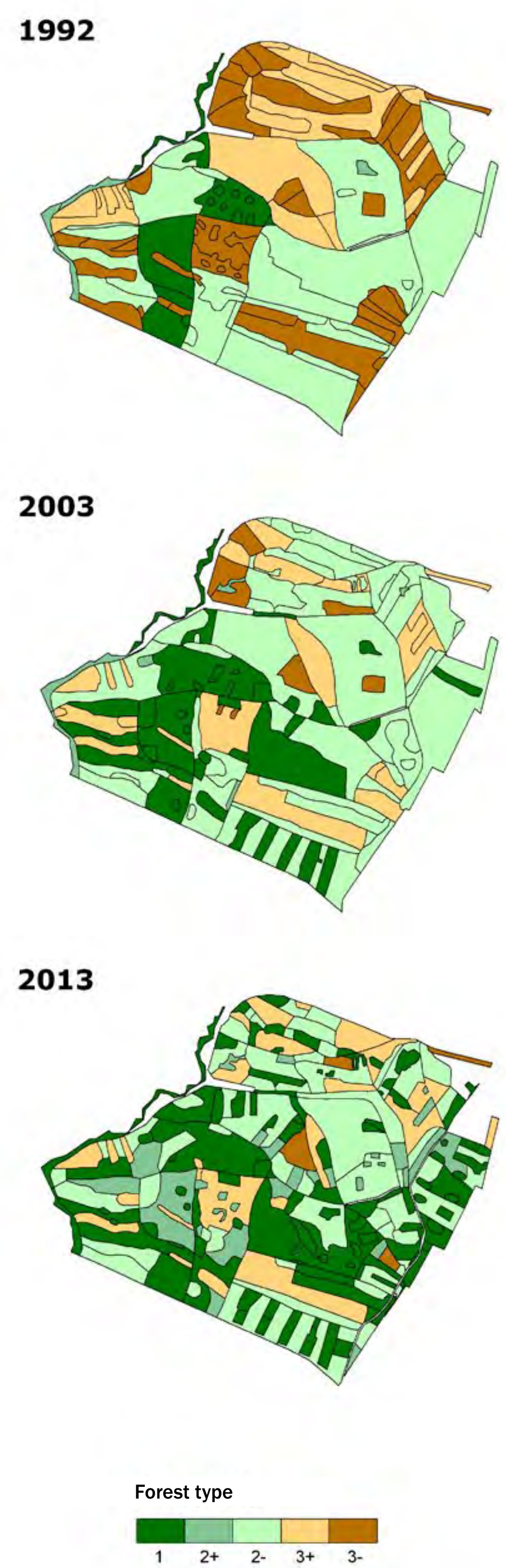


**Fig. 6.** Changes in stand texture and forest type, 1992–2013.

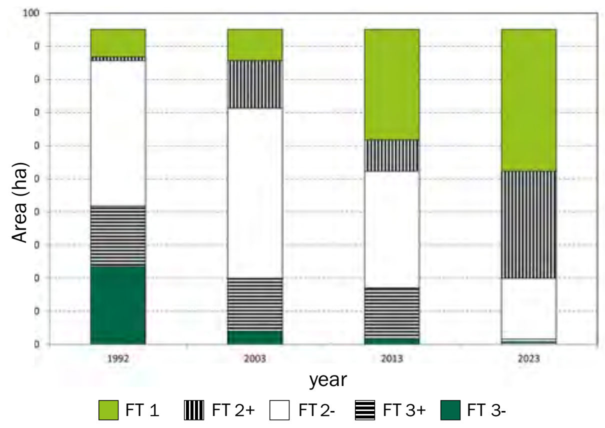


**Fig. 7.** Changes in forest type percentage at Pyramida over the years 1992–2013.

ed and underplanted in 51 groups on a total area of 7.08 ha, no increase in beech has been recorded yet, as it has not exceeded the basal diameter of 7 cm (Vrška et al. 2017).

**Changes in horizontal structure (texture)**

A gradual fragmentation and formation of a heterogeneous spatial structure is visible from Fig. 6. The allocation of restoration felling in formerly large uniform stands is apparent here. These patches are used to a) introduce missing beech and b) make space for and restore interspersed hardwoods in older stands with prevailing pine or sometimes spruce. An analysis of number and size of the patches shows quantitative changes (Fig. 5). Initially (1992), prevailing patches in the category of 3.01–7.00 ha covered 43.4 ha (46% of the area). Now they are replaced by the dominating category of 0.51–1.50 ha, created by fragmentation of the large stands, covering 35.8 ha (38 % of the area) in 2013. Also a more than doubling of the number of patches in the category of 0.02–0.20 ha from 43 in 1992 to 107 in 2013 (Vrška et al. 2017) is evident.

**Changes in forest type representation**

The development of the spatial distribution of forest types at Pyramida is shown in Fig. 6. In the southern half of the area a faster transition to the target forest types (1, 2+) can be observed, which is caused by a better initial state of the stands in 1992. The realised patch cutting measures have not only created a fine spatial structure (see Fig. 6), but the stands have also shifted towards the target forest type by supporting target trees and supporting natural regeneration of autochthonous species.

A quantification of changes in plots of different forest types (Fig. 7) shows a continual increase in Forest type 1 from 9 to 45% of the area in 2013. An opposite trend is clear for coniferous stands (Types 3- and 3+) with prevailing pine, which formed just a minor part of the Pyramida area (2%) in 2013. Also the hitherto even representation of Forest types 2- and 2+, functioning as transitional forest types during the conversion (Vrška et al. 2017), is evident.

## New insights and recommendations

From the silvicultural point of view, complete conversion to the target forest types (1 and 2+) was realised during 20 years on a total of 34.5 ha (36%) of the Pyramida site. From the observed course of conversion it is realistically expected that the conversion will be completed in 66.8 ha (70%) of the area 30 years after the start. If we add the 8.3 ha large (9%) area in which no conversion was needed, the total area of Forest types 1 and 2+ will amount to 75.1 ha (79%) after 30 years of conversion (Vrška et al. 2017). Completion of the conversion of the remaining area, mostly consisting of initial Forest types 3- and 3+ in larger stand groups, will take longer. An educated guess is 50 years.

**Fig. 8.** Coniferous pole-stage stands (here prevailing pine with admixed larch) from the 1980s need not be 'eliminated' to establish new even-aged hardwood stands. In contrast to spruce, pine and larch do not create (not even at full canopy) a dark environment in a stand. Gradually and spontaneously regenerating hardwoods (hornbeam, birch, oak, etc.) can be used for stand conversion, which create an irregular structure and lead to a near-natural stand in the future. Partly also use can be made of the production potential of pine, which is gradually felled (making space for hardwood species), minimising the costs of restoration thanks to natural regeneration. (P. Lazárek)

Conversions of forests stands with the aim of modifying their state for the needs of nature conservation require an active attitude and often mean a higher intensity but also frequency of the necessary measures. However, this enables us to create and modify forests stands with a primary biodiversity conservation function according to need and at sites where this is a strategic objective. To achieve this, it is essential that biologists and foresters accept each other's views (e.g. by means of a practical and understandable manual for stand conversion) and make constantly rounds in forest stands, combined with marking trees and preparing measures.

## Acknowledgements

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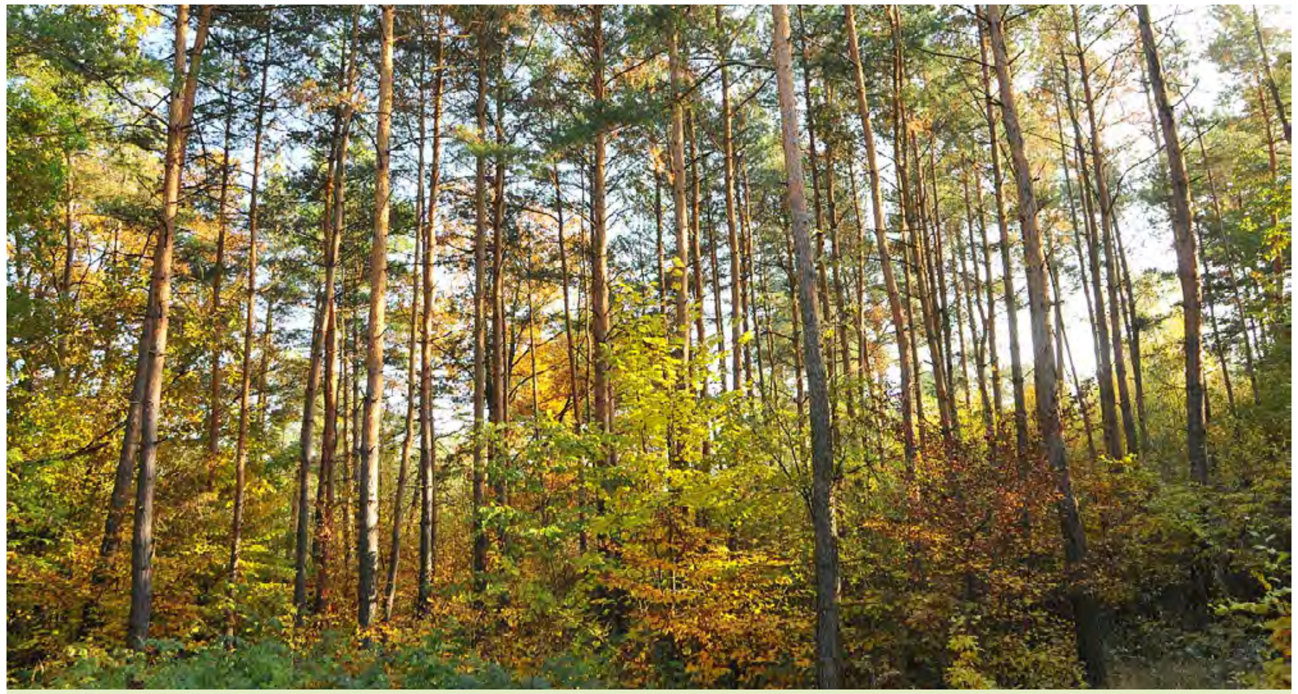

**Fig. 9.** Imminent high pine forests are an ideal growth stage for conversion: they provide sufficient light to hardwood seedlings and at the same time create mechanically stable shelters against heavy snow, which is the greatest risk for these seedlings. (P. Lazárek)

# Long-term vegetation development of sandstone pinewoods after fire and opportunities of fire management

Martin Adámek & Věroslava Hadincová

| | |
|---|---|
| Location | Sandstone areas of N Bohemia and E Saxony; elevation 200–500 m |
| Conservation status | Bohemian-Saxon Switzerland NP, Elbe Sandstones PLA, Kokořínsko PLA, Bohemian Paradise PLA |
| Restored area | Ca 100 ha in total (fire sites); 1.57 ha (vegetation records – relevés) |
| Financial support | 0 |

## Abstract
Pinewoods on sandstone are a habitat in which fires often occur. According to our current knowledge, fires can be considered as a natural component of these habitats. The aim of our research was to monitor the ability of these forests to regenerate spontaneously after fire in the long term. The pinewoods showed a considerable degree of resistance and resilience to fires, which moreover support pine regeneration and species diversity. Fire management thus appears to be a suitable measure of ecological restoration in these forests.

## Site description
The sandstone areas of the Czech Republic are characterised by a rugged relief and mosaics of forest communities. Natural factors fundamentally influencing the distribution of forest stands include steep temperature, humidity and nutrient gradients, leading from deep, shaded and cool gorges through mesic slopes to sunlit, windy and desiccating rock tops. According to the current knowledge, the natural vegetation of these areas mostly consists of acidic beech forests (*Luzulo-Fagetum*), which occur on plateaus and middle parts of slopes with rather deep soils. Thanks to the phenomenon of climatic inversion, gorges are inhabited by natural spruce forests (*Bazzanio-Picetum*), while rock tops and adjacent upper slopes with shallow soils are covered with natural (so-called relict) pinewoods (*Dicrano-Pinetum*) or pine-oak forests (*Vaccinio vitis-idaeae-Quercetum*) (Mikuláš et al. 2007). Due to intensive forest management, introduced in these areas approximately 200 years ago, the original forests have been for a great deal replaced by spruce and pine cultures. The degree of change depended on the ruggedness of the terrain: the greatest changes occurred in the best accessible areas with a flat and less rugged relief, whereas semi-natural to natural vegetation has remained preserved at badly accessible, rocky and slanting sites or on waterlogged gorge bottoms (Kačmar 2013).

An interesting phenomenon we encounter more often in sandstone areas than elsewhere is fire. Local fires are also frequently mentioned in historical records (Belisová 2006). Current palaeoecological works confirm a continual occurrence of fires in these areas during the entire Holocene (Novák et al. 2012, Bobek 2013, Adámek et al. 2015). Although most of today's fires are caused by people (tourists, work in forests), wildfires caused by strokes of lightning are no exception here. In rugged terrain, most local fires start in the driest places of elevated rock tops and southwest-facing steep slopes with *Pinus sylvestris*, regardless of the cause of the fire (Adámek et al. 2015). The occurrence of fires at these specific sites can to a certain extent be considered as a natural component of these habitats.

## Initial state
In the years 2007–2015 research into the influence of fires on forest vegetation was conducted in these areas by monitoring the spontaneous development of stands at various old fire sites. The oldest fire sites were nearly 200 years of age. The forests before the fire were semi-natural to fully artificial stands with prevailing *Pinus sylvestris,* with shrubs of *Vaccinium myrtillus* and *V. vitis-idaea* dominating in the undergrowth. Most of them were created by plantings after clear-felling 30–170 years ago and situated in the upper parts of sandstone rocks and slopes, but on relatively deep soils, where acidic beech forests (*Luzulo-Fagetum*) with admixed pine are considered to be the natural vegetation, only at extreme sites. Thanks to the badly accessible terrain, most of these stands were saved from further interventions after planting (Kačmar 2013). This has led to other tree species entering the stand and the development of semi-natural forest vegetation (Winter et al. 2010).

**Fig. 1.** Typical example of a sandstone landscape (Pravčický důl, Bohemian Switzerland NP). (M. Adámek)

## Restoration objectives
Spontaneous forest restoration after fire.

## Monitoring objectives
Eliciting how resistant pinewoods in sandstone areas are to fires of various intensity, whether and how fast they are able to cope with the effects of fire without silvicultural measures, and what influence fires have had on forest species composition and diversity in the course of nearly 200 years after fire events. For possible application of fire management as an ecological restoration tool, it would be necessary to monitor whether spontaneous forest restoration after fire leads to the desired structure and species composition of a stand.

## Monitoring methods
Field work included recording vegetation relevés in a total of 70 stands at sites where fire broke out 1–192 years ago and have been left to spontaneous development without silvicultural measures. Age and location of the sites were determined from databases of the respective forestry and nature conservation authorities. Data of more than 90-year old fires originates from archival forestry maps.

In each relevé 100 m² in size, all vascular plant and moss species and their percentage cover were recorded. Further the percentage cover of all vegetation layers were recorded including terrestrial lichens and tree seedlings. In total 157 relevés were made. Fire intensity was estimated reciprocally (only at fire sites not older than 35 years) according to the rate of fire penetration of top humus and organic soil horizon, and the height of charred tree stems. It was divided into three categories: a) Low – no fire penetration in organic horizon; b) Middle – fire penetration found, but tree stems charred not higher than 2 m; c) High – organic horizon burnt and stems charred up to >2 m. The fire site relevés were paired with comparative ones from the surrounding vegetation not affected by fire in a way that species composition and abiotic conditions best corresponded with the state of the forests before the fire. The acquired data was analysed by means of multivariate and univariate statistical methods. At the younger fire sites (1–35 years) also numbers of surviving and died individuals of each tree species >20 cm in diameter at breast height were included in the relevé records. This data was used to express the ability of trees to survive fires of certain intensity.

## Monitoring results
Fire disturbance caused almost complete elimination of the shrub layer and pronounced changes in species composition of the herb layer and mosses. Resistance of the tree layer depended on its species composition and fire intensity (Fig. 2). Small fires often just caused minimum mortality of tree species whose cambium is protected by thick bark, such as *Pinus sylvestris*, *Larix decidua* and *Quercus petraea*. By contrast, species like *Picea abies* and *Sorbus aucuparia* were sensitive to fires of low intensity. The most resistant species were *Larix* and *Quercus* (also thanks to their ability to outshoot from the foot of burnt stems), their success in surviving hardly being influenced by increasing fire intensity. Scots pine (*Pinus sylvestris*) and *Betula* spp. were more sensitive. The survival rate of these species decreased to ca 40% and 25%, respectively, with increasing fire intensity. Hardly any individuals of *Pinus strobus*, *Picea* and *Sorbus* survived fires of high intensity. The ability of *Fagus sylvatica* to survive fires was unclear due to the small number of observations. In the

**Tab. 1.** Ability of tree species to survive fire of different intensity. N is the total number of individuals of a species, Survival is the percentage of trees having survived fire.

| **Fire intensity** | **Low** | | **Middle** | | **High** | |
|---|---|---|---|---|---|---|
| **Species** | **N** | **Survival [%]** | **N** | **Survival [%]** | **N** | **Survival [%]** |
| *Quercus petraea* | 11 | 90.9 | 1 | 100 | 8 | 87.5 |
| *Larix decidua* | 28 | 71.4 | 30 | 66.7 | 14 | 85.7 |
| *Pinus sylvestris* | 287 | 81.5 | 231 | 57.6 | 122 | 39.3 |
| *Fagus sylvatica* | 8 | 62.5 | 6 | 83.3 | 4 | 0 |
| *Pinus strobus* | 5 | 100 | 19 | 36.8 | 60 | 5 |
| *Betula pendula* | 42 | 61.9 | 43 | 41.9 | 12 | 25 |
| *Picea abies* | 44 | 31.8 | 42 | 11.9 | 25 | 0 |
| *Sorbus aucuparia* | 11 | 18.2 | 0 | - | 1 | 0 |

case of small fires, it seems to be as resistant as *Betula*, but it is more sensitive to fires of higher intensity (Tab. 1).

An important factor in the degree of change in undergrowth species composition was fire penetration of the organic horizon, which released nutrients fixed to humus and damaged underground organs of dominant *Vaccinium vitis-idaea*. These then needed more time to renew their initial abundance than when the organic horizon was not penetrated by fire (Fig. 2).

In the first years after fire, the original vegetation of *Vaccinium* shrubs and a moss layer consisting of forest species was replaced by vegetation of herbs, grasses, ferns and mosses demanding relatively high soil nutrient availability. Also intensive regeneration of trees, especially *Betula* spp., *Populus tremula*, *Salix caprea* and *Pinus sylvestris*, proceeded. In later development stages, *Calluna vulgaris*, *Pteridium aquilinum*, terrestrial lichens (*Cladonia* spp., *Cetraria islandica*) and rejuvenating climax trees like *Fagus sylvatica*, *Quercus petraea* and *Picea abies* appeared in the undergrowth to a larger extent (Fig. 5).

Differences in species composition and in cover of different vegetation layers from vegetation not affected by fire were still markedly obvious 50 years after fire. After about 140 years the stand was almost indistinguishable from the surrounding non-affected stand of comparable age (Figs. 3–5). This fact indicates the ability of these ecosystems to regenerate spontaneously relatively fast after fire without the need of any silvicultural measures. At fire sites, however, a significantly higher number of species was recorded than in unburnt stands for the entire length of forest development (Fig. 6). This fact indicates a favourable impact of spontaneous forest development on its species diversity in comparison with an artificially planted forest. Release of nutrients fixed to litter before fire and the creation of an irregular stand structure have probably contributed to a higher diversity of plant species (Standovár et al. 2007). Also, various invertebrate and fungus species are associated with accumulated dead-

**Fig. 2.** Two years after a fire of low intensity. The tree layer was hardly damaged, but changes in species composition of the undergrowth are clear. Shrubs of *Vaccinium* spp. are shooting out from underground organs. Kokořínsko PLA. (M. Adámek)

**Fig. 3.** Area 30 years after fire (foreground). The newly created stand already reaches the tree layer (pine, birch). Remains of the original stand – surviving *Quercus petraea* and *Pinus*, and dead pine – are noticeable. Kokořínsko PLA. (M. Adámek)

**Fig. 4.** Forest spontaneously developed for 168 years after fire. The original fire site was probably sown with an unknown tree seed mixture without further silvicultural measures (Schleger 1970). Bohemian Switzerland NP. (M. Adámek)

wood (Marková et al. 2011, Hekkala et al. 2014, Bogusch et al. 2015).

In the course of a nearly 200-year development of pinewoods after fire, a change in the rate of rejuvenation of different tree species was observed. In the initial stages, rejuvenation of pioneer species and Scots pine prevailed, but were continually replaced by climax tree juveniles. In contrast, Scots pine rejuvenation was suppressed in later stages of succession, probably because of shading, litter accumulation and renewed dominance of *Vaccinium* shrubs (Fig. 7). Apparently, since the investigated stands are located on rather deep soils with potential occurrence of beech forests, without repeated fires the pinewoods would gradually be replaced by climax trees, which are however more sensitive to fire than pine. Fires repeated more frequently

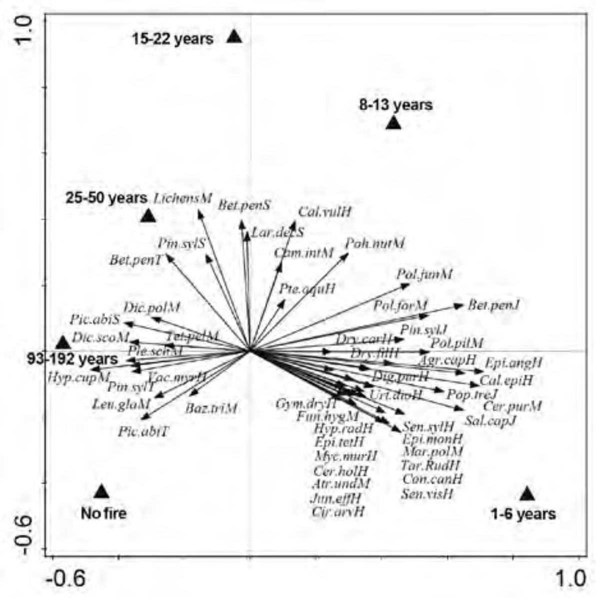


Fig. 5. Graphic output of direct ordination analysis (RDA) of 157 relevés, illustrating the development of species composition of fire site vegetation. The fire sites were divided into age categories (1–6, 8–13, 15–22, 25–50, and 93–192 years after fire) and compared with the surrounding non-affected vegetation (No fire). Plant species abbreviations are composed of the first three letters of the species and the genus name. Capitals indicate vegetation layer: T – tree; S – shrub; H – herb; M – moss; J – tree juveniles. p = 0.002, explained variability = 16.8 %. After Adámek et al. (2016).

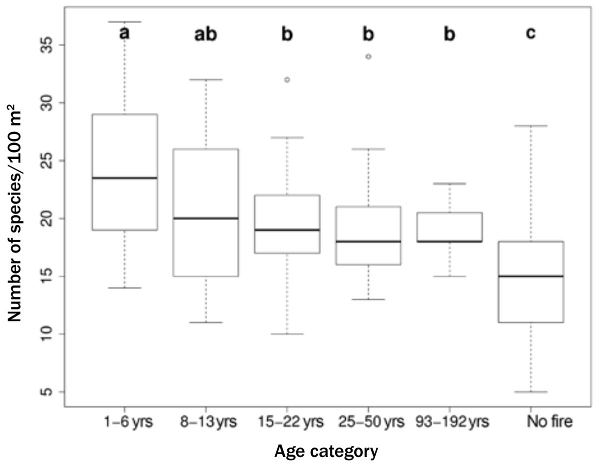


Fig. 6. Differences in species numbers at fire sites divided into age categories and in surrounding non-affected vegetation (No fire). Different letters indicate statistically significant differences between categories. After Adámek et al. (2016).

than once in 200 years can then maintain pinewoods also at these sites, similarly to the Scandinavian boreal forests, where fires support pine at the expense of the more sensitive spruce (Engelmark 1987, Angelstam 1998, Gromtsev 2002). This fact is also supported by discoveries of pine charcoal in soil profiles at these potentially 'non-pine' sites, which were dated back to the entire Holocene period (Bobek 2013). Fire

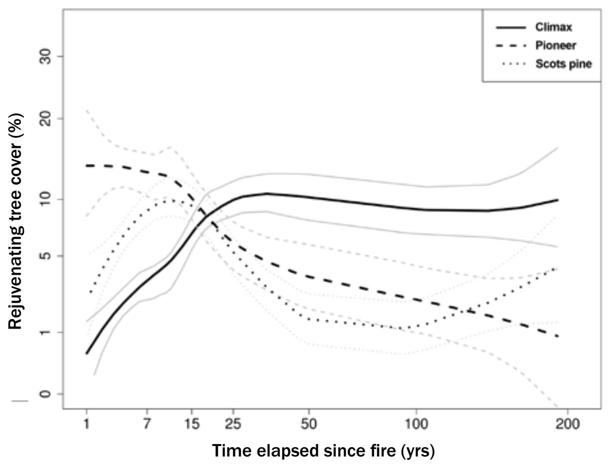


Fig. 7. Development of rejuvenating tree cover after fire. Species were divided into three categories: pioneer species, climax species and Scots pine. Visualisation by means of the local regression (loess) method. Grey lines show the standard error of the mean (SEM).
After Adámek et al. (2016).

can thus be considered an important factor maintaining so-called relict pinewoods in our landscape.

## New insights and recommendations

Minor forest areas affected by fire do not have to be artificially afforested if sufficient sources of diaspores are available in the vicinity. Such areas will develop in a way similar to artificially afforested areas, but of course a higher diversity of plants and other groups of organisms will be found in spontaneously created areas. Controlled fires could thus be a suitable measure for ecological restoration of pinewoods also in the conditions we have, for example in those possessing an inappropriate stand structure caused by intensive forest management. This is already common practice e.g. in the boreal forests of Scandinavia (Kuuluvainen et al. 2002).

## Acknowledgements


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Fig. 8. Natural restoration at Havraní skála in Bohemian Switzerland NP 10 years after fire. The stand is dominated by *Betula* spp. (M. Adámek)


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# Restoration of coppice biodiversity in southern Moravia

Radim Hédl, Vladan Riedl & Markéta Chudomelová

| | |
|---|---|
| Location | Děvín-Kotel-Soutěska NNR, Pálava PLA; elevation 240–550 m |
| Conservation status | NNR, PLA, SAC, SPA, Biosphere Reserve |
| Restored area | 28.5 ha; stronger interventions on an area of approx. 8 ha since 2013 |
| Financial support | No direct financial support; cooperation with LČR enterprise |

## Abstract

Most forest ecosystems in the lowlands of Bohemia and Moravia were historically managed as coppices. Děvín in southern Moravia, where coppicing was practised until the 1930s, is a classical example. After a nature reserve was established here in 1946, large part of the forests kept the structure of aged coppices-with-standards. A 50-year resurvey of vegetation plots from the 1950s showed a significant decline in species diversity of the plant communities. In 2009, the Pálava Protected Landscape Area Authority decided to restore traditional coppicing. Monitoring has shown a positive impact of restoration on the biodiversity of the herb layer, including the support of endangered species.

## Site description

At present, forest types at Děvín range from ravine forests to oak-hornbeam forests and thermophilous oak woods (Fig. 1), while the latter type occurs on a rather small area (Fig. 2). The stands are on average 85, some over 130 years old (Fig. 3). Almost 40% of the stands are formed by lime trees, mainly *Tilia platyphyllos*, with a strong admixture of *Fraxinus excelsior*. Other species, including *Carpinus betulus* and four oak species (*Quercus* spp.), are each represented for up to 10%, often less than 1% (Fig. 4). Although the vegetation is still quite rich in species, it is considerably impoverished compared to past times. In particular light-demanding species have declined and retreated to grow outside of the forest.

In the present Děvín NNR, forest management has a very long history. Coppices with a rotation period gradually increasing from 7 to 40 years prevailed at Děvín at least from the 14th century to the 20th century (Szabó 2010). Apparently no other type of forest management was applied. The proportion between forest and non-forest was historically more or less constant, coppices accounting for approximately 3/4 of the vegetation cover. Stands of *Pinus nigra* and *Quercus cerris* were planted to a relatively small extent in the 19th century. The traditional management was abandoned in the 20th century. The last regular coppicing took place in the mid-1930s (Altman et al. 2013). Since 1946, the area of Děvín has been a nature reserve. This is probably the reason why the forests have preserved their coppice and coppice-with-standards appearance remarkably well. Over the past 70 years, forest management has been applied at much lower intensity than in the past centuries. It is worth mentioning that a game preserve was founded in 1885 but annulled in 1996. Mainly mouflon and bezoar ibex were kept in the preserve.

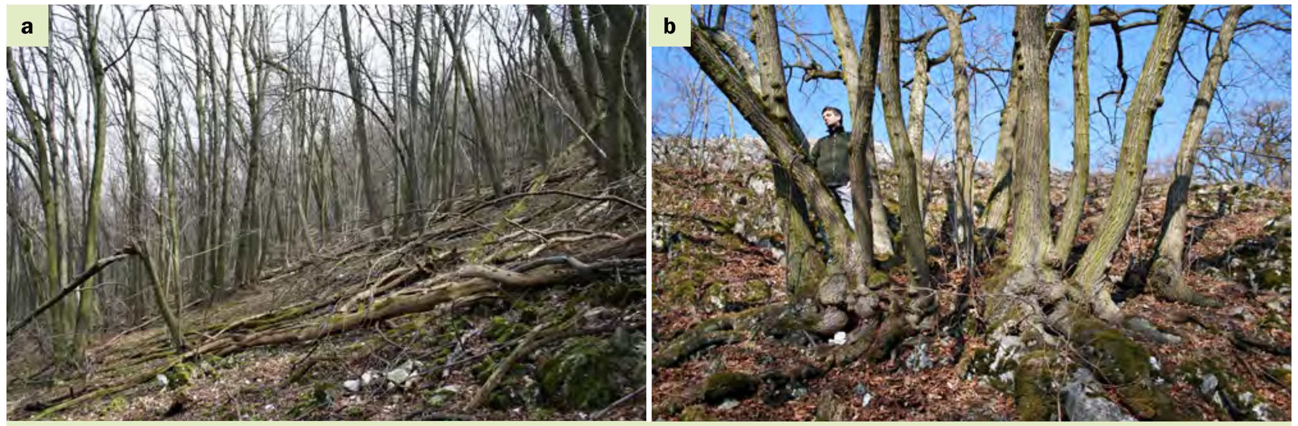


**Fig. 1.** A ravine forest covers the upper part of the northwestern slopes of Děvín. These stands are now well over 130 years old and their tree layer is beginning to break up (a). The large-leaved lime (*Tilia platyphyllos*) polycormons on the southern slopes (b) indicate the long history of coppicing management at Děvín. (R. Hédl and M. Chudomelová)

**Fig. 2.** Map of the present vegetation (adopted from Hédl 2005). Forest vegetation covers about 3/4 of the area, the rest is mostly thermophilous grasslands (in white). The most common types of forest vegetation are oak-hornbeam (light green) and ravine forests (dark green); the least represented are thermophilous oak forests (orange). Plantations of non-native tree species mainly consist of *Pinus nigra* and *Quercus cerris*, shown in grey.

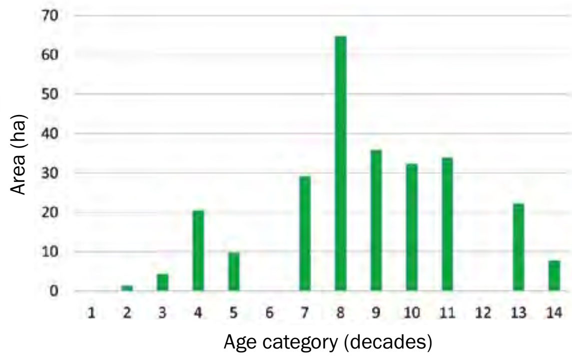


**Fig. 3.** The age structure suggests that the last regular tree cutting, at that time in the form of coppicing, was applied 70–80 years ago. This can be seen in the prevailing age of the stands of 70 years or more (horizontal axis with forest age categories) and corresponds to independently obtained data from tree rings of oak standards (Altman et al. 2013). The younger age categories are the result of constrained management predominantly in the 1970s.

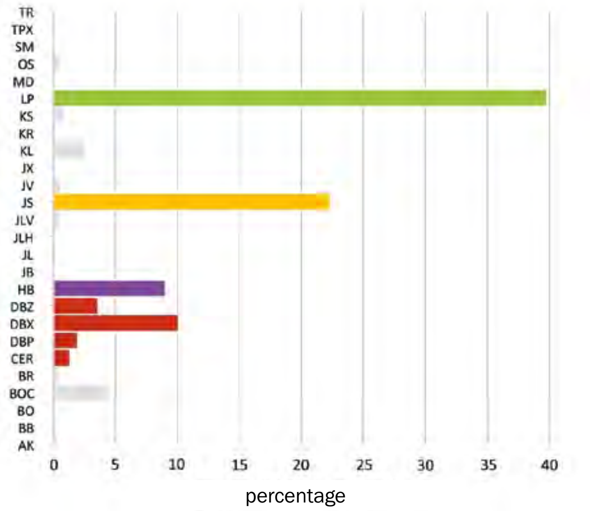


**Fig. 4.** The species composition of trees is dominated by lime (LP, green) and ash (JS, yellow); hornbeam (HB, purple). Different species of oak (DB, red) are represented up to 10%. The other 26 tree species are less abundant.

## Initial state

The abandonment of coppicing management resulted – after several decades of a 'standstill' – in aged forest, a closed tree canopy and generally moister conditions. Probably in connection with atmospheric nitrogen deposition, an increase in soil nutrients was observed. The resulting mesophication process led to a sharp decline in species richness of the plant communities in the Děvín forests (Hédl 2005, Kopecký et al. 2013). The change can be denoted as biotic homogenisation, because many species have declined, but almost no new ones have arrived. An exception is *Impatiens parviflora*, which probably did not reach Děvín until the 1960s. The overall decline in traditional management and the resulting changes in forest plant communities not only in Děvín, but also in the neighbouring Milovice Forest, which historically fell under the same authority (Mikulov Dominion), has been documented in several papers (Chytrý & Danihelka 1993, Hédl et al. 2010, Müllerová et al. 2014, Müllerová et al. 2015).

## Restoration objectives

Restoring the coppice communities and increasing the biodiversity of forest communities in Děvín-Kotel-Soutěska NNR. A specific objective is to support the populations of thermophilous and light-demanding species of forests and forest fringes.

## Monitoring objectives

Capturing the long-term development (decades) as well as short-term dynamics (yearly and seasonal) of species and communities of forest vegetation in Děvín NNR.

## Measures applied

Selected stands have been thinned since 2009 (Fig. 5). In 2009 to 2012, the intensity of the interventions was limited by the forestry legislation, which did not allow for lowering of the canopy closure below a factor of 0.7 (Figs. 6 and 7).

Only after the release of special measures for so-called special-purpose forests, more intense thinning could be carried out, which significantly changed the spatial structure of the forest. More pronounced canopy thinning was introduced in the winter of 2015–2016 on an area of 8 hectares (Fig. 8). Primarily invasive *Robinia pseudoacacia*, *Fraxinus excelsior*, *Tilia* spp. and *Carpinus betulus* were removed. Except for a few trees, all oaks, forming the top layer in the former coppice-with-standards and currently reaching an age of over 100 years, were saved.

## Monitoring methods

In order to describe and monitor the development of forest communities, permanent plots have been established in Děvín since the 1950s. This work was first carried out as part of a forest typology survey by Jaroslav Horák between 1953 and 1964. The results were summarised in Horák (1969). The vegetation data from about 180 plots captured the state of forest plant communities not long after the coppicing management had been abandoned. Approximately 50 years later, in 2002 to 2004, all plots were revisited and vegetation in them recorded using the same method (Hédl 2005).

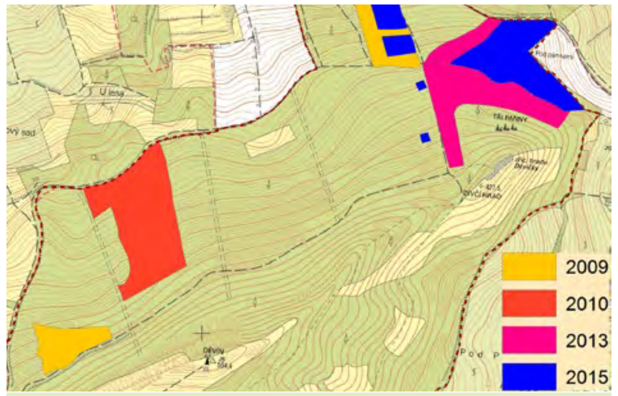


**Fig. 5.** Map of the northern part of Děvín-Kotel-Soutěska NNR, highlighting management interventions carried out between 2009 and 2015. The intensity of interventions was gradually increased over time. Monitoring plots were established in the northeastern corner of the area in 2015. The impact of coppicing restoration on the diversity of forest undergrowth was already observed after the first year.

**Fig. 7.** Trunks harvested from stands on the northern slope of Děvín in winter 2013–2014. Photo taken in May. (R. Hédl)

A network of 75 permanent plots monitored every five years was established in 2008. These are squares of 15 × 15 m including five circular subplots with a radius of 1 m, where the soil and canopy properties are measured. Part of the plots is monitored annually, and in 2016 this subset was expanded by adding plots in the freshly thinned stands. Four additional subplots were added symmetrically to the existing 5 subplots in order to better estimate the variability of the observed variables within each plot. Vascular plants and epigeic spiders, beetles and ants are monitored.

The plots are part of the LTER monitoring network (www.lter.cz). They are the result of long-term cooperation between the Institute of Botany of the Czech Academy of Sciences and the Nature Conservation Agency of the Czech Republic (Pálava Protected Landscape Area).

## Results

During the second half of the 20th century, as mentioned above, environmental conditions changed and the species diversity of plant communities consequently declined in the forests of NNR Děvín (Fig. 9). These changes can directly be linked to the abandonment of traditional coppicing management. Attempts to restore coppicing by thinning of the tree overstorey in the winter of 2009–2010 have led to promising results. Communities of vascular plants and spiders were recorded in 2010 and 2011, showing positive effects of canopy thinning on functional diversity (Šipoš et al. 2017).

Data from the plots established to monitor the impact of the restoration of coppicing, established in 2016, so far just shows the initial conditions for vascular plants. Material collected for invertebrates is in the process of identification (March 2017). These data, however, allow for comparison of species richness between plots where no thinning was performed and plots where thinning was carried out at moderate intensity in 2013, and at high intensity in the winter of 2015–2016. The vegetation responded immediately with an increase in number of species (Fig. 9). Newly appearing species are often annuals which reach the forest through diaspores (seeds, fruits) from the surrounding agricultural landscape and, if they get the opportunity, germinate immediately. Besides annuals, the endangered *Vicia pisiformis*, apparently persisting in the soil seed bank, was repeatedly recorded in the thinned plots.


**Fig. 6.** Appearance of the stands thinned in 2013. It corresponds to a moderate coppice restoration intensity (Type B), presented in the analysis of the effect on the biodiversity of the herb layer. (R. Hédl)

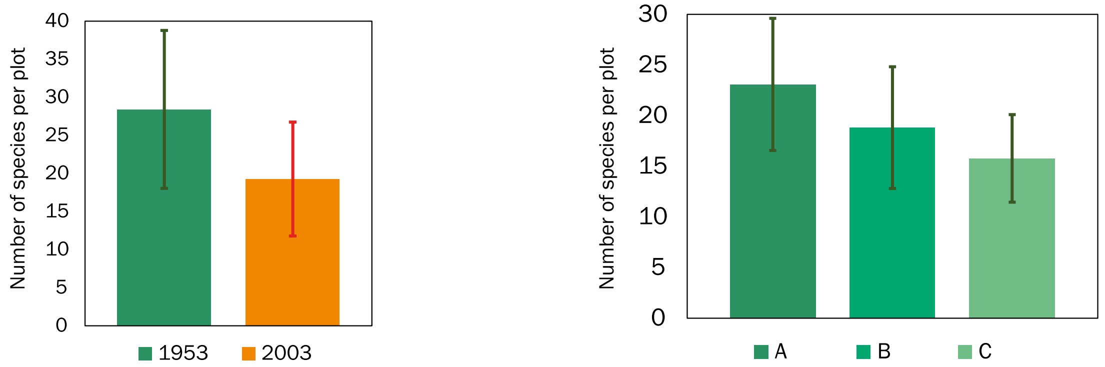


**Fig. 8.** Changes in diversity of plant communities in forests of Děvín-Kotel-Soutěska NNR. Diversity is expressed as the number of herb species in the forest undergrowth in plots of a standard size. Graphs show average values (columns) and standard deviations (vertical bars). Plots are hundreds of $m^2$ (left graph) and 3.14 $m^2$ in size (circles of 1 m radius; right graph), respectively.

The left graph shows the decrease in the number of species in plots resurveyed after fifty years, when the intensity of management significantly decreased. The difference is statistically significant when using the paired t-test ($t = 10.10$, $p < 0.001$, $n = 122$).

The right graph shows the positive effect of intense (A) and moderate (B) thinning on the number of species compared to control areas (C). The effect of management intervention is statistically significant (ANOVA, $F = 18.25$, $p < 0.001$; Tukey HSD test, $p < 0.05$, $n = 45$).

**Fig. 9.** Appearance of forests strongly thinned in winter 2015. It corresponds to a heavy coppice restoration intensity (Type A) used in the analysis of the effect on the biodiversity of the herb layer. Photo taken in April 2016. (J. Kmet)

**Fig. 10.** Cowslip primrose (*Primula veris*) flowering in the spring of 2015 in plots where canopy thinning was performed in 2013. (M. Chudomelová)

**Fig. 11.** The yellow anemone (*Anemone ranunculoides*) is another typical species of the spring aspect of Děvín forests. (M. Chudomelová)

The most important outcome, however, is the support of the diversity and fitness of light-demanding forest species. A typical example is *Primula veris*, for which abundant flowering was recorded after thinning in 2013 and 2015 (Fig. 10). *Dictamnus albus*, which is otherwise almost confined to forest-free rocky steppes nowadays, was found in bloom in intensely thinned plots. This perennial herb has been able to survive decades of unfavourable conditions in the form of underground rhizomes.

## New insights and recommendations

An important finding in terms of restoration of coppice biodiversity is that the vascular plant communities respond very rapidly with an increased number of species. With a few exceptions these are not synanthropic species, but light-demanding species of forest communities. This reaction is the strongest about 2–3 years after the cutting, and will probably dissipate in the following 5–10 years. In order to restore the biodiversity of the communities linked to coppiced forests, it would be necessary to harmonise the needs of nature conservation and forest management so that at least part of the forests of Děvín NNR is coppiced at regular intervals of for example 25 or 30 years. To achieve this goal, it is necessary to revise the list of conservation objectives in the NNR and also to secure the distribution of wood products, at best among the local community. There are examples from neighbouring countries where coppicing management was restored at municipal property (Gerolfing Municipal Forest, www.bnn.pan-gmbh.com/faltblatt/Gerolfing02.pdf). State ownership, unfortunately, does not appear to be an ideal option in such cases. Although the LČR state enterprise partly develops efforts to modify the forest management at Děvín, its prime objectives are motivated economically.

## Acknowledgements

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# Restoration of management and communities of coppices-with-standards in southern Moravia

Radim Hédl, Dušan Utinek, Markéta Chudomelová & Jan Šipoš

| | |
|---|---|
| Location | Utinkův háj, Municipality of Čejkovice, Znojmo District, 48°53′05″ N, 16°15′06″ E; elevation 230–235 m |
| Conservation status | Regional Biocentre No. 111 in the Principles of Territorial Development of the South Moravian Region; special purpose forest for biodiversity conservation and significant for forestry research and education |
| Restored area | 2 ha |
| Financial support | Support of forest management only (provided by the South Moravian Region) |

## Abstract

Restoration of forest biodiversity at lower and middle altitudes implies the reintroduction of traditional management in the form of coppices and coppices-with-standards. So far, this has been realised only seldom, mostly in protected areas. An exceptional opportunity to observe the development in the conditions of a forest established around the mid-20th century is Utinkův háj, a private property near the town of Znojmo. Monitoring conducted in 2012–2016 showed an immediate reaction of the herb layer already in the second year after converting the stand to a coppice-with-standards. The increase in biodiversity was positively linked to the intensity of tree canopy thinning and was mostly due to ruderal annual species. The dominant factor affecting the species composition and structure of the herb layer was the dominant tree species, in this case *Quercus* or *Tilia*.

## Site description

In the first half of the 20th century, the site was still farmland. Shrubs and trees occurred only in part of it (http://kontaminace.cenia.cz). In the period after World War II, grassland was planted with oaks (*Quercus robur* and *Q. petraea*), *Tilia cordata* and partly *Robinia pseudoacacia*, *Juglans regia* and *Ulmus* spp. A part of the forest, measuring 4 ha, was purchased by D. Utinek in 2009 with the intention of converting high forest to coppice-with-standards forest. The traditional way of forest management, historically strongly prevailing in southern Moravia (Szabó et al. 2015), is thus being introduced at a locality where probably no forest occurred in the past. The first part of the conversion took place on an area of 2 hectares in the winter of 2011–2012 (Figs. 1a, b).

## Initial state

Utinkův háj is ecologically different from other currently restored coppices or coppices-with-standards. There are virtually no typical forest species in its undergrowth. These were not even found in the soil seed bank (M. Chudomelová, unpublished data). This situation is interesting and unique in the sense that restoration of traditional forest management

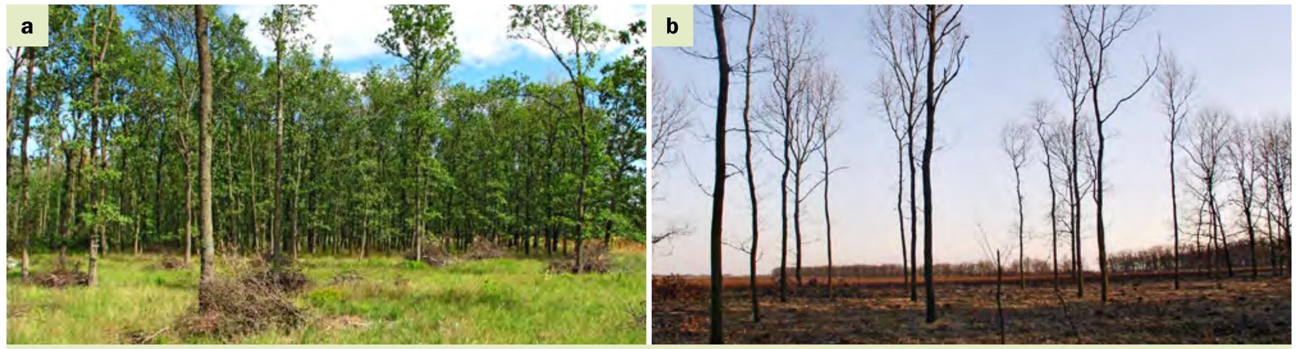

**Fig. 1.** Forest in Utinkův háj just after conversion to a coppice-with-standards forest – strong intervention variant. (R. Hédl and D. Utinek)

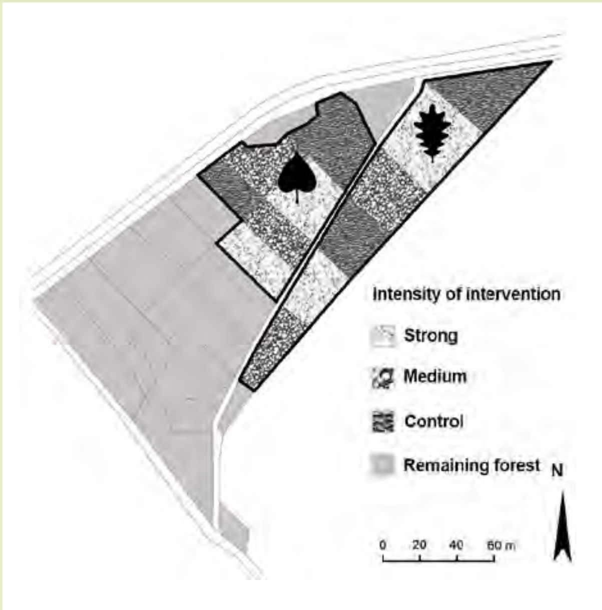


**Fig. 2.** Map of Utinkův háj from winter 2011–2012, showing the conversion to a coppice-with-standards. The forest is divided into a part dominated by lime and a part dominated by oak (leaf symbols). Monitoring plots, in which the composition of the herb layer is recorded every year, were set up in conversion blocks. The main road Pohořelice–Znojmo runs along the northern side of the forest.

practically always applies to forests with long-term continuity (so-called ancient forests, as defined by Szabó & Hédl 2010). It starts from scratch, making it interesting to observe how populations of light-demanding organisms gradually colonise the forest from the surrounding landscape. It is very difficult to predict how long forest species will need to arrive and colonise the site.

In addition to this, the site offers another interesting aspect: *Quercus* dominance in one part of the forest in contrast to *Tilia* dominance in the other. The dominant tree species has a major influence on the availability of light and on soil conditions. This had resulted in a completely different appearance of the herbaceous undergrowth even before the coppice-with-standards was introduced.

## Restoration objectives

Creating an ecologically and economically stable forest system with a short rotation period, providing regular supply of fuelwood. This system is a coppice with oak trees as standards.

Partial goals:

- Creating an ecologically stable, permanently yielding and balanced forest property.
- Reducing the proportion of *Robinia* in stands where natural woody species are represented, and especially preventing *Robinia* from entering other stands.
- Creating conditions for biotic communities of open forests by means of converting the forest to a coppice-with-standards.
- Gaining experience with conversion of an originally high forest to a coppice-with-standards forest both in terms of management characteristics and its significance for biodiversity.

## Measures applied

The conversion to coppice-with-standards included two types of intervention and a control in two forest stand groups, one with dominant *Quercus robur* and the other with prevailing *Tilia cordata*. Each type of intervention was carried out in two replicates in both stands. A strong intervention type included felling with preservation of standards, i.e. direct conversion to a coppice-with-standards. The number of standards left is relatively high (more than 100 trees per ha) due to the age of the stand (about 50 years) when the conversion was initiated. An intermediate type of intervention led to the elimination of about 25% of the wood stock and was thus a form of canopy thinning. For the time being, the control stands have been left without intervention (Fig. 2). It is the same design of interventions as was realised in the Municipal Forests of Moravský Krumlov in 1999 (e.g. Utinek 2004, Vild et al. 2013). All trees were measured with standard methods prior to intervention.

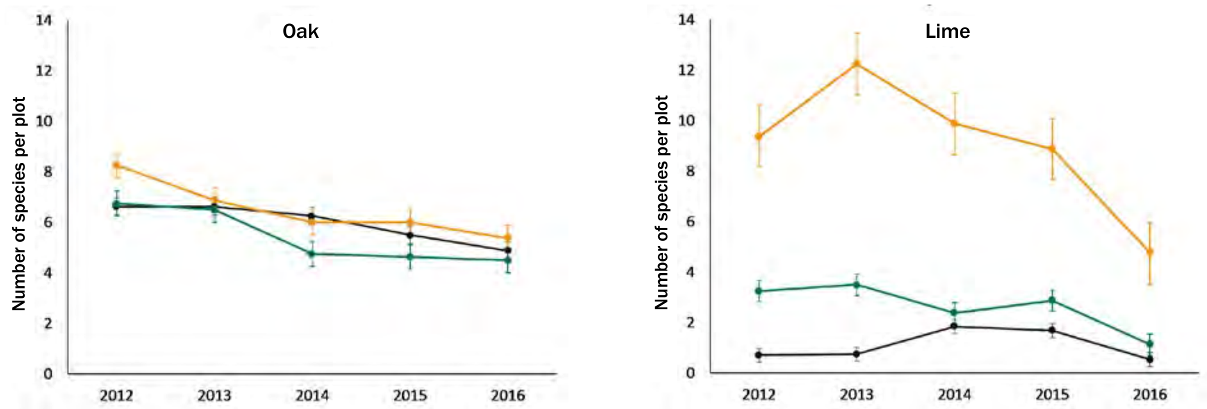


**Fig. 3.** Development of number of species in plots of 3.14 m² (N = 48), half of which are in the oak-dominated forest, half in the linden-dominated part. Three variants of conversion to coppice-with-standards include strong intervention (red lines), intermediate intervention (green) and a control (black). For a description of the types of intervention, see Measures applied. Mean values (dots connected by lines) and standard errors of the mean (vertical lines) are shown.




**Fig. 4.** Rejuvenation of lime from sprouts immediately after the overstorey was opened: in 2012 (a), when the number of species in the herb layer had increased stepwise; in 2014 (b), when lime sprouts were already dense trees of over 3 m tall. (R. Hédl)

## Monitoring objectives

Determining the influence of canopy thinning of various intensity in contrasting stands of lime (*Tilia*) and oak (*Quercus*) on the yearly dynamics of species composition and diversity of vascular plant communities.

## Monitoring methods

Since the first vegetation season following the management intervention, the development of the herb layer has been monitored. Species composition and abundance of vascular plant species were documented in 48 plots of 3.14 m$^2$ (1 m radius) for five seasons (2012 to 2016). An entomological survey has been carried out since 2016 to determine the influence of canopy thinning of various intensity on invertebrates, but no evaluable data are yet available.

## Results

Development of the species richness of the herb layer in the years 2012 to 2016 is shown in Fig. 3. The influence of the tree species (oak or lime) in the overstorey was essential. Restoration of a coppice-with-standards in the oak stand had a negligible influence on species richness, while under lime an immediate and conspicuous increase in number of species as well as cover of the herb layer could be observed. Canopy thinning had mainly an impact on the annual ruderal species which usually accompany the opening of a forest overstorey. Diversity, expressed as the number of species in plots in the first (2012) and second (2013) vegetation season significantly increased. However, perennial grasses responded to the canopy thinning in their cover as well. In the following years (2014–2016), diversity at the plot level decreased again, as shading by *Tilia* sprouts increased (Fig. 4). The results have been published in Hédl et al. (2017).

## New insights and recommendations

It has been demonstrated that the knowledge of the impact of restoration of traditional forest management, here particularly coppicing, cannot be easily generalised. In our case, the tree species in the overstorey have been shown to be a major influence. Remarkably fast dynamics were observed under *Tilia*, while the vegetation under *Quercus* reacted much slower and not so strongly. Another, rather expected finding is that the annual species which arrived in the seed rain from the surrounding landscape, or possibly emerged from the seed bank, reacted instantly to the canopy thinning. These species include e.g. *Conyza canadensis*, *Cirsium vulgare*, *Myosotis arvensis*, *Erigeron annuus*, *Polycnemum arvense* and *Stellaria media*. If the aim of restoration is to support rare and endangered species, patience is essential – especially in the case of secondary forests. Continuation of the experiment and its extension to the remaining forest is planned for 2022. The entire system should function for decades, so there will be enough room to assess the long-term effects of coppice management.

## Acknowledgements

Monitoring of vegetation in permanent plots was carried out with the support of the ERC-LONGWOOD project. We would like to thank O. Vild for collecting field data.

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# Ecological restoration for the benefit of a critically endangered butterfly

Antonín Krása

| | |
|---|---|
| Location | Kolín District, Dománovický les; elevation 222–269 m |
| Conservation status | SAC, NR |
| Restored area | 10.6 ha |
| Financial support | ME Landscape Management and Restoration Programmes, state budget – financial compensation for impeding forest management due to restrictions by nature conservation, sources of the Central Bohemian Region Authority |


## Abstract

Dománovický les is the only site in Czechia where scarce fritillary (*Euphydryas maturna*) has survived to date. However, this butterfly of sparse forests, whose caterpillars feed on ash, used to find itself on the brink of extinction also here. Therefore, a rescue programme was adopted in 2011 under which a whole range of measures have been realised, manifesting itself in growth of this butterfly's population. Thanks to that, this fritillary is not directly threatened with extinction today.


## Site description

Dománovický les is a sort of open-air museum of Central European forestry. This is by virtue of the relative diversity of this site, where several types of forest communities alternate on an area of ca 355 ha. Various silvicultural measures realised in the past hundred years have played a significant role in creating its current appearance.

**Fig. 1.** Scarce fritillary (*Euphydryas maturna*), male. (A. Krása)

Hercynian oak-hornbeam forests are the most widespread community, but also dry and moist acidophilous oak forests, basiphilous thermophilous oak forests and small treeless patches are found here. Dominant trees of the natural composition here are *Quercus robur*, *Q. petraea*, *Tilia cordata*, *Carpinus betulus* and *Fraxinus excelsior*. Other species are present in smaller number. *Cornus sanguinea* and *Ligustrum vulgare* are important and common in the shrub layer. The herb layer is very species-rich in many places. A whole range of endangered and protected species grow here, e.g. orchids, the most significant of which are *Cypripedium calceolus* and the rather rarely occurring *Orchis purpurea* and *O. militaris*. The older hardwood stands are rather rich in structure and include many age classes, are locally quite dense and shady, while they are more open to thin with sufficient light falling into them elsewhere.

Besides these, also non-indigenous spruce forests, locally accompanied by *Pinus sylvestris* and *Larix decidua*, can be found here, just as rather old stands of *Quercus rubra* and *Q. cerris*. *Q. rubra* is somewhat problematic, as it has the tendency to rejuvenate and invade the surroundings. There are older, roughly eighty-year old spruce stands as well as younger, roughly forty-year old ones. The most extensive old stands have for a great deal been felled, but younger ones still form large compact tracts. This leads to fragmentation and isolation of micropopulations of many local species and complicates their spreading, which also counts for scarce fritillary (*Euphydryas maturna*, Fig. 1).

In the Czech Republic, this fritillary only occurs at Dománovický les. Earlier it went extinct in the Elbe lowlands and southern Moravia. Its caterpillars mainly feed on ash, but in spring they also eat, to a lesser extent, *Ligustrum*. For adult butterflies richly flowering shrubs (among others *Cornus sanguinea*) and herbs, from which they obtain nectar, are indispensable. Eggs are most often deposited on moderately shaded young ash trees of about 2 m tall, but not exclusively. However, the fritillaries avoid dense shady stands as well as all places where there are not enough host plants. In the



**Fig. 2.** Mixed stand before reconstruction. (A. Krása)

**Fig. 3.** Area after stand reconstruction. (A. Krása)

years 2009 and 2010, when just a few butterflies and their egg batches were observed and found, this species found itself on the brink of extinction in the Czech Republic.

## Initial state

In the past century, Dománovický les underwent a pronounced transformation, just as most of our mixed and hardwood forests. Its appearance, not only its structure and light conditions, but also age and species composition, distinctly changed. All this was the result of gradual conversion of originally middle and low forests to high forest. The forests were felled less and less frequently than in the past, and tree rejuvenation was not used anymore in regeneration; new stands were generally of seed origin. Retained older hardwood stands gradually changed into false high forests, created by preserving the initial coppice forests. This is confirmed by e.g. abundant polycormons or deformed stems close to the ground, and also by remains of standards of a generation older in some stands. In this way, initially sparse forests became much denser and darker, leading to markedly worse conditions for many of the local plants and animals, particularly scarce fritillary.

Another negative measure was widespread draining. Even though the SAC site is slightly higher than the surrounding landscape, there seems to have been a problem with waterlogging here, as the whole area has a network of up to 2 m deep channels to drain water from the forest. However, today water is rather lacking here.

## Objectives

Successively replacing inappropriate stands with more suitable ones, reversing undesirable trends (forests growing denser and darker, replacement of indigenous trees by non-indigenous ones), diversifying site conditions and improving the site as a whole to the benefit of sparse forest species, primarily scarce fritillary.

## Measures applied

The different measures are summarised in Tab. 1, important details are given below.

Regular thinning is realised on a clearing which is being encroached. This is not ideal from the silvicultural point of view, because the planted oaks do not thrive, whereas the ash stand is locally too dense. Individual trees are cut away to

**Tab. 1.** Overview of realised measures.

| Measure | Area (ha) / Number | Number of plots | Realised | Measures applied |
|---|---|---|---|---|
| Regular thinning | 0.32 | 1 | 2011–2016 | Elimination of non-target trees and selected ash trees in places where they create a dense stand or where they are too large |
| Canopy opening | 8.63 | 23 | 2011–2013 | Lowering stand density to a level of 0.7, support of ash rejuvenation or additional planting of ash saplings |
| Changing species composition | 1.03 | 2 | Winter 2011 | Planting of target trees (oak and ash) in place of a felled spruce stand; realised in stands of felling age |
| Stand reconstruction | 0.63 | 1 | Autumn 2013 | Elimination of undesired trees (here: conifers and *Quercus rubra*) replaced by target trees (oak and ash); realised in stands of pre-felling age |
| Adding ash trees | 800 | | 2013 | Additional planting of ash saplings on older clearings where lacking |

create a low open stand. The intensity of this measure has to increase every year.

Canopy opening relates to the older forest aged ca 60–80 years. It is planned in several phases, only the first one of which has been realised. In the second one, which will follow after 5–10 years, stand density should decrease to a level of 0.5 (simply said: about half of the trees will be cut). Places where seedlings or planted saplings become too dense or rejuvenation is strong require thinning, the intensity of which depends on the situation.

Stand reconstruction has been applied to several forest types, its implementation differing per type. The primary aim was to eliminate individual conifers from mixed stands with ash (Fig. 2, result in Fig. 3). Areas covered with spruce pole stands and *Quercus rubra* were however felled completely. Planting was carried out with standard *Quercus robur* saplings and large-sized ash trees. Felling of premature stands required permission of the National Forestry Authority according to § 33, par. 4 of Forest Act No. 289/1995.

Additional planting of ash trees (ordinary ones and large saplings) on older clearings is realised despite the spread of ash withering and dieback caused by the fungus *Hymenoscyphus fraxineus* (anamorph *Chalara fraxinea*). From the purely silvicultural point of view this is an ineffective measure, but for the scarce fritillary even a few-year survival of saplings is sufficient and not replaceable otherwise.

All measures require fencing, which eliminates the negative effects of deer browsing.

## Monitoring methods

The state of the scarce fritillary population has been monitored annually since 2011. Basic information on the numbers of mature butterflies (imagoes) is provided by transect monitoring carried out in June. In 2016 we also used the Mark and Recapture Method. In July and August, egg batches and so-called caterpillar nests (created by spinning leaves together), are checked. In this way their number as well as the number of trees on which they occur are determined.

## Results

Regular thinning (see Tab. 1, Fig. 7) is successful because it prevents abundant growth of juveniles. This plot is therefore still one of the two most important ones as for number of detected scarce fritillary imagoes and egg batches.

Canopy opening (Fig. 8) has also provided positive results, albeit with a delay of several years after the measure was realised and despite the great differences between and inside plots. This holds for the growth of seedlings and planted saplings of ash as well as their utilisation by the fritillary.

Changing species composition (performed after felling) has not provided any positive results yet. The stand cannot be considered as established because it was affected by drought and late frost in the year after planting. The ash saplings have remained too small, so that the fritillary has not yet started to employ them.

On the other hand, stand reconstruction (performed in young stands) is definitely successful. While the state of the stand was gradually deteriorating before the intervention and the number of butterflies and egg batches was declining, a dramatic reversal for the better took place after it. The planted large-sized trees generally took root and the butterflies started to employ them immediately in the next season (Fig. 5). This positive effect is evident to date (Fig. 6).

The effect of adding ash trees (ordinary small saplings) on older clearings will manifest itself in a longer term, but these saplings have already been used for laying eggs in several places. Hence also this measure can be considered successful.

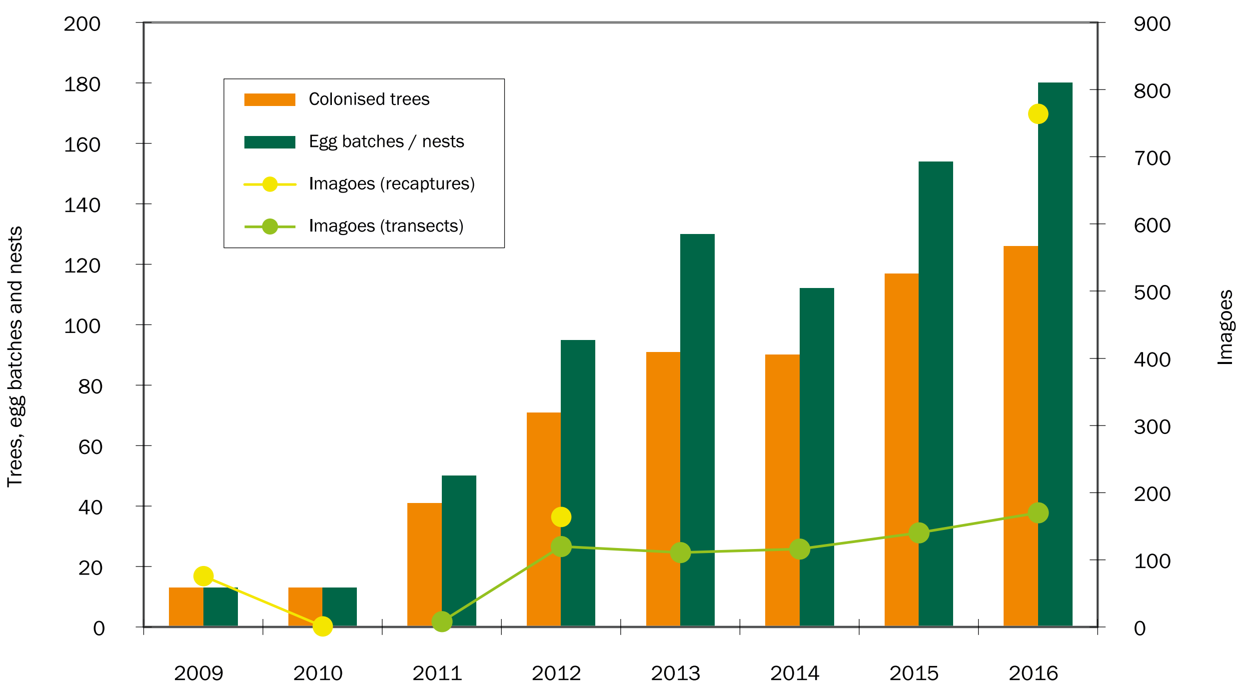


**Fig. 4.** Development of scarce fritillary population density in the years 2009–2016.

During 6 years all planned measures have been realised and the area of appropriate stands has been expanded distinctly. Most interventions can be considered successful, except for changing species composition. It has led to an increase in the diversity of site conditions of Doménovický les as a whole, meeting all specified objectives, even if these measures need to be carried out also in the future. The success of the performed measures is best shown in the graph of scarce fritillary population growth (Fig. 4).

The fritillaries now have a wide choice of microsite conditions, which they employ differently. To our surprise they thrive well in the open area where reconstruction was realised, but they are more sensitive to weather abnormalities (downpours etc.) here. It is therefore necessary to have adjacent plots which are better covered by tree crowns.

## New insights and recommendations

- The planting of larger saplings, on which the butterflies laid eggs in the next season, has proved to be a good measure. By contrast, regular planting material needs several years to reach an appropriate size, so the butterflies cannot employ them immediately.
- It was also demonstrated that smaller interventions at sites away from earlier felled and afforested plots are better, as bad weather can easily have negative effects in larger and more open plots, whereas these are more moderate in small plots. Also the timing and location of the intervention with regard to the species' distribution centre are key factors. The reconstruction was carried out in the time of rather strong population growth and beginning expansion (even though only locally), moreover in the vicinity of plots where up to ten butterflies occurred, whereas species composition change was performed shortly after a population collapse, when only a few butterflies lived in the vicinity. All this manifested itself in the great success of reconstruction, while species composition changes have hitherto been unsuccessful.
- Concerning canopy opening it was clearly demonstrated that stands with *Quercus rubra* are absolutely unpromising regarding its rejuvenation because its sprouts were found to suppress ash seedlings and saplings in places where it grows. Plots close to the fritillary's population centres were used sooner by the butterfly, while the ones farther away were used later or not yet at all. This is also related to the fact that the current realisation of this measure in a large number of plots is rather counterproductive. It takes the butterflies time to colonise the most distant ones, so it is better to perform the measure gradually from the centre of occurrence towards the periphery.
- In the case of thinning and adding ash on old clearings, the benefit for the scarce fritillary population is obvious. It is however clear that also these measures have contributed to a diversification of the environmental conditions.

Each of the measures has provided partial positive results, but they function best as a complex. The diversity of approaches and their realisation in small parts, but continually, is thus the most important experience and a recommendation for the future. To provide the survival of scarce fritillary in the Czech Republic a long-term perspective, however, its reintroduction at other localities in the Elbe lowlands needs to be initiated.

**Fig. 5.** Ash saplings in reconstructed plot, used by fritillary caterpillars for feeding. (A. Krása)

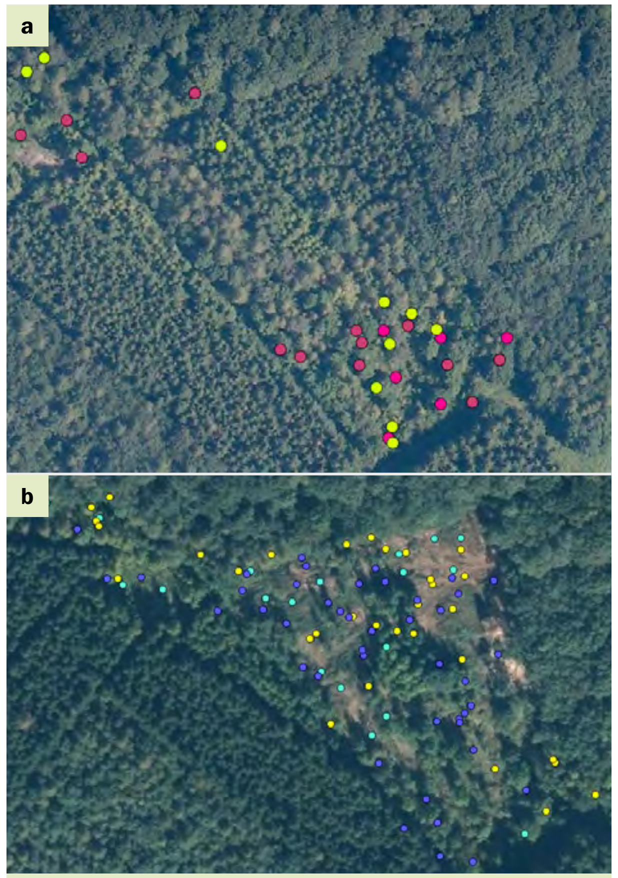


**Fig. 6.** Comparison of the usage of reconstructed plots by scarce fritillary:
a) Before intervention (2011–2013; pink – 2011; green – 2012; purple – 2013);
b) After intervention (2014–2016; light blue – 2014; yellow – 2015; dark blue – 2016).

The dots represent ash trees with egg batches and caterpillar nests in the respective years. Comparison shows an increase in usage of the plots after the intervention. (A. Krása)


## Acknowledgements

We are grateful to our colleagues Pavel Bína and Jaroslav Pipek, who have had the lion's share in implementing the realisation of the measures and in improving the state of the

scarce fritillary population. We also like to thank the owners of the tracts in question, Helena Benešová and Jana Bauerová, who agreed with the realisation of the necessary measures at the right moment, although this has caused them considerable financial loss and other problems.

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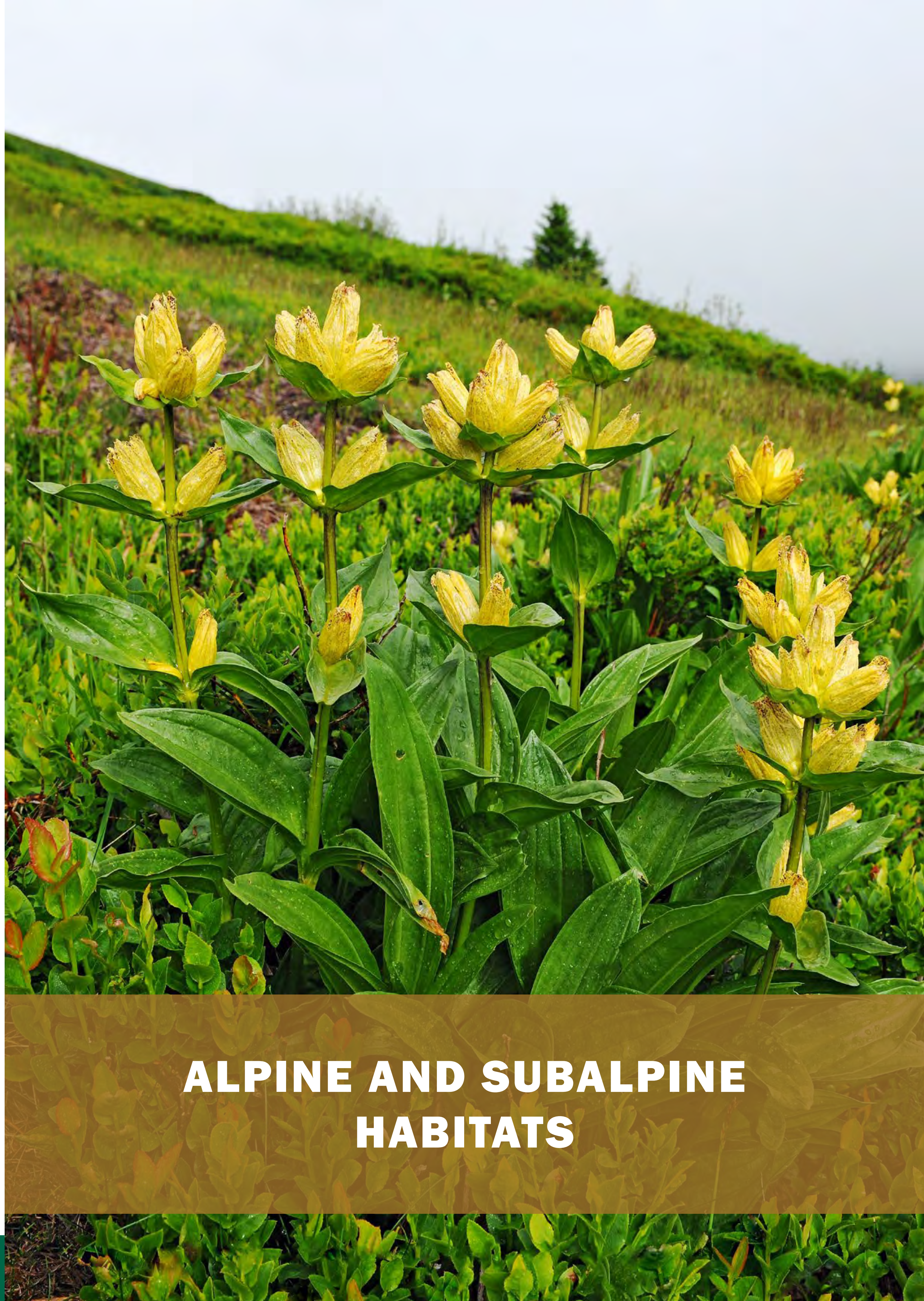
**Fig. 7.** Plot where regular cleaning is performed. (A. Krása)

**Fig. 8.** Plot where the stand was thinned; strong ash rejuvenation. (A. Krása)





# ALPINE AND SUBALPINE HABITATS

# Introduction

František Krahulec & Leo Bureš

Tracts beyond the timberline did not use to be exempt from utilisation as farmland in the past. Mostly consisting of grassland, they were used for grazing or mowing. Particular farming methods in these areas were clearly also influenced by property conditions and risks like herds crossing the border.

All three Czech mountain ranges used to form land borders, which became also state borders in the Krkonoše (*Karkonoszy, Riesengebirge*) Mts and Králický Sněžník (*Śnieżnik, Glatzer Schneeberg*) Mts after the annexation of Silesia by Prussia. The Silesian part of the Jeseník (*Gessenke*) Mts was included in Austrian Silesia. The various dominions had different regulations concerning the utilisation of subalpine vegetation. For example, on Vysoká hole in the Jeseník Mts, four dominions bordered each other and were probably for that reason more engaged in grass farming (Fig. 1). Grazing was attractive in the Jeseník glacial cirques, where high-yield plant communities are found. Also the biomass, containing a high rate of herbs, was of better quality.

With the changed settlement patterns after World War II and the subsequent socioeconomic changes, farming beyond the timberline practically disappeared.

In recent years, it has been discussed whether the process of biodiversity decline of these communities cannot be stopped by reintroduction of some form of farming. However, all changes that have taken place over the past more than fifty years should be considered before a critical analysis of the risks is carried out. These changes include the following.

- The entire area has been affected by acid rain. This has led to a widespread loss of bases from the soil. The speed and degree of impoverishment very much depends on the parent bedrock – sandy soils created by weathering of granite have undoubtedly been washed out the fastest. Acid rain also included nitrogen compounds, part of which has been captured in the soil.
- Tourism has increased the utilisation of ridges considerably. In many parts of the ranges, numbers of up to hundreds of thousands of visitors a year have been recorded. Paths have very often been improved with inappropriate materials, e.g. limestone and basalt (melaphyre) in the Krkonoše Mts, locally also slag or ash, causing an essential change in the soil chemistry, especially of slopes along the paths. Some paths have moreover been asphalted, which has led and still leads to intensive car traffic, even up to the ridges.
- The rise in visitor numbers, the traffic as well as the substrates used for path improvement have meant and still mean a higher number of diaspores of non-indigenous species as well. In the past, many of them would not have settled as they did not meet the right soil conditions, e.g. calciphilous species like *Gentianopsis ciliata* and *Carex flacca* in the Krkonoše Mts. In some areas, e.g. the plateau of the western Krkonoše Mts, the close vicinity of paths but also hectares of land below the paths are ruderalised. Locally, unwanted substrate has been washed down far from the paths.
- Especially in the Hrubý Jeseník range (in the Krkonoše Mts only on Mt Lysá hora) down-hill skiing has expanded beyond the timberline, which has led to a change in snow conditions due to the maintenance of ski tracks.

**Fig. 1.** Subalpine grassland communities on NE slope of Mt Vysoká hole. In the centre an old cart track on which hay was carried from Vysoká hole to Malá Morávka. (L. Bureš)

*Gentiana punctata*, growing in the Hrubý Jeseník Mts at the only site in the Czech Republic, was earlier considered extinct. (L. Bureš)

**Fig. 2.** View of the Vysoká hole ridge from Mt Břidličná hora on; left on the horizon: Mt Praděd. (L. Bureš)

This pressure is expected to rise considerably in the coming years because of worsening snow conditions at lower elevations. In the Krkonoše Mts snowmaking has not yet been allowed at alpine elevations, but changes may occur. In the Jeseník Mts, just as in the Krkonoše Mts, snowmaking on ski slopes reaching beyond the timberline is so far not practised.

- In recent years, climate change has become apparent and conditions beyond the timberline have improved for a whole range of species (especially ruderal ones). Prolongation of the vegetation season leads to completion of the entire generative reproduction cycle and to seed production. In this way there is an increasing risk that more suitable genotypes will be selected.

Also other influences not known from the past could evidently be found. We consider the mentioned ones to be the most important.

Negative interventions at alpine elevations of the Krkonoše and Jeseník Mountains performed in the past have recently been eliminated. One of the first in the Krkonoše Mts was a clean-up of limestone paths in the area of the Úpa peatbogs (Figs. 4 and 6). It was really absurd to see the removal of limestone from peatbogs, where the Krkonoše National Park Authority had brought it on. The result of this clean-up has exceeded our expectations: eutrophication along the path is inconspicuous and communities with *Carex rostrata*, which obviously manages to immobilise nutrients, have regenerated well. In other places, e.g. near the path between Výrovka and the Památník obětem hor chapel and on the plateau of the western Krkonoše Mts, nutrients continue to be washed away and ruderal communities are developing further. However, the clean-up of a large number of tourist trails and their vicinity has been successful. In places with a lack of nutrients, ruderal communities do not develop.

For a number of years, eradication of *Rumex alpinus* has been practised, which is successful only there where herbicide spraying was combined with subsequent management of the vegetation, i.e. mowing. Around paths which are subsequently not managed, this dock keeps on germinating from the seedbank. Pulling out *Veratrum album* subsp. *lobelianum* and *Senecio hercynicus* is neither very successful, see Fig. 5. Without eliminating the source of eutrophication (path material) this activity will not help. It is also important that no strong disturbance takes place and diaspores of ruderal species are not introduced. Particularly the latter factor needs to be kept in mind when considering introduction of grazing.

**Fig. 3.** View of the top plateau of the eastern Krkonoše Mts, 2011. (K. Antošová)

Introduction of mowing (and therewith export of nutrients from the system) can only be successful in places where there is a sufficient amount of bases in the soil. If there is a lack, mowing and subsequent biomass removal can quickly lead to a creation of even poorer communities.

Another management project which has been and still is being carried out in the Krkonoše Mts is *Pinus mugo* elimination (see Harčarik, p. 50). In the Krkonoše Mts, dense plantings of this pine are thinned, on the Králický Sněžník massif and particularly in the Hrubý Jeseník Mts non-indigenous plantings are eliminated over large areas. In the Krkonoše Mts, *Pinus mugo* was planted in a number of unsuitable places or in an inappropriate way: densely, in rows or with a straight stand margin. Unsuitable places also included sites of many rare and endangered plant species. We need to stress two praiseworthy features. Firstly, the pine was eliminated in a way preventing disturbance of the surface, and so no ruderalisation followed. Another positive factor was that the elimination was accompanied by an extensive information campaign, so that no large public protests have been organised.

This differs from the situation in the Hrubý Jeseník range, where efforts to limit *Pinus mugo* met with considerable resistance even from part of the Jeseníky PLA Authority. The first management measures at higher elevations started therefore later. These included a reduction of artificial plantings of *Pinus mugo* in the Velká kotlina and Malá kotlina glacial cirques, i.e. at the botanically most valuable sites. Projects aimed at reducing *Pinus mugo* were elaborated in 1973, based on a resolution of a scientific conference organised to that aim. However, the approved projects were realised only after the 1989 revolution. At several sites on the Vysoká hole ridge, also the non-indigenous *Alnus alnobetula* and expanding *Phalaris arundinacea* have been reduced after 1989. In recent years, the situation in subalpine elevations of Hrubý Jeseník has rapidly improved: stands of the non-indigenous *Pinus mugo* have been eliminated from several large areas (cryoplanation terraces of Petrovy kameny, mountain tops of Keprník and Šerák, Tabulové kameny, Malý Děd), and mowing has been resumed in large plots of flower-rich subalpine tall broad-leaved vegetation and expanding *Vaccinium myrtillus*.

**Fig. 5.** *Senecio hercynicus* expanding to tundra communities under the influence of anthropogenic changes, in this case through the vicinity of a road body of external basic material. (T. Janata)

Similarly to the difficult enforcement (and even more difficult realisation) of the first *Pinus mugo* reduction, the mowing of flower-rich subalpine grasslands was initially not supported by state nature conservation. To monitor the influence of this measure and general effects, permanent experimental plots have been established at Velká kotlina and Malá kotlina. Some results of annual mowing at these sites over a period of 28 years are presented in this publication (Bureš, p. 55). Also an experiment with cattle grazing, although still very limited, has been introduced in the close vicinity of Švýcárna cottage.

We consider it a good thing that knowledge from various experiments, which may help solving similar problems (which undoubtedly recur) also in the future, is compiled. It would be worth gathering unsuccessful management attempts as well: usually nobody boasts of these and therefore they may be repeated, ending up in failure.

**Fig. 4.** Revitalisation of tourist trail through the Úpa peatbogs (removal of limestone and building of a log path) in 1996. (L. Jiřiště)

**Fig. 6.** Reparation of a log path through the Úpa peatbogs in 2000. (J. Harčarik)

# Restoration of alpine vegetation in the Krkonoše Mts

Josef Harčarik

| | |
|---|---|
| Locatoin | Parts of Krkonoše ridge beyond the alpine timberline, 50°41‘–50°48‘ N, 15°29‘–15°47‘ E; elevation 1250–1600 m |
| Conservation status | NP, SAC, SPA |
| Restored area | 91 ha |
| Financial support | Operational Programme Environment, ME Landscape Management and Restoration Programmes; costs €4,620–21,200 per ha |

## Abstract

Natural dwarf pine (*Pinus mugo*) stands are a very important vegetation formation in the Krkonoše Mts. However, this pine has also been planted here, namely on a total area of nearly 700 ha. Particularly the stands genetically partly originating from non-indigenous sources, established before World War I, have significantly affected the geobiodiversity of the area, especially beyond the alpine timberline, i.e. in the Krkonoše tundra. Therefore, a management plan was compiled for the restoration of sites with post-war plantings. This plans consists in thinning dwarf pine at different intensity, therewith creating a near-natural mosaic of dwarf pine stands and alpine grassland vegetation. The plan is currently being realised (2005 – present).

## Site description

*Pinus mugo* stands cover 2,180 ha, representing about 4% of the territory of the Krkonoše NP and its buffer zone, making it one of the most significant vegetation formations in the area. It occurs most of all beyond the alpine (upper) timberline (2,055 ha) and is further part of some montane and supramontane habitats (e.g. scree fields, raised bogs). Natural stands form ¾ of the total dwarf pine area (ca 1,500 ha), whereas over one quarter consists of artificial plantings (about 680 ha). The stimulus to afforest alpine treeless vegetation in the Krkonoše Mts was the destructive floods in the second half of the 19th century, but also the intention of foresters to reforest parts of the ridge which had been influenced by human activity in the previous centuries (see e.g. Lokvenc 1995, Lokvenc 2001). Planting of dwarf pine was carried out in two periods. In the first one, from 1879 to 1913, it was planted on an area of 261 ha (plantings also took place at the turn of the 1930s and 1940s, but to a very limited extent). In the other period, from 1952 to 1992 (when they were stopped at the initiative of the Krkonoše NP Authority), another 292 ha of land beyond the timberline was afforested (Lokvenc 2001). However, the proposers initially had ideas of a considerably larger extent of plantings in the post-war period. After the Krkonoše NP was established, more precisely after an agreement with the Krkonoše NP Authority in the 1970s and 1980s, this plan was partly reduced. Besides, dwarf pine was also planted at lower elevations, e.g. on clearings created by air pollution (total area 125 ha).

**Fig. 1.** *Pulsatilla alpina* subsp. *alba* in dwarf pine stands, 2015. (J. Vaněk)

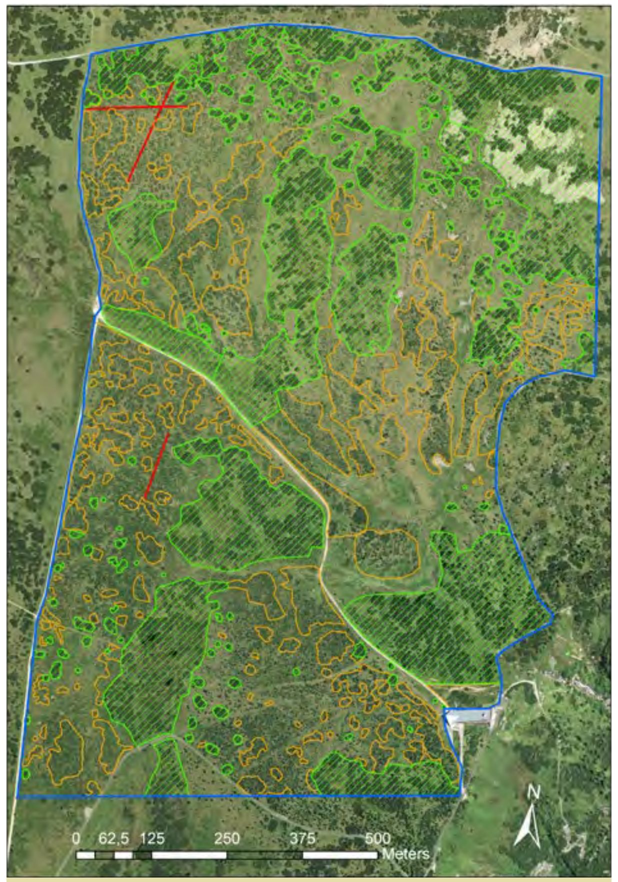



**Fig. 2.** Distribution of dwarf pine after the intervention at Pančavská louka and Labská louka: natural dwarf pine stands (green hatched polygons), retained groups of dwarf pine plantings (orange polygons), transects (red lines). The object in the lower right corner is Labská bouda.

The restoration area consists of a mosaic of various types of alpine treeless vegetation, particularly natural dwarf pine scrub (*Pinion mugo*), alpine grasslands (*Juncion trifidi*, *Nardo strictae-Caricion bigelowii*), alpine and subalpine shrub vegetation (*Loiseleurio procumbentis-Vaccinion*, *Genisto pilosae-Vaccinion*), and subalpine tall herb vegetation (*Calamagrostion villosae*, *Calamagrostion arundinaceae*, *Adenostylion alliariae*).

## Initial state

As a result of multidisciplinary research performed since the early 1990s (incl. a comparison with processes and phenomena in Scandinavian tundra), areas beyond the timberline and in glacier cirques were defined as Krkonoše arctic-alpine tundra (Soukupová et al. 1995, Štursa et al. 2010), but also an analysis of the interactions between dwarf pine and different tundra phenomena was carried out.

It was found that regular and too dense dwarf pine plantings, realised mainly in the post-war era from the 1950s to the 1990s, are very different in structure from natural stands (Vaněk 1999, Soukupová et al. 2001, Vaněk 2004) and affect the abiotic and biotic conditions of the Krkonoše tundra at the same time. This causes e.g. reduction and disappearance of open spots of alpine treeless vegetation with grass-herb vegetation; reduction of populations of plants and animals associated with them, including protected, endangered and endemic species; mechanical damage of geomorphological features (e.g. flattening (planation) of the natural lumpy shape of frost soils); and also disturbance of physical processes (e.g. changes in microclimatic conditions) conditioning their genesis and development (see e.g. Kociánová & Soukupová-Papáčková 1994, Svoboda 2001, Harčarik 2002, Sekyra et al. 2002, Wild & Wildová 2002).

**Fig. 3.** Thinned dwarf pine in plot below Harrachovy kameny, 2015. (J. Vaněk)

**Fig. 4.** Manual transport of dwarf pine to a road, 2015. (J. Vaněk)

It was exactly the amount of this newly acquired knowledge that not only confirmed the justification of stopping the afforestation of alpine vegetation with dwarf pine in 1992, but also led to the preparation of a management plan which, conversely, integrates part of the dwarf pine plantings into the Krkonoše tundra and preserves the geobiodiversity of this unique environment. The first proposal to manage post-war dwarf pine plantings (Pilous & Kociánová 1992) evoked a rather long and initially also heated, but ultimately very beneficial and constructive discussion between foresters and scientists. This eventually led to a definite proposal (Harčarik 2007) which became the basis for the restoration management of alpine vegetation. The post-war plantings became the subject of the proposed management, since they significantly influence the natural values of the area in question. They had often been carried out in places of very valuable habitats, moreover by means of a technology causing the plantings to connect in a rather short time, thus deteriorating or eliminating other components of the Krkonoše arctic-alpine tundra, including disturbance of natural processes. The management plan proposes a 10 to 90% reduction of dwarf pine plantings on a total area of 180 ha, depending on the natural values of

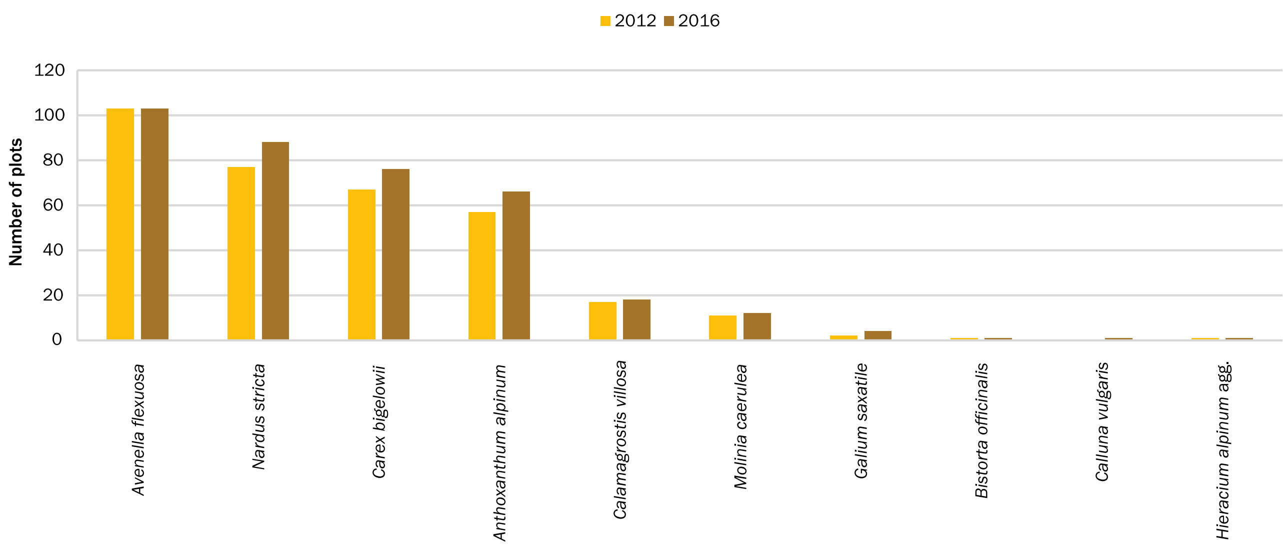



**Fig. 5.** Results of the monitoring of vascular plants colonising plots after removal of dwarf pine shrubs. A total of 105 plots 0.5 × 0.5 m in size were monitored on 3 transects. Data of 1 year (2012) and 5 years (2016) after intervention.

the locality, at the same time taking various environmental features (e.g. state of health, ruderalisation of the vegetation, presence of indigenous dwarf pine shrubs etc.) into account. Approximately 110 ha of post-war plantings are planned to be left untouched (Harčarik 2007).

**Fig. 6.** Transport of dwarf pine shrubs by helicopter, 2015. (J. Vaněk)

## Restoration objectives

Simulating near-natural structures of alpine areas in places of artificially planted dwarf pine stands, restoring natural processes, preserving and locally regenerating the geobiodiversity of the Krkonoše tundra.

## Measures applied

| | |
|---|---|
| 1982 | Elimination of dwarf pine plantings on north slope of Mt. Studniční hora, 1 ha (Štursa, in verb.). |
| 1994 | Elimination of dwarf pine plantings N of Harrachovy kameny in 3 experimental monitoring plots, 0.72 ha in total. |
| 1997 | Reduction of dwarf pine on north slope of Mt. Studniční hora, 1 ha. |
| 2005–2008 | Reduction of dwarf pine at two sites on Pančavská louka, 3 ha; besides revitalisation of the site, this management measure was to check if the dwarf pine reduction technology would be the most appropriate one. |
| 2010–2011 | A 10–90% reduction of dwarf pine plantings in the area of Pančavská louka and Labská louka, 37.7 ha in total. |
| 2015 | A 10–90% reduction of dwarf pine plantings in the area of Labská louka and Harrachova louka, 47.4 ha in total. |

The resulting mosaic of dwarf pine stands (natural and retained plantings) and alpine grassland vegetation after the restoration management measure in the area of Labská louka and the northern part of Pančavská louka is shown in Figs. 2 and 8.

## Planned management measures

The dwarf pine planting reduction project should continue at other proposed sites in the Krkonoše tundra according to a management plan. At the moment a reduction project is being prepared for the eastern Krkonoše Mts, i.e. in the wide surroundings of Luční bouda. After realisation of this dwarf pine reduction, the alpine treeless area in the Krkonoše Mts will be left without interventions.

**Fig. 7.** Plot with dwarf pine plantings before intervention, 2015. (J. Vaněk)

**Fig. 8.** Plot with dwarf pine plantings after intervention, 2015. (J. Vaněk)

## Monitoring methods

At the sites in the area of Pančavská louka and Labská louka, where a management measure was carried out in 2010–2011, monitoring plots were established to follow the succession after the elimination of dwarf pine shrubs. A total of 105 plots 0.5 × 0.5 m in size were fixed on three transects (see Fig. 2 for location). Every year since 2012 the presence or absence of each plant species has been recorded in these plots.

## Results

The number of records for different species in the years 2012 and 2016 is shown in Fig. 5. It is obvious that the performed intervention has led to a fast colonisation of these plots by exclusively autochthonous species which occur in the surrounding alpine grasslands. Common graminoid species prevail, whereas broadleaved herbs colonise the plots after dwarf pine elimination rather seldom. The latter include rare and endangered species (outside the monitoring plots e.g. *Pseudorchis albida*, *Pulsatilla alpina* subsp. alba and *Arnica montana* have been recorded). Spreading of unwanted (e.g. synanthropic) vegetation has not occurred in any plot. In important parts of the area in question, the places where dwarf pine shrubs were removed 5 years before are already practically indistinguishable from the surrounding vegetation.

## New insights and prospects

In the management measures carried out to date, nature-friendly technologies and work methods have been verified. Despite the large amount of manual work and costly technologies (transport of part of the biomass by helicopter, chipping etc.), the project of restoring alpine vegetation in places of post-war dwarf pine plantings to the proposed extent is feasible and economically (and of course also scientifically) defensible.

## Public support

It was already clear during the preparation of the management measure that it is, particularly as seen by the public, a rather controversial activity requiring thorough explanation. The dwarf pine reduction is situated in the core area of the Krkonoše NP, where a minimum of human intervention into the natural environment is preferred. It is also the area with the strongest restrictions for common visitors to the Krkonoše Mts. The situation is, in contrast to e.g. the Jeseník Mts, more complicated by the fact that dwarf pine is an indigenous shrub here. The long discussions during the preparation of the management plan led to its sympathy and acceptance by professional foresters. Realisation of the dwarf pine reduction project in 2010–2011 and 2015 thus also tested the attitude of the lay community to this plan. Most visitors to the Krkonoše Mts have been convinced of its necessity and usefulness by informing and explaining them extensively why the Krkonoše NP Authority has agreed with this intervention. Let us hope that they will accept this also in the coming years.

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**Fig. 9.** A view of Harrachova louka from Mt Kotel after the management measure shows a near-natural mosaic of natural dwarf pine stands and plantings and alpine grassland vegetation, 2016. (J. Harčarik)



# Restoration of degraded subalpine grasslands in the Jeseník Mts

Leo Bureš

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|---|---|
| Locatoin | Hrubý Jeseník Mts, plateau on top of Mt Vysoká hole; elevation 1460 m |
| Conservation status | PLA, NNR, SAC, SPA |
| Restored area | 10 plots covering 0.1 ha in total |
| Financial support | ME Landscape Management and Restoration Programmes; costs €1,050 per ha |


## Abstract

Over the past ca 70 years the structure of subalpine grasslands on the entire ridge of Mt Vysoká hole has changed because mowing and grazing was stopped. The species diversity has decreased and completely closed vegetation with a large amount of accumulating plant biomass been created at the site. In 2003, an experiment was established in which experimental plots were first mown and then their turf was disturbed at various intensities. Its aim was to find a way of restoring the original community and increasing its diversity.


## Initial state

In the first half of the 20th century, the subalpine grasslands of the Jeseník Mts had a different appearance compared to today. For example, many hawkweeds (*Hieracium* sp.) grew and in August flowered here in numbers comparable to the Krkonoše Mts. In that time, they were still mown and locally also grazed. We know from witnesses in the village of Malá Morávka that before World War II, Moravian cottagers went with handcarts to Mt Vysoká hole in August in order to collect hay.

From several credible historical sources it follows that the structure of the *Avenella* grasslands on the entire ridge of Vysoká hole has rapidly changed over the past ca 70 years. Their species diversity has decreased and closed vegetation with a large amount of accumulating dead plant biomass has developed. Under the completely closed sward, a continuous, clotted, 4–7 cm thick layer of raw humus is present. Lichens, including *Cetraria islandica*, and the last plants of *Hieracium alpinum* agg. have completely disappeared from the vegetation. *Bistorta officinalis* has considerable expanded almost everywhere and locally already become a dominant species over large areas (Fig. 1).

The alpine grassland communities on the Vysoká hole plateau where *Avenella flexuosa* prevails today have to date evidently incorrectly been classified as belonging to the *Cetrario-Festucetum supinae* association known of the Krkonoše Mts, which is associated with shallow and desiccative rankers. This is generally true for Krkonoše, but in the Jeseník

**Fig. 1.** Vegetation with a large amount of dead *Avenella flexuosa* and *Bistorta officinalis* biomass at Mt Vysoka hole in 2003. (L. Bureš)

**Fig. 2.** First mowing of grasslands not cut for 80 years, August 2003. (L. Bureš)

**Fig. 3.** Thick, non-decaying layer of raw humus, August 2004. (L. Bureš)

**Fig. 4.** Plot with removed turf in the corner of the first experimental quadrat after 10 years, August 2013. (L. Bureš)

Mts mostly deep humus and never desiccating podsols are found under these plant communities.

## Restoration objectives

Opening up completely closed grassland communities and increasing their species diversity.

## Measures applied

In 2003, in order to verify possible methods of restoring open and species-rich alpine grassland communities at Vysoká hole, we set out 5 quadrats 10 × 10 m in size in collaboration with the Jeseníky PLA Authority. These have then annually (in the first half of August) mown with brushcutters provided with tricuspid blades as close to the ground as possible in an attempt to disrupt the clotted biomass (Fig. 2). Immediately after mowing, the plots were always carefully raked and the collected hay was removed.

In 2004, the turf in a rectangle of 100 × 70 cm in Quadrat 1 was removed to find out the depth of the dead biomass which was impossible to disrupt by mowing. We were surprised not only by its thickness (4–7 cm), but also by the exceptional compactness of the mass, which could only be cut, not torn (Fig. 3).

Vegetation succession in this small plot with removed turf showed us in the following years some possibilities and ways to solve the problem, because the plot gradually started to be encroached with moss, lichens and grass seedlings. In 2013 it was already for three quarters covered with *Nardus stricta* tussocks (Fig. 4) and in 2016 differed strikingly from the rest of the quadrat.

When, after mowing all five quadrats for two years, we saw that the vegetation was not changing considerably by just mowing and only the aboveground biomass was decreasing but the clotted compact dead biomass layer had remained unchanged, various rigorous mechanical operations were carried out on the turf in some quadrats in 2005: disturbance and removal of the clotted dead biomass. To this aim we used a Stihl blade cultivator attached to a high-powered professional brushcutter (Fig. 5a, b).

In Quadrat 2, after carefully mowing half of the area, we disrupted the turf and the clotted biomass layer only lightly. The hackled mass was left at the site.

Also half of Quadrat 3 was hackled that way, but the dead biomass was carefully raked up and removed. The entire half was lightly cultivated and raked.

In Quadrat 4, the turf was disrupted in a similar way in 2005, but to a large depth, in a one-metre wide strip in the middle of the quadrat. The turf including the clotted dead biomass was hackled with a cultivator to a depth of 10–15 cm. In the half of the strip treated that way the hackled turf was left, while it was carefully raked up and removed in the other half.

In the middle of Quadrat 5, a metre-wide strip was disturbed with a cultivator in a similar way, but just lightly.

Already in 2007 it was visible that light mechanical disturbance had not affected the vegetation much, in contrast with deep disturbance and raking. In order not to intervene in the succession of the disturbed plots, we established three new quadrats of the same size in 2008, in the vicinity of the first ones.

**Fig. 5.** Mechanical turf disturbance with a cultivator on a brushcutter, August 2005. (L. Bureš)

Quadrat 6 was placed in a way that included vegetation with *Calluna vulgaris* and *Vaccinium vitis-idaea* (Fig. 6). In this quadrat no mechanical disturbance was applied, as the objective was to monitor the influence of mowing on these two plant species.

In experimental Quadrat 7, after mowing and deep raking, we cultivated half of the area in 2008 (Fig. 7). All the hackled turf mass was carefully raked up and removed. This way the soil surface and the mineralised humus horizon was uncovered.

Quadrat 8 was left as a reference plot and has since 2008 only been mown and raked annually.

In 2009, in the vicinity of the first eight quadrats, another two quadrats were set out in vegetation with a conspicuously high cover of *Bistorta officinalis*. In these quadrats fertilisation was the subject of the experiment: in August 2009, after mowing, half of Quadrat 9 was copiously and equally fertilised with 20 litres of sheep droppings (brought from home). The entire area of Quadrat 10 was fertilised with 2.5 kg of granular NPK.

## Monitoring methods

Making phytosociological relevés in every 10 × 10 m quadrat just before mowing.

**Fig. 6.** Newly established Quadrat 6 (with *Calluna* in the centre) before the first mowing, August 2008. (L. Bureš)

## Results

Whereas mowing alone did not affect the vegetation much, mechanical disturbance and turf removal had their effects instantly in the following years. However, they differed in degree: the changes were minimal at shallowly disturbed unraked sites, and often just a little stronger at shallowly disturbed raked sites, while changes in deeply hackled plots with removed turf were striking and became more prominent every year after. Deep turf disturbance had its effects in some quadrats in the course of time. For example, I recorded lichens of the genus *Cladonia* and the moss *Pohlia nutans* in the disturbed strip in Quadrat 4 as late as the year 2010, and also even in small areas with already decayed dead biomass and exposed mineral soil in Quadrat 3 in 2013.

The most interesting was Quadrat 7, where the turf in the B half of the plot (see Tab. 1) had been hackled and removed. Already in 2011, *Nardus* seedlings started to appear on the exposed soil in this quadrat, in 2012 and 2013 also *Calluna* and *Festuca supina* seedlings turned up, the moss *Polytrichum* came up massively, and on open soil other bryophyte species appeared. *Bistorta officinalis* almost disappeared. After several years the vegetation of this half differed considerably from the reference half (still mown annually). The total coverage increased, but between grass tussocks open, skeletal mineral topsoil remained, without non-decaying clotted dead biomass. The succession in both halves of Quadrat 7 is illustrated in Tab. 1.

**Fig. 7.** In the newly established experimental Quadrat 7, besides mowing an entire half was deeply disrupted with a blade cultivator, August 2008. (L. Bureš)

**Tab. 1.** Monitoring results of experimental Quadrat 7 (established 2008) on Mt Vysoká hole with *Nardus* and *Calluna*. Demarcated area 10 × 10 m, exposition SE, slope 5°, elevation 1463 m, 50°03’43.8” N, 17°14’14.7” E. The relevés in columns B capture succession in the half with removed turf, columns A capture the half with the reference plot.

| Year | 2008 | 2009 | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 12. 8. | 12. 8. | 8. 8. | | 3. 8. | 3. 8. | 21. 8. | 21. 8. | 16. 8. | 16. 8. | 19. 8. | 19. 8. | 16. 8. | 16. 8. | 16. 8. | 16. 8. |
| Part | | | A | B | A | B | A | B | A | B | A | B | A | B | A | B |
| Cover $E_1$ (%) | 100 | 80 | 90 | 10 | 80-85 | 10-20 | 80 | 50 | 80 | 60 | 80 | 50 | 70 | 60 | 75 | 60-70 |
| Height $E_1$ (cm) | 20-40 | 10-30 | 30 | 20 | 10-25 | 25 | 10-35 | 10-40 | 10-30 | 30 | 10-30 | 40 | 10-35 | 10-40 | 10-30 | 10-30 |
| Cover $E_0$ (%) | 0 | 15 | <5 | 15 | 10 | 20 | 10 | 10-20 | 10 | 15 | 0 | 40 | 0 | 50 | 0 | 10 |
| *Avenella flexuosa* | 4 | 3 | 4 | 1 | 3 | 2 | 3-4 | 3 | 3 | 3 | 4 | 2-3 | 3 | 3 | 4 | 3 |
| *Bistorta officinalis* | 2 | 3 | 2 | 1 | 3 | + | 2 | + | 2-3 | + | 1-2 | r | 1-2 | r | 2 | r |
| *Calamagrostis villosa* | . | . | . | . | . | . | . | . | . | . | . | . | . | r | . | . |
| *Calluna vulgaris* | 1 | . | . | . | . | . | | + | . | 1 | . | 1 | . | 1 | . | 2 |
| *Carex bigelowii* | 2 | 1 | 2 | + | 1-2 | r | 1-2 | + | 1 | + | + | r | 1 | r | 1 | + |
| *Festuca supina* | . | 1 | 1 | 1 | 1 | 1 | 2 | 1-2 | 1 | 1 | 2 | 1 | 2-3 | 1 | 1 | 2-3 |
| *Luzula luzuloides* subsp. *rubella* | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . |
| *Calamagrostis villosa* | . | . | . | . | . | . | . | . | . | r | . | . | . | . | . | . |
| *Nardus stricta* | 1 | . | 1 | . | r | + | + | . | + | + | r | 1 | r | 1 | + | 2 |
| *Vaccinium myrtillus* | . | . | . | . | . | . | .. | . | . | . | . | . | . | . | . | r |
| *Solidago virgaurea* subsp. *minuta* | + | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . |
| *Polytrichum commune* | . | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 1-2 | . | 2-3 | . | 2-3 | . | 1 |
| *Pohlia nutans* | . | . | . | . | . | . | . | 2 | . | 1 | . | 2 | . | 2 | . | 2 |
| *Dicranella cerviculata* | . | . | . | . | . | . | . | + | . | + | . | 1 | . | + | . | r |
| *Kiaeria blyttii* | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . |
| *Polytrichum piliferum* | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | + |

The structure of the restored vegetation is illustrated in Fig. 8. For comparison, Fig. 9 is added, showing details of the vegetation structure in the half where the turf was not disturbed.

In the quadrats where no mechanical disturbance of turf and clotted layers of non-decaying dead biomass was performed, annual mowing led to very slow changes. However in the first years, the total amount of aboveground biomass in the mown plots decreased rather quickly, flowering *Avenella* and *Festuca* (the dominant grasses) were lower than in the unmown surrounding, the mown vegetation became thinner, and the total cover of live biomass decreased. In some of the mown plots, *Bistorta officinalis* visibly retreated (Quadrat 2). Among grass tussocks weakened by mowing, spots of exposed light grey, compact, non-decaying dead biomass increased in size (Fig. 10).

**Fig. 8.** In the E half of experimental Quadrat 7, where the turf was deeply disrupted and the clotted dead biomass removed, stones are sticking out and mosses are expanding, August 2016. (L. Bureš)

**Fig. 9.** In the W half of experimental Quadrat 7, where the turf was not disrupted, the dead biomass is locally already browning and rotting, August 2016. (L. Bureš)

**Fig. 10.** In mown plots, rather large bare spots with layers of non-decaying dead biomass appeared, August 2005. (L. Bureš)

Not until ten years after the interventions had begun, the dead biomass started to rot off from below in some places and change colour at the surface: from initially grey to brown, dark brown and finally black. Its originally 4–7 cm thick layer became thinner with time, and blackening dead biomass was found in patches of just a 1 cm thick. It was at these black patches of decayed biomass that the first young tussocks of the grasses *Nardus stricta* and *Festuca supina* and the sedge *Carex bigelowii* started to appear in 2013.

The fertilisation of Quadrats 9 and 10 did not affect the vegetation or the density of *Bistorta officinalis* visibly in the following years. It was not until 2016 that we recorded a 20% denser vegetation of *Festuca supina* and *Avenella flexuosa* and a lower *Bistorta* cover in the NE half of Quadrat 9, fertilised with sheep droppings, than in the unfertilised SW half.

All mown plots attracted game animals and clearly more browsed grass was found there than in the unmown surrounding. When young aftermath was formed in mown plots in favourable years, the influence of grazing was more distinct. Not only chamois dung appeared there, but also hare droppings.

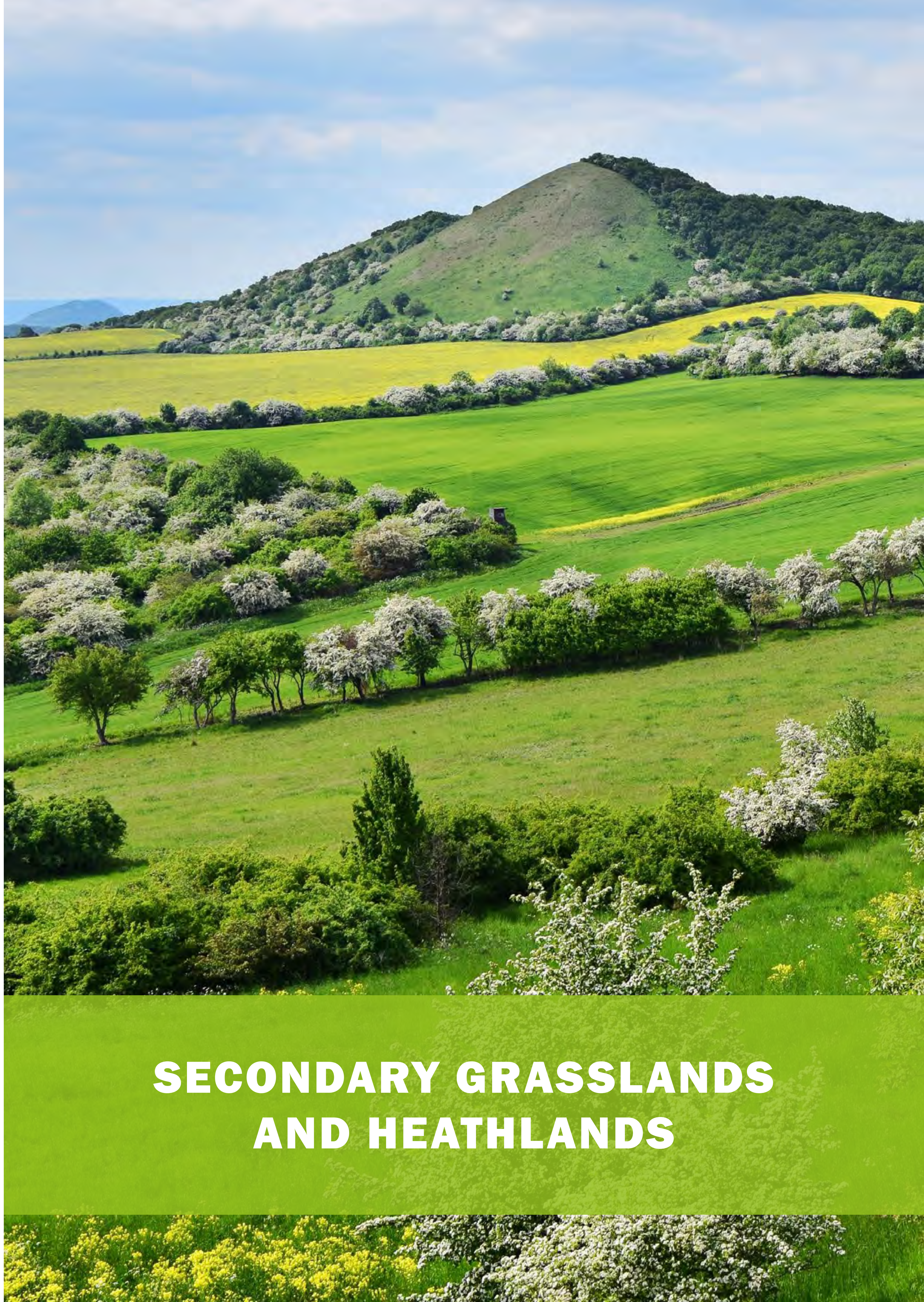
In Quadrat 6, mowing caused a clear decline of *Calluna*, but supported expansion of *Vaccinium vitis-idaea* and also emergence and subsequent expansion of *Vaccinium myrtillus*. Mowing decreased the cover of *Bistorta* considerably only in experimental Quadrat 1.

## New insights and recommendations

The thirteen-year long experiment, established to verify possible methods of restoring degraded subalpine grassland communities in the Jeseník Mts and to find practical methods for this restoration, has achieved its objective. Open plant communities with a high rate of *Festuca supina*, without *Bistorta officinalis* and with open spaces for successful establishment of other species originally growing here (including hawkweeds) can be restored in a few years. The most appropriate method seems to be large-scale turf removal, ideally realised annually in several geometrically irregular plots of 100–200 m² located irregularly over the top plateau of Vysoká hole, 50–100 m from each other. In this way a mosaic of different succession stages is created and the chance of successful re-establishment of especially anemochorous species is increased.

If in plots with exposed soil, establishing hawkweeds are destroyed by chamois, some of these plots can be easily fenced, thus enabling the development of native, rare and sometimes even endemic hawkweed species, e.g. *Hieracium chrysostyloides*.

**Fig. 11.** The vegetation in the upper part of the SE slope of Mt Vysoká hole is more diversified than on the top plateau. (L. Bureš)



# SECONDARY GRASSLANDS AND HEATHLANDS

# Introduction

Ivana Jongepierová, Karel Prach, Lubomír Tichý & Igor Malenovský

Grassland ecosystems are one of the most significant habitats in Central Europe. They were created there, except for primary treeless vegetation at extreme sites, as a result of long-time farming activities by man. Nearly two-thirds of threatened plant species grow in meadows and pastures, which are also a habitat preferred by a range of invertebrate taxa, particularly insects and arachnids. Also several threatened flagship vertebrates, e.g. corncrake (*Crex crex)* and European ground squirrel (*Spermophilus citellus*), are strongly associated with grasslands.

However, grassland ecosystems not only have a great natural value, they are also an important cultural heritage characterising the Central European landscape. It is therefore not surprising that they have become objects of interest to many scientists and conservationists, who not only study species composition and processes occurring in these ecosystems, but mainly try to find ways of preserving or restoring the original species diversity. This is demonstrated not only by dozens of scientific articles and an overview of restoration activities and case studies in the earlier publication dealing with ecological restoration in the Czech Republic (Jongepierová et al. 2012), but also by several conferences on this topic, e.g. Management and Restoration of Grassland Ecosystems (Prach et al. 2015b) organised by the Czech Botanical Society in collaboration with the Nature Conservation Agency of the Czech Republic in 2014.

While the previous section dealt with montane grasslands, primary as well as secondary treeless vegetation, this section is focused on the importance and restoration of grassland ecosystems and heathlands at lower elevations. Needless to describe the irreversible damage that has been caused to these locations in the second half of the 20$^{th}$ century as a result of socialist mass production. Besides a decline in biodiversity, important ecological functions such as water retention and filtration and anti-erosion functions were reduced in that period. From 1960 to the late 1980s also the total area of meadows and pastures decreased continuously so that Czech farmland had the highest ploughing rate in Europe (reaching 75%) by the end of the 1980s. The remaining permanent grasslands were mostly fertilised strongly. By contrast, many sites on steeper slopes or in remote areas were not farmed for a long time and became gradually encroached with scrub.

**Fig. 1.** *Klasea lycopifolia* population in Čertoryje NNR. (I. Jongepierová)

Vraníky hill in the Central Bohemian Uplands. (J. Prahová)

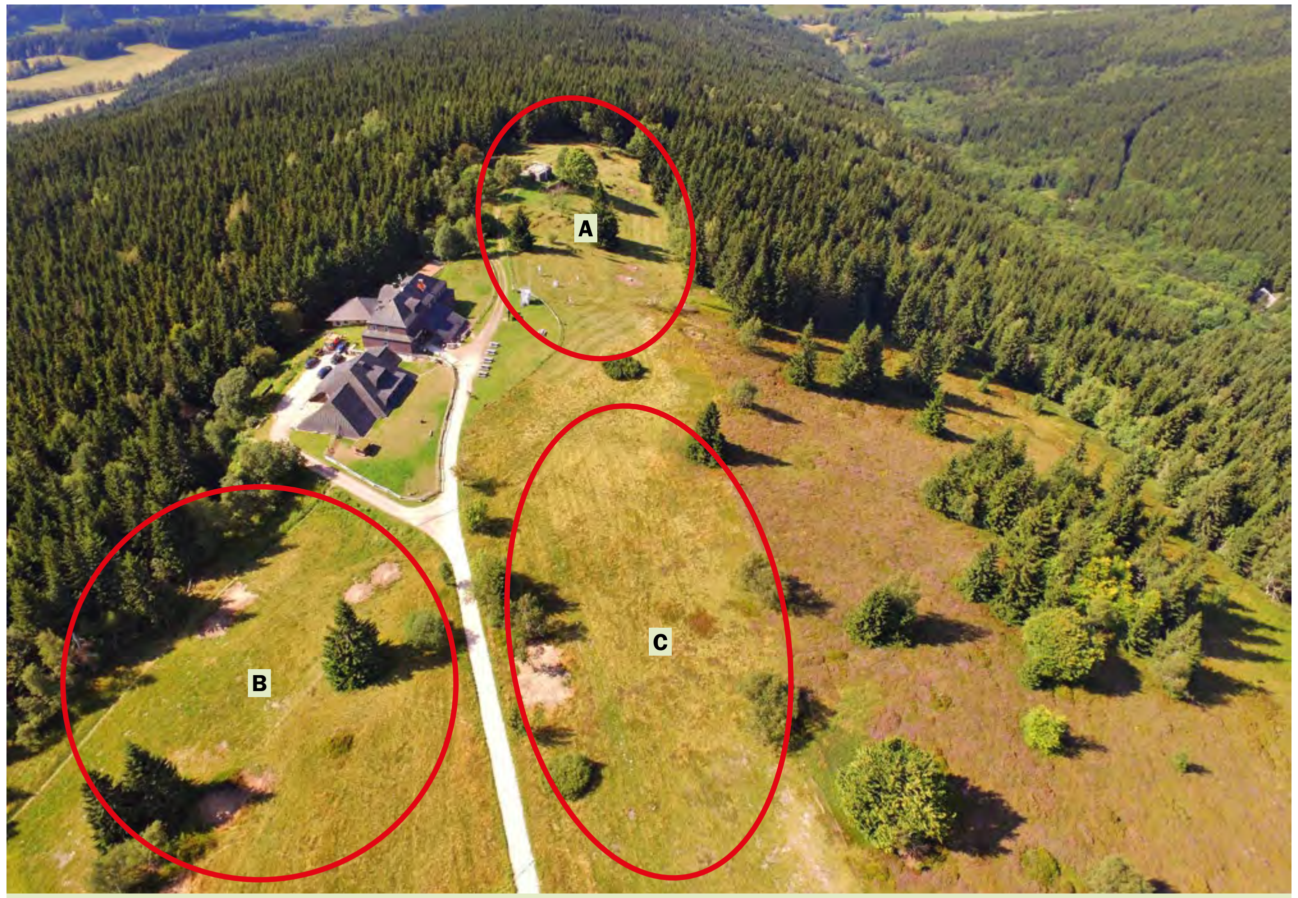



**Fig. 2.** Plateau near Rýchorská bouda, ca 8 ha of grassland at an elevation of 1000 m in Krkonoše NP Zone I, where species-rich *Nardus* grasslands are being restored under LIFE project Corcontica (2012–2018). Management activities: Plot A – manual haymaking, manual compost spreading, tree cutting; Plot B – haymaking with light machines, disturbing *Nardus* swards with low-positioned mulching device, compost spreading; Plot C – haymaking or cow grazing + tree cutting, trunk milling. (Archive of Krkonoše NP Authority)

**Fig. 3.** Sklenářovické údolí NM, ca 100 ha of grassland in Zones II and III of Krkonoše NP, where integrated management of a village lost after World War II is being performed.

Restoration of farming in the Krkonoše Mts is taking place on a total area of ca 490 ha of grassland, approx. one third of which is mown. At the most nutrient-poor sites, fertilisation with composted dung is locally supplemented with manual application of bases in the form of finely ground dolomitic limestone at a rate of 50 kg/ha. (Archive of Krkonoše NP Authority)

Due to the change in economic conditions, the area of managed grassland ecosystems has increased again since 1989. However, most of them are species-poor grasslands created by sowing commercial seed mixtures, so that the quantitative growth in acreage has not automatically meant a return to their biological quality. Besides the necessary measures to rescue the still existing species-rich grasslands, it is particularly important to direct attention to the way they are restored in agricultural areas (with which meadows and pastures are traditionally associated) as well as in other habitats maintained by man, such as embankments, town parks, etc. Application of the principles of ecological restoration – the primary aim of which is not production, but improvement of non-production ecosystem functions (restoration of so-called ecosystem services) – is also supported by two NCA standards, Restoration of grasslands using regional seed mixtures (SPPK D02 001: 2017) and Grasslands (SPPK C02 007: 2018).

Not only plants play a role in the restoration of grassland communities, although they form the frame of these ecosystems, but also the other biota. Ecological meadow and pasture restoration can be employed to reinforce declining populations of threatened insect and bird species and to increase the quality of the soil, because its microbial life is much more diverse in meadows than on arable land. Better structured soil of higher quality retains water better than degraded soil and can, as a result, lower the risk of flooding in a way that should not be disregarded. Grasslands capture nutrients and other chemicals (e.g. from field runoffs or groundwater) effectively, making them an important filter around drink water sources. A meadow or pasture also prevents nutrients from being washed out and reduces water and wind erosion incomparably better than arable land. Grassland communities further conserve farmland the best. Under them, no degradation takes place (as e.g. under stands of fast-growing trees), but the quality of the soil – both its physical and chemical features – is gradually improved by the fact that a large part of the primary production of these communities is deposited in belowground organs. Appropriate grassland ecosystem management and restoration thus have a broad effect on the landscape and thereby on the whole society.

Ecological meadow and pasture restoration can be divided into two basic issues: restoration of degraded meadows and pastures, and grassland recreation at sites where they are presently absent but used to be or could have been found.

## Restoration of degraded meadows and pastures

**Return to former farming methods (mowing or grazing)**

After regular management of former meadows and pasture has been terminated, their vegetation starts to be dominated by competitive plant species such as *Calamagrostis epigejos*, *Arrhenatherum elatius*, *Phalaris arundinacea*, *Carex brizoides*, *Filipendula ulmaria* and *Urtica dioica*. Shrubs and trees later often arrive, which eventually complete the change in vegetation.

Dry grasslands are most threatened by the accumulation of dead plant biomass. Due to the created litter layer, they warm up slower in early spring. Evapotranspiration of such vegetation is also slower so that the dead biomass retains a large amount of water for a rather long time. In relation to this, decomposition of organic substances increases the nutrient availability and retards the growth of the vegetation by 7–10 days in comparison to sites without biomass from the previous year. Dry grassland encroached by shrubs thus gradually becomes a habitat entirely different from the initial one. This also counts for animals, which react to changes in the spatial structure of the vegetation, microclimate and species composition (which play a key role for e.g. specialised phytophagous insects and their predators).

**Fig. 4.** Restoration of a pasture at Sidonie in the Bílé Karpaty PLA has also led to restoration of a large blue (*Phengaris arion*) population. (L. Ambrozek)

Resumption of mowing and elimination of biomass is then the most frequent and often also a sufficiently effective type of conservation management for such degraded vegetation (Blakesley & Buckley 2016). Frequency and time of mowing play an important role in the improvement of its state. In the first years, in order to eliminate nutrients and suppress dominant plants, it is advisable to mow more often and earlier in the season than is common with preserved species-rich vegetation. Also dry degraded sites require at least one more cut, which helps to maintain lower aboveground competition. The restoration can sometimes proceed very quickly, especially if at least some of the original species have remained in the vegetation (e.g. in the form of seeds in the soil) or occur in the immediate surroundings from where they can easily reach the restored site. However, the mobility of grassland plant species (especially dry grassland species) is generally rather low, so that effective seed dispersal is usually not expected to be more than a few dozen metres. In some cases, species are dispersed to larger distances, for example in the case of alluvial meadows by floods, elsewhere by grazing herds of cattle passing by or shifting farming machines, to a certain extent also by the activity of wild animals.

Another alternative, besides mowing and grazing, is mulching with green hay from species-rich grasslands. If it is harvested in the appropriate time, i.e. just before the seeds of the main species ripen, also many germinant seeds are transported to the new site with the hay. Mulch moreover slightly shades the vegetation and prevents seedlings from drying out. Green-hay transfer can however be recommended as a first management measure after removal of dead biomass or shrubs. In the following years it is inappropriate because mulch enriches the soil with nutrients and increases soil humidity just like the dead biomass used to do.

When restoring a pasture, it is advisable to combine grazing with cutting plants that are not eaten by the animals (e.g. *Calamagrostis epigejos*), at least in the first years. On the other hand, not all shrubs have to be removed. Some retained young shrubs will – thanks to browsing – gradually grow into dense shapes, under the protection of which many plant and also animal species intolerant to intensive grazing or shade-tolerant species can later survive. Some shrub and tree species and animals associated with them are moreover

**Fig. 5.** Large blue (*Phengaris arion*). (O. Konvička)

threatened taxa of our flora and fauna. The issue of pastures as such is however so complicated (see e.g. Mládek et al. 2006) that it cannot be contained in this chapter.

An essential condition for high species diversity is preserving the environment heterogeneity at the highest possible level. On the landscape scale, this used to be secured by fragmented ownership with most of the actively managed plots being not more than a few hundred to thousand square metres in area. Presently, most plots are however farmed by tenants who include them into extensive areas. More and more abandoned meadows or pastures have again been managed with the introduction of farming subsidies, especially after the entrance of the Czech Republic into the European Union in 2004. Mechanisation adapted to the subsidies and fixed mowing terms have however again led to uniformity and mowing too large areas in one term, which has shown to be destructive not only for invertebrate species (Konvička et al. 2008).

**Fig. 6.** In Brouskův mlýn NNR in the Stropnice floodplain, phased manual mowing (incl. biomass removal) of six segments of peaty and strongly waterlogged meadows with a total area of 8.4 ha was carried out in 2016. In the first mown plots, nectar-rich plants are starting to flower, while in the last meadow parts mowing is being finished. (Z. Hanč)

An acceptable solution is mosaic management, in which a meadow is gradually mown in 2–3 terms of approximately monthly intervals or unmown spots are left in a mosaic or at least as strips (Konvička et al. 2005). Farmers making use of agri-environmental measures under the Rural Development Programme for the period 2014–2020 are obliged to postpone the mowing of strips of up to 1 ha large to a next term in blocks larger than 12 ha.

**Tree and shrub removal**

This is performed in case shrubs and trees have encroached a meadow or pasture. It has been practised (on hundreds of hectares) in e.g. the Bílé Karpaty Mts and the former military area of Mladá. Also herds of large herbivores have recently been introduced into some military areas, which should help to suppress shrubs and trees and opening up their vegetation as a whole to obtain a savannah-like character.

**Fig. 7.** Mosaic mowing in Čertoryje NNR, 2017. (J.W. Jongepier)



A separate problem is the option of restoring coppicing or wood pastures on encroached meadows and pastures, which are historical management methods in forests, but can – due to the current legislation – only be applied in forest tracts when an exemption is granted (see Introduction in section Forests).

**Manipulation with soil nutrients (including immobilisation)**

Most grassland ecosystems today show an excess of nutrients, so it is desirable to decrease their level somehow. In the long term, this can be achieved by regular multiple mowing with thorough removal of the cut biomass (see the previous paragraph), which reduces mainly the nitrogen content. This is more complicated with pastures because part of the nutrients is mostly soon returned. Besides nitrogen also phosphorus, which is hard to export from an ecosystem (Honsová et al. 2007), is often essential. Manipulation with nutrients can sometimes be achieved by adjustment of the water regime. For example in fen meadows, the restoration of natural calcium carbonate precipitation in the form of tufa leads to an immobilisation of phosphorus (Lamers et al. 2015).

**Removal of organic soil horizon**

This relates to the previous paragraphs, since it can lead to a radical and sudden decrease in nutrient level. Handling the considerable amount of removed material is however a problem. In the Czech Republic, this method has been successfully applied in the restoration of *Dianthus arenarius* subsp. *bohemicus* populations at its only remaining site (Šlechtová & Bělohoubek 2012). Presently, psammophytic vegetation in Váté písky NNM (see Řehounková & Jongepierová, p. 99), Vojenské cvičiště Bzenec NM (Fig. 7) and Pánov NM is restored this way.

**Manipulation of the water regime**

It would be good to reirrigate wet meadows and pastures which have needlessly been drained in the past, for example by filling up drains or making them dysfunctional in other ways, which locally happens spontaneously. On the other hand, the species richness of some meadows was conditioned by localised delicate superficial drainage being filled up, causing some hygrophilous dominants to expand. It is then appropriate to consider restoring this drainage (mostly connected with adequate management).

**Burning**

This can prevent expansion of shrubs and trees and accumulation of litter or influence the nutrient regime. Moreover, it reduces competition and enables generative reproduction of some species, which is otherwise markedly limited in densed grassland communities. Burning of 'grass' was commonly practised in the past, but is today hindered by fire safety legislation. However, burning is more and more considered as a tool in conservation management (Pešout 2016). It was officially applied in e.g. the Brdy PLA in 2016 when restoring heathlands (see Fišer et al., p. 107). Burning was already promoted as an appropriate tool for the restoration of heathlands in the Czech Republic in the 1980s by Jarmila Kubíková. The option of small-scale burning has been included in the new draft management plan for Váté písky NNM and is also elsewhere being considered as a management tool for e.g. meadows in the Bílé Karpaty Mts with respect to the fact that this type of management has been applied for similar communities in Ukraine to date (Roleček, in verb.). It is,

**Fig. 8.** Restoration of drift sands in Vojenské cvičiště Bzenec NM, 2013. Eutrophic layers are overlaid with oligotrophic ones. (I. Jongepierová)

**Fig. 9.** Raking dead biomass and disturbing soil to support *Gentianella lutescens* subsp. *lutescens* in U Zvonice NM, 2015. (I. Jongepierová)

**Fig. 10.** Gap with rosettes of germinated *Gentianella praecox* subsp. *bohemica* plants at the site of Chvalšiny after seeding in the previous year. (J. Brabec)

however, necessary to be cautious with fire, for example with stands of black locust, as *Robinia pseudoacacia* is a pyrophyte, i.e. a plant whose seeds germinate much more easily after short exposure to high temperatures.

**Artificial gap creation or turf removal**

Most regularly mown dense grassland swards have a low percentage of so-called vegetation gaps, i.e. places in which plants can reproduce generatively (from seed). Even pastures grazed in the summer months have a sward that is so dense that seedlings do not survive the competition of a closed sward in spring, the best time for seed germination because of the sufficient soil moisture. If we want to support plants which need bare soil for their germination, we can create this either by harrowing the present sward or even by scraping off or turning the turf. This can however not be recommended as a general measure, but rather as a local contribution to creating a mosaic of habitats in justified cases, based on knowledge of the ecology of particular species. It is applied to support the germination of e.g. dwarf gentians (*Gentianella* spp.) (Brabec et al. 2011, Brabec 2012) and *Echium maculatum*, in which case the disturbance is performed in rather small plots by thoroughly removing dead biomass and moss with rakes. Sparse grasslands with isles of bare soil in the sward moreover provide many threatened invertebrate species with opportunities for nesting (e.g. bees and digger wasps), reproducing or insolating (e.g. butterflies and orthopterans) and hunting (e.g. spiders and predatory beetles).

**Transfer or sowing of desired plant species**

Presently degraded meadows can in particular cases be sown with seeds of target plant species, best collected in an adjacent non-degraded sward. This can also be secured by transferring and spreading hay or freshly cut biomass with already ripened seeds of key species from a nearby site of comparable species composition. The effectivity of this operation will be lower if the grassland which is sown has a higher cover. The present community creates strong competition for most key plants, not only in the aboveground biomass but particularly in the root system. Even in plant communities apparently open for a long time (e.g. former quarries), species occupy all favourable microsites, so that the probability of new plants to establish is low. We can, however, increase this probability by harrowing or manual hoeing. In exceptional cases we can plant a target species, but usually one has to deal with the fact that its cultivation and subsequent return to nature requires a lot of labour (and thus high financial expenses). Moreover, it is necessary to have perfect knowledge of the biology of the species in question.

**Suppression of unwanted plant species**

In some cases, mowing a complete sward may be less effective with regard to the elimination of some species than pulling out individual plants manually. For example under humid conditions and if growing in light soils, entire plants of *Calamagrostis epigejos* can be easily pulled out. Similarly, individual plants of *Solidago canadensis* and *S. gigantea* can be eliminated. A special approach, leading to the support of target species, is sowing hemiparasitic plants, which weaken dominants in the sward, especially grasses (see Těšitel 2015, Těšitel et al. 2017, Těšitel & Mládek, p. 81).

## Re-creation of grasslands on arable land

Converting arable land to species-rich grass-herb vegetation usually requires a long time. Its success not only depends on restoration method and (if used) seed mixture composition, but also on the local conditions of the site to be 're-grassed' (Jongepierová & Malenovský 2012, Jongepierová et al. 2012, Scotton et al. 2012, Ševčíková et al. 2014). The colonisation of the re-created vegetation by specialised phytophagous insect species may stagnate if the taxa have a limited ability to spread (Woodcock et al. 2010a). In these cases, the restoration of insect communities is particularly

**Fig. 11.** Manual extraction of *Solidago gigantea* in Váté písky NNM, 2006. (I. Jongepierová)

more successful in landscapes with a large area of semi-natural species-rich grassland in the immediate surroundings (Woodcock et al. 2010b).

The most frequently used re-creation methods are briefly presented below.

**Spontaneous succession**

In the Czech conditions, mere succession without subsequent management may restore grasslands only at very dry or conversely at very wet sites, where the establishment of shrubs and trees is restricted. In abandoned arable fields at dry sites in the warmest parts of the country, monitoring has shown that older swards are approaching natural steppe vegetation in their species composition (Jírová et al. 2012).

Mostly, however, regular mowing must start roughly from the third year after the abandonment of a field. This method can be used if the farmer does not need forage immediately. It works very well in places where permanent meadows or pastures have been preserved in the immediate surroundings. Restoration of grasslands with a favourable species composition takes approximately ten (Lencová & Prach 2011) to twenty years (Prach et al. 2014), but plants and some groups of vertebrates may require a much longer period of time before the original diversity of species-rich vegetation is restored (see Jongepierová et al., p. 76).

**Commercial seed mixtures**

The sowing of commercial legume-grass seed mixtures is the most frequent way of large-scale conversion of arable land to grassland. Even though this cannot be regarded as ecological restoration, such initially species-poor swards may be spontaneously colonised by target plant and animal species with time, especially if they still occur in the surrounding. This is confirmed by monitoring results from the Bílé Karpaty Mts (Prach et al. 2014, Jongepierová et al., p. 76). In places where subsequent colonisation by desired species is limited for their absence in the surrounding, they can be added to swards created by sowing commercial grass mixtures using sowing or planting.

**Regional seed mixtures**

Regional seed is defined as seed collected, reproduced and applied in a particular area without plant breeding processes. Its species composition is based on that of the natural communities of the area (Scotton et al. 2012). The species richness of plants, especially herbs, also supports a higher diversity of animals which are dependent on them for food or other reasons.

The main advantage of this seed is that it helps to maintain the natural genetic variability of populations to a considerable extent, thereby preventing a spread of foreign genotypes or even non-indigenous species or varieties. Introduced non-indigenous genotypes namely hybridise with the indigenous ones and thus may spread regionally less appropriate genes and 'dilute' the original genetic diversity and resistance of a population.

Instructions on how to obtain and use regional seed can be found in several publications (Scotton et al. 2012, Jongepierová et al. 2012, Jongepierová & Prach 2014, Ševčíková et al. 2014). The main principles are given below.

- Seeds can be obtained from a grassland as part of freshly mown grass biomass (green hay), which is applied immediately to the tract to be restored. This method is mainly used in the Netherlands and Germany, not only on arable land but also at other sites, e.g. fly ash deposits (Kirmer et al. 2014).
- If the cut biomass is dried after mowing, the hay can be used directly as a seed source or be threshed out before use (threshed hay).
- When harvesting with a combine harvester, the sward is mown and threshed right at the site.
- In brush harvesting the seeds are combed out of the standing sward.
- In case of need, a smaller amount of seed can be collected also manually.
- It is advised to cultivate herbs in seedbeds, since it is complicated to collect their seeds in the field (different sizes and ripening times).

On a large scale, species-rich regional seed mixtures for grassland creation on arable land have to date only been used in the Bílé Karpaty Mts, where an area of over 600 ha has already been 'regrassed' this way (Jongepierová 2008, Jongepierová & Prach 2014, Prach et al. 2013, 2015a, Jongepierová et al. 2015, see also Jongepierová et al., p. 76).

**Fig. 12.** *Pseudocleonus grammicus*, a phytophagous weevil of the Curculionidae family, associated with *Carlina acaulis* and *C. vulgaris*. As a result of its low mobility (incapability of flight) it only occurs at sites with a long mowing or grazing history. (F. Trnka)

**Fig. 13.** Collecting regional seed with a brush harvester in the Morava floodplain. (I. Jongepierová)

**Obr. 14.** Obřanská stráň – area of former gardens where in the mid-1990s sods were transferred from a place where a tunnel was reconstructed later. (L. Tichý)

#### Transfer of upper soil layers or turf blocks

Upper soil horizons from a source can be spread over the site to be restored, or entire turf blocks can be transferred to it. However, this is not only technically and financially demanding, but also the damage caused to the donor site poses a problem. This method can be justified on a small scale or in places where the source site is being lost (e.g. progressing mining or building).

The idea of this measure is that transferring soil or soil blocks from a source site helps the desired (target) plant species to spread to the degraded surrounding vegetation. The history of the reparation of a railway tunnel at Obřany near Brno may serve as an example. Here, an important site with dry grassland flora, Obřanská stráň NM, should have practically been destroyed in the 1990s. Eventually, it came to a compromise between nature conservation and railway authorities. At the site where the tunnel was to be repaired, the upper part of the soil including vegetation was removed over an area of about 200 m². The sods were transferred to former garden plots which had been included in the nature reserve. The place was fenced with stones so that it is apparent and can still be localised exactly today. The bulk of the steppe species (including some protected ones) from the original steppe vegetation at this site have maintained themselves, and the plot has had a steppe grassland character since the start. However, until this day hardly any of the transferred xerophilous species have expanded to the surroundings. Similar cases have been recorded concerning the transfer of a small number of sods to a limestone quarry at Hády and the Dálky quarry near Čebín from surrounding dry grasslands. In both cases, a considerable part of the plants again survived the transport and replanting, but just a few species spread to the surrounding or if they did, only very slowly, which is also documented by monitoring results from other locations (Šeffer & Stanová 1999, Klimeš et al. 2010).

## Conclusions

There is a variety of options to restore grassland ecosystems, and most of them are effective. However, there may be problems with financial demands, lack of regional seed or source sites, disinterest and sometimes also inappropriate legislation and administrative difficulties. For the future it is, however, necessary to manage all presently preserved meadows and further regrass arable land especially at sites prone to water and wind erosion. This demands the use of regional seed mixtures where possible, or at least seeding of Czech grass and legume varieties. In regions with a lack of species-rich meadows, where subsequent spontaneous colonisation by unsown target species is slow, it is advisable that tracts sown with species-poor grass seed mixtures are improved by adding seed of local grassland species.

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# Restoration of a floodplain meadow on the Morava river

Dagmar Uhýrková, Karel Fajmon & Ivana Jongepierová

| | |
|---|---|
| Location | Bzenec, ca 3.7 km SE of the church, 48°57‘22“ N, 17°18‘49“ E; elevation 169 m |
| Conservation status | SPA |
| Restored area | 8 ha |
| Financial support | Rural Development Programme |


## Abstract

In the Morava River floodplain, at a site named Vlčí hrdlo near the town of Bzenec, spontaneous succession (and in addition regular mowing) has been proceeding for the past decade, directing from an abandoned arable field to an alluvial meadow. The vegetation of the regenerating grassland has been monitored since the start (2008). The results hitherto show a promising development towards the target vegetation as represented by the adjacent alluvial meadow.


## Site description

According to the regional geomorphological classification, the area belongs to the Vienna Basin, an intramontane depression filled with Neogenic marine and limnic sediments. These are presently covered with Quaternary alluvial gravelly to clayey sediments on which gley fluvisol has developed. The area is climatically classified as a warm region (T4) (Mackovčin et al. 2007, Uhýrková 2013, Uhýrková et al. 2014, http://mapy.nature.cz).

At close quarters of the site flows the straightened Syrovinka stream, a tributary of the Morava River. In the vicinity a so far unused water catchment area is located, belonging to the Kvartér řeky Moravy Protected Natural Water Accumulation Area (http://heis.vuv.cz/), which may influence the hydrology of the site in the future.

**Fig. 1.** View of Vlčí hrdlo, 2011. (J.W. Jongepier)

Still in the mid-20th century, the site was part of a complex of alluvial meadows with dispersed willows. A large part of these meadows, including the site of Vlčí hrdlo, was however – besides the remnants of a streambed (see Fig. 3) – ploughed up in the 1970s and subsequently used as arable land. Another part was not farmed at all and became encroached with shrubs and trees, creating an interesting community of alder carrs with *Carex elata*, phytosociologically close to the *Carici elongatae-Alnetum glutinosae* association variant with *Glyceria maxima*. The remaining meadows (tract called Ondrovská) used to be affected by intensification, especially excessive fertilisation.

## Initial state

After the 1997 floods, the groundwater level went up rose, which strongly complicated farming with heavy machines at Vlčí hrdlo. In 2008, ploughing was ceased and the arable field became fallow land, which has been developing back towards an alluvial meadow through spontaneous succession (Uhýrková et al. 2014). Besides regular mowing, this restoration is strongly supported by a good supply of diaspores of the original alluvial meadow species growing in the surrounding, in particular the adjacent Ondrovská meadow and the unploughed part of the permanently waterlogged parts of Vlčí hrdlo itself.

## Restoration objectives

Restoring an alluvial meadow with vegetation close to the *Cnidio dubii-Deschampsietum cespitosae* association in which dispersed solitary willows occur.

## Monitoring objectives

Assessing the success and speed of spontaneous succession in the restoration process of an alluvial meadow.

**Fig. 2.** Monitoring of one of the permanent plots, 2016. (K. Fajmon)


**Fig. 3.** Map of Vlčí hrdlo, adjacent Ondrovská meadow and surroundings. – Yellow dots mark permanent monitoring plots (see Fig. 4). Background data © ČÚZK.

## Measures applied

**Restoration measures**

Retaining spontaneous succession. In the long-term, also the purchase of plots by the Czech Union for Nature Conservation and their transfer from the Arable to the Permanent Grassland land use category will be important for the restoration and preservation of the meadows.

**Management measures**

Since 2009, the site has been mown once annually at the turn of May and June, in some years for a second time in August or September. The hay is raked up and removed.

## Monitoring methods

In 2008, the initial state of the vegetation on the fresh fallow was captured by making three relevés (measuring 4 × 4 m). Regular vegetation monitoring (using a scale of cover percentages) started in 2012, when four plots 4 × 4 m in size were fixed here (see Fig. 3), three of which roughly located in the place where the relevés had been made in 2008. At the same time, we recorded the vegetation in a reference plot of the same size in a preserved part of Ondrovská meadow, representing the approximate target state. To refine the general vegetation characteristics of the adjoining sites (Vlčí hrdlo and Ondrovská), several relevés were also made in the unmown wet parts (for details, see Uhýrková 2013).

The permanent plots on the fallow have been recorded every other year, i.e. in 2014 and 2016, to this day. The reference plot in Ondrovská meadow was located with a GPS device and again recorded in 2016 (and then also fixed).

Besides making relevés, also botanical surveys were made at both Vlčí hrdlo and Ondrovská meadow in 2012 (Uhýrková 2013). The arrival of meadow species in the fallow is further monitored outside the permanent plots.

## Results

The vegetation on the fallow is developing more or less in the direction of the reference alluvial meadow named Ondrovská, but the quick initial change from mostly annual weed vegetation to vegetation with perennial weeds and the first meadow species (especially generalists) has passed into the much slower stage of supplementation with other species adapted

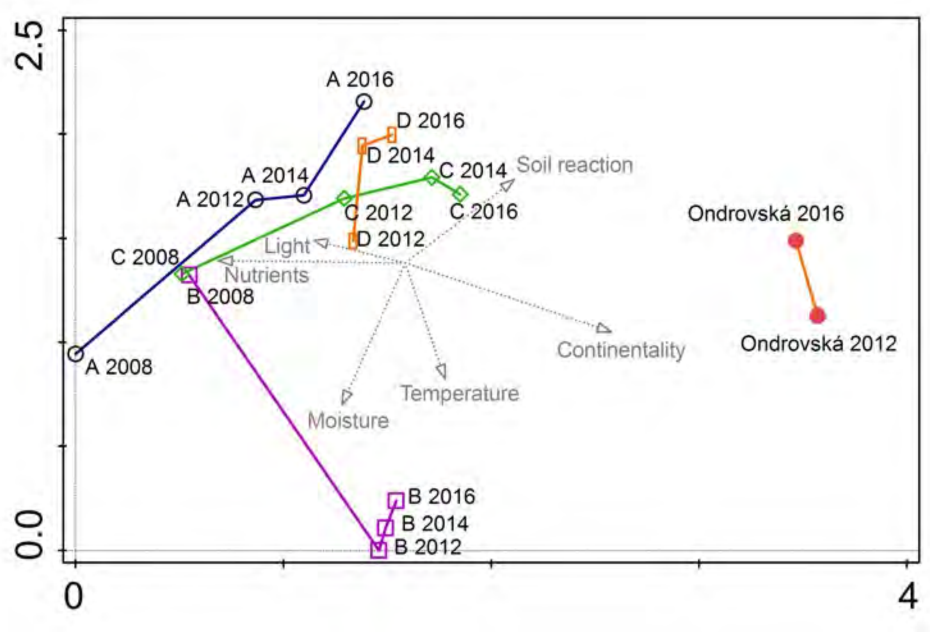


**Fig. 4.** DCA ordination diagram of records from permanent plots at Vlčí hrdlo (empty symbols) and Ondrovská meadow (full circles). – Letters in the empty coloured symbols correspond with the codes of permanent plots in the map in Fig. 3, numbers indicate year of relevé. Means of Ellenberg indicator values, passively projected in the diagram to outline some of the main gradients, are illustratively given in grey.

Shifts between the years 2008 and 2012 in records from the fallow are partly also caused by a physical shift of the recorded plots, because they had not been fixed in 2008 and were located in 2012 only based on marks in an aerial photograph. Similarly, this might have happened with the reference records from Ondrovská meadow, where the plot was however located based on coordinates using a GPS device the following year.

**Fig. 5.** *Gratiola officinalis*. (K. Fajmon)

to regular mowing, including species typical of continental inundated meadows. This stage may last very long and will be different for various parts of the site, depending on the distance to sources of target species diaspores.

General changes in vegetation over the period 2008–2016 is shown in the DCA ordination diagram created in the Canoco 5 programme (Šmilauer & Lepš 2014) in Fig. 4 with passively projected means of Ellenberg indicator values (Ellenberg 1991, Tichý 2002). The diagram clearly shows differences between the permanent plots, which are among others caused by microsite conditions. Plot B, situated in a shallow flat terrain depression with rather long inundated topsoil, differs the strongest. In recent years it has been relatively stable, obviously due to a better water supply. The changes in vegetation over the monitoring period namely seem to be influenced considerably by a long continuous fall in groundwater level due to the recently more frequent periods of extreme drought in the entire region. Also the relation between interannual changes and Ellenberg values for moisture indicates that the changes in the vegetation have to do with a decline in moisture.

At least since 2012, the fallow at Vlčí hrdlo is permanently inhabited by some species of alluvial meadows and marshes, which had probably survived in unploughed places near the margin of the former stream (Uhýrková 2013). Besides common species with a ruderal tendency such as *Carex hirta*, *Cirsium canum*, *Inula britannica* and *Plantago uliginosa*, also some rare species grow here, e.g. *Gratiola officinalis*, *Scutellaria hastifolia* and *Cardamine matthioli*. *Verbascum blattaria* was found once, in 2012. In 2016 we even managed to find *Viola pumila* in the fallow close to Ondrovská meadow. The marginal parts of the fallow, whether along wet places in the former stream or at the boundary with the permanent meadow, are thus mostly species-richer than the central part.

The conversion of fallow to alluvial meadow is inhibited by expanding *Calamagrostis epigejos* and abundant occurrence of the weed *Cirsium arvense* and invasive neophytes like *Solidago gigantea*, less also *Symphyotrichum lanceolatum*, rather limited to unmown margins.

## New insights and recommendations

The monitoring results of the first eight years of restoration indicate that spontaneous succession in the studied area is an appropriate and functional restoration method. It is however a long-term process.

With regard to the relatively high cover of perennial weeds, particularly *Cirsium arvense*, the expansive *Calamagrostis epigejos* and the invasive *Solidago gigantea*, restoration management should include mowing of the meadow twice a year.

To support particular animals, it would further be appropriate to limit a second cut to wet years in the future and divide the first cut into two or three terms from late May to late August (after the danger of new weed encroachment in the sward due to postponing of the cut to the summer months has passed).

It is advisable that long inundated plots along the former stream, which cannot be mown in a regular way, are mown at least in dry years or that the biomass is removed once every few years in winter, in the time of black frost.

In order to restore the scenery as well as to increase site diversity, several solitary white willow (*Salix alba*) and crack willow (*S. euxina*) trees will successively be planted in the area.

**Fig. 6.** The fallow was massively colonised by *Leucanthemum vulgare* already in 2012. (D. Uhýrková)

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# Restoration of species-rich grasslands in the White Carpathian Mts

Ivana Jongepierová, Karel Prach, Karel Fajmon, Eliška Malaníková, Igor Malenovský & Lukáš Spitzer

| | |
|---|---|
| Location | White Carpathian Mts (Bílé Karpaty); elevation 250–610 m |
| Conservation status | PLA, SCI |
| Restored area | 560 ha divided over 40 sites restored with a regional seed mixture; ca 250 ha by means of spontaneous succession, ca 7,000 ha by means of commercial grass-legume seed mixtures |
| Financial support | ME Landscape Management and Restoration Programmes, SAPARD, Rural Development Programme |


## Abstract

The development of vegetation and communities of phytophagous insects on former arable land, in the course of the past decades converted to grassland with a regional seed mixture, a commercial seed mixture or by spontaneous succession, was studied in the Bile Karpaty Mts in 2009–2014. The study included a comparison with reference sites, i.e. long-existing meadows in the surrounding. The results showed that the re-established grasslands become gradually enriched with unsown meadow plant species, but also other organisms spread to them. Leafhoppers, true bugs and phytophagous beetles have formed relatively species-rich communities at the restored sites, but the re-created grasslands are not yet very attractive habitats for butterflies and burnet moths. For example at the oldest sites sown with a regional seed mixture, we recorded on average ten butterfly and burnet species less than at reference sites after 15 years of development, and threatened species with higher demands are hitherto missing at these sites.


**Fig. 1.** Vojšické louky meadows restored with a regional seed mixture. (I. Jongepierová)

## Initial state

In the Bílé Karpaty Mts, several thousand hectares of meadows were ploughed up in the second half of the $20^{th}$ century. Since 1989 (rarely also earlier) most of the arable fields created this way have gradually been converted back to grassland, as they were unsuitable (with a few exceptions) for long-time agricultural use. Some fields have been left to spontaneous succession, but most of them have been 're-grassed' using a commercial grass-legume seed mixture. These mixtures were of course one-sidedly aimed at high production, did not meet specific local conditions and lacked most of the common herbs important for biodiversity as well as for the nutrition and health of farm animals. For these reasons in the early 1990s, CUNC LC Bílé Karpaty, in collaboration with the Bílé Karpaty PLA Authority and the Grassland Research Station at Rožnov-Zubří, initiated the preparation of a species-rich regional grass-herb seed mixture which has gradually been applied on an area totalling the abovementioned acreage.

## Abiotic conditions

Soil chemical analyses (of ca 5 cm deep soil samples taken at all studied sites) indicate moderately acidic to basic soils (pH 5.3–8.9 at restored sites; 5.3–7.6 in permanent grasslands) and a slightly variable nutrient content, apparently influenced not only by natural conditions but also by previous arable land management. The organic matter content at the restored sites amounts to 5.1–17.1 %, in permanent grasslands 8.3–24.8 %.

Total nitrogen reaches values of 1,282 to 4,864 $mg.kg^{-1}$ at restored sites and 1,596 to 7,516 $mg.kg^{-1}$ in permanent grasslands. Phosphates show values of 10 to 195 $mg.kg^{-1}$ and 7 to 111 $mg.kg^{-1}$, respectively. The calcium content is 694–70,420 $mg.kg^{-1}$ at restored sites and 1,086–7,471 $mg.kg^{-1}$ in permanent grasslands.

The mean annual temperature at the studied sites varies between 7 and 9 °C, the mean annual rainfall between 500 and 900 mm.

**Fig. 2.** Turquoise blue (*Polyommatus dorylas*). (J. Zavřel)

## Measures applied

| Year | Restoration measures |
|---|---|
| 1990 | Abandonment of arable land at several sites and their conversion to grassland by spontaneous succession; regular mowing once annually at these sites since the late 1990s.<br>Start of large-scale conversion to grassland by means of commercial grass-legume seed mixtures. |
| 1993–1995 | Collection of common grassland species seeds in species-rich grasslands of the Bílé Karpaty Mts. |
| 1994 – present | Producing seeds of herbs in seedbeds. |
| 1999–2006 | Utilisation of a combine harvester to collect local grasses, particularly *Bromus erectus*. |
| 2007 – present | Harvesting of (mainly grass) seeds with a brush harvester, constructed after a model developed by the British company Emorsgate Seeds. |
| 1999 – present | Sowing of regional grass-herb seed mixtures containing 85–90% grasses, 3–5% legumes and 7–10% other herbs (weight percentages); if possible including 20–30 regional herb and grass species; optimal seeding amount 17–20 $kg.ha^{-1}$; sowing possible in spring or autumn; since 2017, around 20–50 ha annually sown with this mixture by local farmers. |
| | **Management measures** |
| | Mowing 2× annually at least in the first two years after sowing, reducing weeds necessary, after that mowing 1× annually is sufficient at dry sites. |
| | An early cut (first half of June) suppresses grasses and supports herbs. |
| | Replanting of solitary trees, especially oaks and limes, which improves the scenery and also increases biodiversity. |
| | Autumn grazing of the aftermath supports biodiversity. |
| | Replanting of solitary trees, especially oaks and limes, which improves the scenery and also increases biodiversity. |

## Monitoring methods

| Year | Botany |
|---|---|
| 1999–2004, 2009 | Monitoring of succession (vascular plants, soil fauna) after sowing experimental permanent plots at the site of Výzkum (Jongepierová et al. 2007; Jongepierová 2008; Mitchley et al. 2012). |
| 2009; 2014 | Monitoring of succession (vascular plants) at 35 large sites restored with regional seed mixtures (Prach et al. 2013). |
| 2010–2013 | Monitoring of succession (vascular plants) at 31 sites restored with commercial seed mixtures, 16 sites left to spontaneous succession, acquiring data from 23 reference grasslands (Prach et al. 2013, 2014, 2015, Jongepierová & Prach 2014, Jongepierová et al. 2015, Johanedisová et al. 2014).<br>At each of the 82 studied sites (restored with a regional mixture, with a commercial mixture, and spontaneously) 3 relevés were made and compared with likewise obtained relevés from the 23 reference grassland sites. The age of the sown arable fields studied in detail varied from 1 to 31 years, that of fields sown with the regional seed mixture only up to 15 years. |

| Year | Zoology |
|---|---|
| 2012–2013 | Monitoring of communities of phytophagous insects (butterflies incl. burnets, leafhoppers, true bugs) at 16 sites restored with a regional seed mixture and at 16 reference grasslands (Malaníková 2016). |
| 2014 | Monitoring of communities of phytophagous insects (butterflies incl. burnets, leafhoppers, true bugs, phytophagous beetles) at 17 sites (selected from the set of sites where vegetation development was monitored): four sown with a regional mixture, four sown with a commercial mixture, four left to spontaneous succession, and five reference grasslands. |
| | Collection of standardised samples of insects (leafhoppers, true bugs, phytophagous beetles) by sweeping grasslands with a net three times per season (end of spring, beginning and end of summer) at a total of 24 monitored restored sites and 19 reference grasslands (four sites sown with a regional mixture and two permanent grasslands were monitored repeatedly in the period 2012–2014). Data on butterflies and burnet moths were obtained by timed surveys (Kadlec et al. 2012) during two visits to each site in early and late summer. |

## Restoration objectives

Creating species-rich grasslands, increasing biodiversity, reducing erosion, improving scenery, improving hay quality.

## Results

### Botany

All three grassland restoration methods generally lead to vegetation corresponding to the reference grasslands, but their trajectories differ in some respect. At sites restoring spontaneously and those sown with a commercial seed mixture, species typical of mesophilous grasslands (*Arrhenatherion elatioris* alliance) appear to a greater extent, whereas sites sown with a regional seed mixture have a higher number of xerothermic grassland species, i.e. of the main target community (*Bromion erecti* alliance). In the last one, 43 of the 44 species sown successfully established. At older sites, regardless of the restoration method, a total of another 44 (unsown) target species established spontaneously, although most of them having a small cover. Relatively rare species included *Astragalus danicus* and *Gentiana cruciata*. At the same time, the number of unsown target species at the sites increases depending on the time elapsed since restoration started and on the proximity of seed sources in the surrounding (Prach et al. 2015, Jongepierová et al. 2015). At all studied restored sites, a total of 328 vascular plant species have been recorded, 87 of which are target species.

On the whole, the process of restoration of species-rich White Carpathian grasslands is about halfway as for the percentage of established target species. We may apparently also in the future partly rely on spontaneous colonisation of target species, but we can also consider additional sowing of species which have not established to date.

The most significant of the studied factors influencing the development of the vegetation of regrassed sites towards reference grasslands has appeared to be restoration method and soil chemistry, followed by landscape context (availability of diaspores in the surrounding).

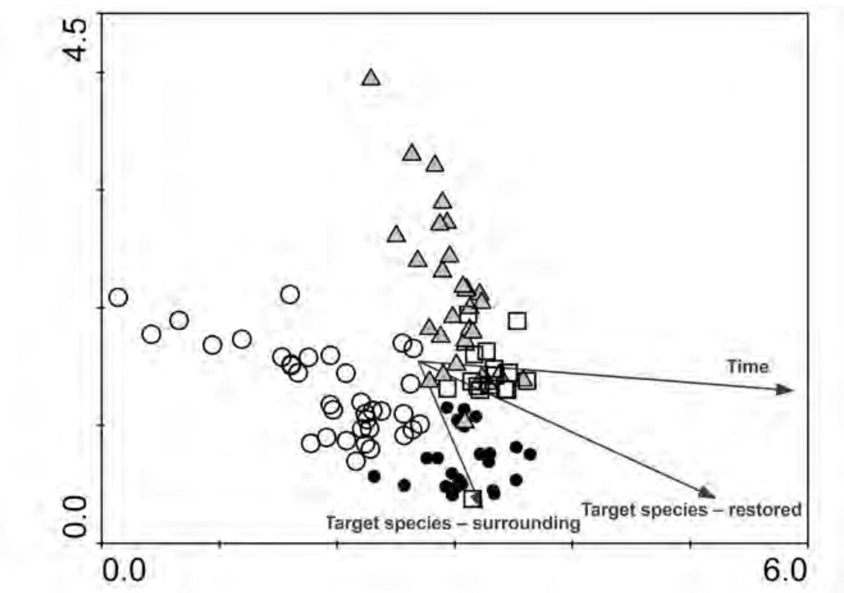


**Fig. 3.** Indirect gradient analysis (DCA ordination method) of relevés from former arable fields restored with a regional seed mixture (open circles), commercial seed mixture (triangles) and by spontaneous succession (squares) compared with passively projected permanent (reference) grasslands (full circles). Time since start of restoration and number of unsown target species – established at restored sites or growing in their surroundings – were used as passively projected variables. Convergence of differently restored sites towards each other and towards the permanent grasslands is noticeable. Adopted from Prach et al. (2015).



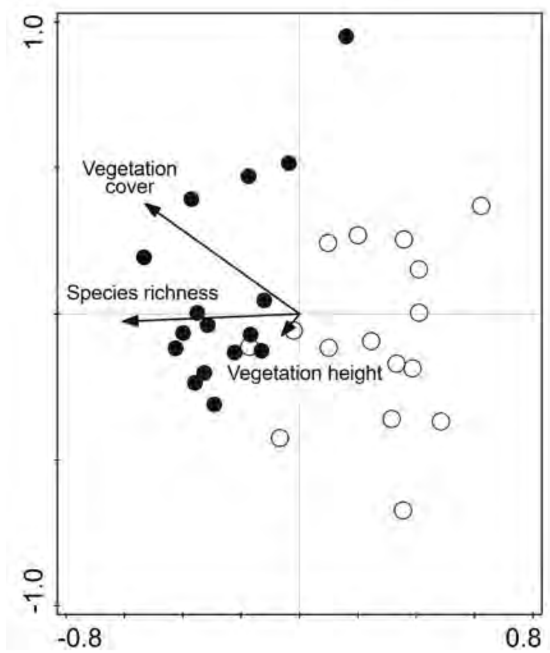


**Fig. 4.** Indirect gradient analysis (PCA ordination method) of leafhopper (Auchenorrhyncha) samples from 16 former arable fields with a regional mixture (open circles) compared to 16 permanent (reference) grasslands (full circles) in their close vicinity (data from 2012–2013). Species richness, height and cover of the vegetation were used as passively projected variables. The division of sites along the first ordination axis indicates differences in species composition of leafhopper communities between both types of sites.

### Zoology

In total 87 species of leafhoppers (Auchenorrhyncha), 96 species of true bugs (Heteroptera), 66 leaf beetle species (Coleoptera: Chrysomelidae), 109 weevil species (Coleoptera: Curculionoidea) and 76 butterfly and burnet moth species (Lepidoptera: Rhopalocera and Zygaenidae) have been recorded at the restoring sites.

The average total numbers of leafhoppers, true bugs and phytophagous beetle specimens in the samples nor the total species richness or the numbers of Red List species (Farkač et al. 2005) differed statistically significantly between the restored and the reference grasslands. The α-diversity of these insect groups at the restored sites is thus already at present comparable to that of preserved grasslands in the surrounding. However, the species composition of their communities at regrassed sites is different from that in the ancient grasslands, which could especially be explained by the hitherto different species richness and species composition of the vegetation, and in the case of leafhoppers also by their different spatial structure (lower total cover of herb layer at sites sown with a regional mixture) (Fig. 4).

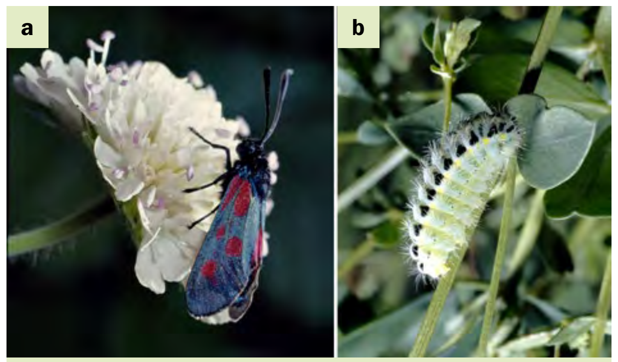


**Fig. 5.** The burnet *Zygaena viciae* is one of many species of diurnal Lepidoptera often occurring in preserved White Carpathian grasslands, but hitherto missing at restored sites at the time of monitoring (except for some of the oldest sites sown with a commercial mixture). Its caterpillars (b) develop on various species of leguminous herbs. (R. Hrabák, archive of Moravian Museum, Brno)

Many insect species characteristic of preserved meadows in the Bílé Karpaty Mts – either trophically associated with particular plant species or preferring structurally complex grasslands – are completely missing or rare at the restored sites. On the other hand, certain leafhopper, true bug and beetle species were found in rather large numbers especially at restored sites, while they were mostly absent from the preserved grasslands in the surroundings. Besides common pioneer and ruderal species these also included some rare taxa, often specialists of short xerothermic grassland habitats, e.g. the froghopper *Neophilaenus infumatus* and the planthopper *Tettigometra impressopunctata*. Newly restored sites thus may increase the α-diversity of the respective insect groups in the studied area. Nevertheless, the species composition of the leafhopper, true bug and weevil communities at differently restored sites was found to overlap to a great extent. Leaf beetle communities in the reference plots were the most similar to sites restored by spontaneous succession. Most weevil specimens were recorded at sites sown with a regional seed mixture. However, no difference in species composition of the model insect groups between the differently restored plots was statistically confirmed.

Unfortunately, not all monitored insect groups reacted to grassland re-creation on arable land so fast and positively. Butterfly and burnet communities at restored sites were generally markedly poorer in species (including the threatened ones) as well as individuals compared to the permanent grasslands. In 2014, the oldest sites sown with a commercial seed mixture (average age 22 ± 8 years at the time of monitoring) resembled the preserved grasslands in this regard the most. Conversely, the relatively young sites sown with a regional mixture (11 ± 3 years) were the poorest in butterflies. The most common butterfly species at the restored sites were meadow brown (*Maniola jurtina*) and small heath (*Coenonympha pamphilus*), which have the characteristic ability of colonising even intensively managed grasslands with a minimum of herb species.

Most monitored restored sites still have the character of vast homogeneous areas missing solitary trees and scrub which can provide butterflies with shelter against unfavourable weather and space for resting. Moreover, the spatial structure as well as the composition of the vegetation in these areas still markedly differ from the preserved grasslands and apparently also many nectariferous plant species which adult butterflies demand as a food source are missing. Nevertheless, here and there weak populations of some currently threatened White Carpathian meadow butterflies have been observed at restored sites, e.g. twin-spot fritillary (*Brenthis hecate*) and turquoise blue (*Polyommatus dorylas*). However, full-fledged restoration of butterfly and burnet communities will probably still take many years and will only be possible providing the spatial diversity of the restored sites is increased by renewal of missing landscape structures such as solitary trees, orchards, hedgerows, scrub, etc.

## New insights and recommendations

Our results show that in the Bílé Karpaty Mts, where there is a still rich supply of seeds of target meadow species in the landscape, newly established grasslands are gradually enriched by unsown meadow species and other organisms. Sowing a regional mixture speeds vegetation succession up by more than 10 years and helps directing it towards dry grasslands of the *Bromion erecti* alliance, typical of the area, instead of mesic grasslands of the *Arrhenatherion elatioris* alliance, which is the community that former arable land sown with a commercial grass mixture and spontaneous succession leads to. Various phytophagous insect groups react to grassland restoration at different speeds. Whereas leafhoppers, true bugs and phytophagous beetles form species-rich communities at restored sites rather quickly, these sites are not yet very attractive habitats to most butterfly species. This situation might improve in the future by planting solitary trees and increasing the number of nectariferous plant species, either by targeted additional sowing or by spontaneous establishment.

## Acknowledgements

We thank Libor Fiala and František Kopeček for performing the monitoring of butterflies, Petr Kment, Jan Bezděk and Robert Stejskal for identifying Heteroptera, leaf beetles and weevils, respectively. Karla Vincenecová is thanked for her help with botanical monitoring. The research was supported by grant GA ČR P504-10-0501, partly also GA ČR 17-09979S, research project RV067985939, and contributions from the national Biodiversity Conservation programme of the CUNC in the years 2012–2014.

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**Fig. 6.** Solitary trees planted at sites restored with a regional mixture in the buffer zone of Čertoryje NNR. (I. Jongepierová).



# Restoration of diversity in vegetation dominated by *Calamagrostis epigejos*

Jakub Těšitel & Jan Mládek

| | |
|---|---|
| Location | Švihov, 49°50'08" N, 15°51'44" E; České Budějovice, 48°58'33" N, 14°26'47" E; Vojšické louky, 48°50'54" N, 17°25'39" E; Návojná, 49°06'41" N, 18°03'00" E; elevation 390–440 m |
| Conservation status | PLA, NNR, SAC |
| Restored area | Small-scale experiments |
| Financial support | GA ČR 14-26779P |

## Abstract

The expansion of *Calamagrostis epigejos* is a major complication in the restoration and maintenance of species-rich grasslands in Central Europe. Based on small-scale experiments, we demonstrate here that sowing of hemiparasitic species of the genus *Rhinanthus* may be used to suppress dominance of this grass and support characteristic plants of species-rich meadows at the same time.

## Introduction

Wood small-reed (*Calamagrostis epigejos*) is a competitively strong clonal grass. It has massively spread over the landscape in the past decades. Its expansion also affects semi-natural species-rich grasslands, from which *C. epigejos* eliminates competitively subordinate species. The grass is often supported by low-intensity management, otherwise recommended for the maintenance and preservation of these communities. Suppressing it with conventional measures is very difficult. Sowing hemiparasitic plants, which manage to weaken *C. epigejos* by belowground parasitism, may however be a suitable alternative.

The principle of this new type of management consists in connecting yellow-rattle (*Rhinanthus* spp.) plants by means of their special sucking organs, so-called haustoria, to the small-reed root system (Fig. 1), which is very sensitive to parasitism, in contrast to herbs. *Rhinanthus* sucks water and dissolved nutrients (both mineral and organic) from the vascular bundles (xylem). In this way, it considerably weakens the growth of small-reed. Moreover, the grass is often shaded by *Rhinanthus* as well as by the surrounding vegetation during the spring months. Thus, *Calamagrostis* gradually depletes all reserve nutrients and disappears from the meadow community almost completely within 2–3 seasons.

## Site description

The vegetation of the Švihov site consisted of intermittently wet meadow vegetation of the *Molinion caeruleae* alliance at the beginning of the experiment. The experiment at České Budějovice was located in ruderal vegetation in a post-industrial zone. Both sites had long (more than 10 years) been abandoned before the experiments started in 2012. By contrast, the experimental plots of Vojšické louky and Návojná had long been mown once a year until 2012, mostly around mid-July. Degraded broadleaved dry grassland vegetation of the *Bromion erecti* alliance occurred there. *Calamagrostis epigejos* was dominant in the herb layer before the start of the experiment at all sites.

## Restoration objectives

Suppressing expansive *Calamagrostis epigejos* and subsequent restoration of diversity of the meadow vegetation by sowing hemiparasites of the genus *Rhinanthus*.

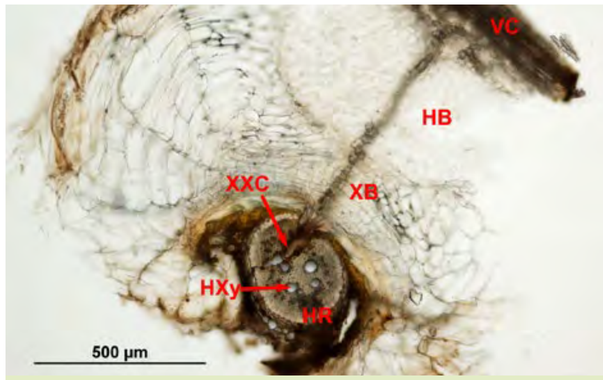


**Fig. 1.** Anatomical transverse section of a *Rhinanthus alectorolophus* haustorium attached to a root of *Calamagrostis epigejos*. VC: vascular core of the haustorium, HB: hyaline body, XB: xylem bridge, XXC: host-parasite xylem-xylem contact, HXy: host xylem, HR: host root. (J. Těšitel)

**Fig. 2.** View of the experimental site at Návojná with *Rhinanthus alectorolophus* growing in the second vegetation season, 18 May 2014. (J. Mládek)

## Measures applied

All experimental sites, autumn 2012: mowing the grassland, raking up the old biomass and sowing 500 *Rhinanthus* seeds per m² before the end of November to ensure breaking their dormancy by cold.

At two sites (Švihov, Vojšické louky) mowing twice per season was tried out as a possible alternative treatment. In the results, this was compared with the effect of yellow-rattle sowing on small-reed. *Rhinanthus alectorolophus* was used in the experiments at Švihov, České Budějovice and Návojná, whereas *R. major* was used for the experiment at Vojšické louky. In the following years the sites were mown manually in July. The experimental plots mown twice at Švihov and Vojšické louky were also mown in October.

## Monitoring methods

The experiments were arranged in blocks, each containing plots with all performed treatments and their combinations. The initial state of the plots (vegetation composition, dominance of *Calamagrostis epigejos*) was documented before the treatments by making relevés (Švihov, Vojšické louky, České Budějovice) or an estimation of the biomass percentage of each species (Návojná) through calibration (according to the method by Tadmor et al. 1975). Further, *Calamagrostis* biomass production was determined (Švihov, Vojšické louky). After that, the plots were monitored annually in the same way in early summer.

## Results

Sowing *Rhinanthus* reduced the dominance of *Calamagrostis* considerably at all sites (Figs. 3–6). At Švihov and Vojšické louky, the effects of sowing *Rhinanthus* and mowing twice per season were found to add up: *Calamagrostis* was best suppressed by a combination of these two treatments. Detailed analyses of the changes in species composition (not shown) indicate that *Rhinanthus* alone supported the occurrence of typical meadow species, whereas mowing twice per season had an ambiguous influence on rare species (suppressing e.g. the threatened *Clematis recta* at Vojšické louky).

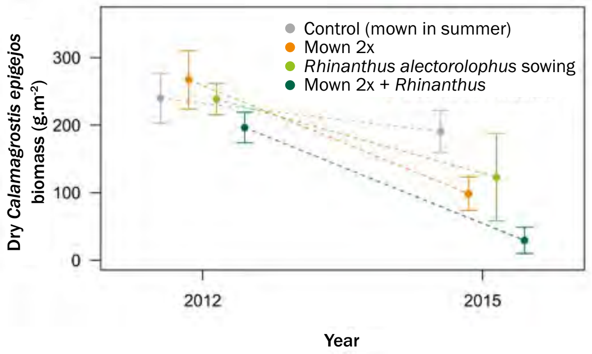


**Fig. 3.** Effects of the experimental treatments on weight of dry *Calamagrostis epigejos* biomass at Švihov.

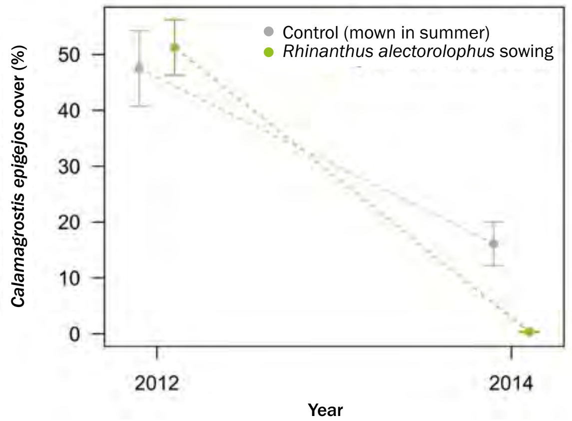


**Fig. 4.** Effect of *Rhinanthus alectorolophus* sowing on cover of *Calamagrostis epigejos* at České Budějovice.

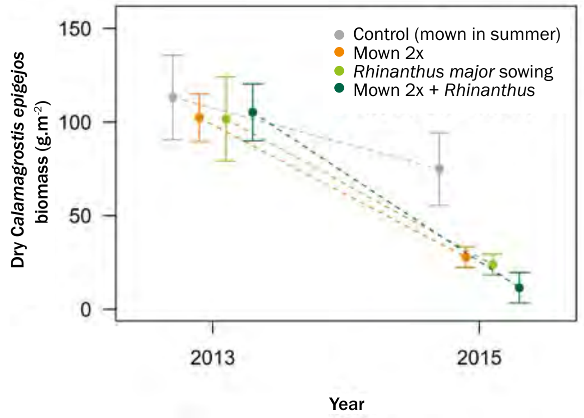


**Fig. 5.** Effects of the experimental treatments on weight of dry *Calamagrostis epigejos* biomass at Vojšické louky.

## New insights and recommendations

Sowing root hemiparasites of the genus *Rhinanthus* may be an effective tool in suppressing *Calamagrostis epigejos*. Depending on local conditions, it can be combined with other types of management, such as mowing twice per season, sward disturbance and raking up old biomass in autumn (particularly in areas with high vegetation productivity).

Since *Rhinanthus* prefers parasitising grasses (i.e. including *Calamagrostis*), it indirectly supports herbs, which are often the reason for conserving grassland communities. The present four pilot studies indicate the possibility of using hemiparasites in restoring the species richness of various types of vegetation. Another appropriate step would be to test this in a large-scale application. With regard to the high costs and the limited amount of seed currently available on the European market, sowing small sites or strips is recommended. Only the minimum density of 300 seeds per 1 m² should be used (Mudrák et al. 2014), enabling *Rhinanthus* to establish successfully in closed vegetation and to weaken *Calamagrostis* considerably. *Rhinanthus* seeds from sown plots can gradually be spread to other plots in the following years by choosing the appropriate time of mowing, drying and collecting hay. The first cut needs to be timed approximately at the end of June, when the seeds ripen in the capsules. For the first introduction, *Rhinanthus* seeds can either be collected from a local population (realistic for sowing hundreds of m²) or be obtained as commercially available seed supply, because e.g. *Rhinanthus alectorolophus* was a common weed in arable fields a hundred years ago and no genotypes have been described in the Czech Republic.


## Acknowledgements

We wish to thank Jan Horník, Tamara Těšitelová, Miroslav Dvorský, Karel Fajmon, Ondřej Nezval, Tomáš Ritzka, Pavla Mládková and David Opálka for their help with the field work.


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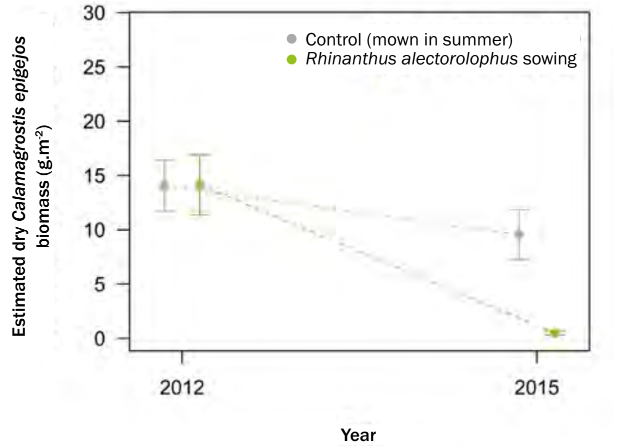


**Fig. 6.** Effect of *Rhinanthus alectorolophus* sowing on dry *Calamagrostis epigejos* biomass estimate at Návojná.


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**Fig. 7.** Experimental plot at Návojná, where *Rhinanthus* clearly supported flowering herbs like *Leucanthemum vulgare*, *Polygala comosa* and *Campanula patula* already in the second season. (J. Mládek)

# Grazing of dry grasslands in the Bohemian Karst

Hana Mayerová & Tomáš Tichý

| | |
|---|---|
| Location | Český kras (Bohemian Karst) PLA – limestone karst between Prague and Beroun, 49°52'–50°00' N, 14°02'–14°21' E, altitude 199–499 m |
| Conservation status | PLA, NNR, NNM, NR, SCI |
| Restored area | 25 ha |
| Financial support | ME Landscape Management and Restoration Programmes, Vápenka Čertovy schody a.s., Velkolom Čertovy schody a.s. |

## Abstract

In 2005, dry grassland and steppe sites in the Bohemian Karst PLA, used as pastures several decades ago, were included in a project on a gradual restoration of historical management by sheep and goat grazing. Long-term monitoring results show that grazing has positive effects on species richness and composition of both vegetation and invertebrates specific to steppe ecosystems.

## Site description

The Bohemian Karst landscape has been settled by man continuously for the past few thousand years, and human settling has always been connected to livestock grazing (Mládek et al. 2006, Stolz & Matoušek 2006). Due to the relatively low yield of dry grasslands on shallow soils based on limestone, sheep and goat grazing has been common in the Bohemian Karst, as these animals tolerate lower-quality fodder and rocky terrain (Poschlod & Wallis De Vries 2002). Grazing maintained open vegetation patches even in the time of closed canopy forest, and thus supported plant and animal species associated with this type of habitat (Konvička et al. 2005). The intensity of grazing has varied through history, mainly for socio-economic reasons. In the 20th century, the extent of grazing livestock decreased significantly, mainly after World War II (Novák & Tlapák 1974). With the decline in grazing, the area of open patches decreased due to site fragmentation and succession into woodland.

**Fig. 1.** Herd of sheep and goats in enclosure. The outside area is yet to be grazed. (H. Mayerová)

The main vegetation type is dry grasslands, according to the European vegetation classification belonging to the *Festucion valesiacae* alliance (Chytrý 2007), with transitions to the *Alysso-Festucion pallentis* and *Seslerio-Festucion pallentis* alliances, and also to the *Bromion erecti* alliance. Notable species include *Adonis vernalis*, *Pulsatilla pratensis* subsp. *bohemica*, *Anacamptis pyramidalis* and *Stipa pulcherrima*. *Juniperus communis* individuals document the grazing history of the sites.

## Initial state

The remaining patches of grasslands were degraded due to a rising cover of dominant grasses and sedges at the expense of low-competitive species. At the beginning of the project, plant and invertebrate species diversity was decreasing, small bare soil patches were disappearing, litter was accumulating, and microhabitat diversity was declining.

## Restoration objectives

Restoring and maintaining high-quality dry grassland habitats, restoring and maintaining the scenery formed by a mosaic of various forest and open grassland vegetation, maintaining suitable sites for populations of protected species.

## Management measures

Small-scale rotational grazing (Mládek et al. 2006, Pavlů et al. 2003) in electrically fenced areas with mixed herds of sheep and goats (at a ratio of 3:1) from April to October. The herd includes 100–130 animals per site and spends a few weeks at each site (depending on its area) once or twice during the grazing season. Grazing restoration started in 2005 and more sites were added in 2006 and 2011. The sites observed are mainly Paní hora (grazed since 2005) and Šanův kout (since 2006) in Karlštejn NNR, and further Zlatý kůň NNM (grazed since 2005) and Kotýz NNM (since 2011), all differing in quality, species richness and level of degradation.

Reasons for choosing a mixed herd of sheep and goats were that both are traditional livestock in the area and that the combination has the desired effect on the vegetation, as sheep graze lower tussocks, whereas goats prefer shrubs and taller grasses (even flowering).

Fences are moved every 2–7 days, when the tussocks are strongly grazed, so that grazing pressure changes during the season according to biomass production. At each site, also ungrazed strips (located in different places for each grazing cycle) are left for plants and invertebrates to reproduce.

## Monitoring methods

Before the reintroduction of grazing, permanent plots (1 × 1 m) were established for vegetation monitoring, so that long-term data describing the development of species composition is available. There are 8 to 12 pairs of permanent plots (grazed paired with a control protected with a cage against animal grazing) at each site. In these plots, the percentage cover of each plant species is recorded every spring (for details, see Mayerová et al. 2014).

## Results

Monitoring results show the effect on the initial state of the sites: more degraded sites with lower species richness, e.g. Kotýz, react to grazing faster and the numbers of vascular plant species recorded in permanent plots increase markedly in the first few years of management. The observed process is without doubt enhanced by the fact that the herd moves between sites during the grazing season and the animals can therefore act as vectors of seeds. Plant populations are therefore not dependent on the seed bank at the site, but can be reinforced from more distant sources. At these species-poorer sites also control plots show an increase in species richness, while the control plots are only protected against the effect of grazing, not against the input of seeds. This overall increase in species number per plot can cause non-significant results when testing for the effect of grazing on species richness, as the results from Kotýz show (Fig. 2).

Sites which were in better condition before the start of the project, e.g. Paní hora and Zlatý kůň, need a longer time before showing any effect of grazing on species richness, approximately five or six seasons. Moreover, there is an increase in species number in grazed plots and a decrease in control plots, which has not been observed in species-poorer plots. This can be seen on the results from two vegetation types at the Zlatý kůň site. Plots with *Festucion* vegetation, where the initial species richness was around 15 species per 1 m², showed a significant reaction to grazing after four years by an increase in number of species in grazed plots. The decrease in the control plots started later, after eight years (Fig. 3). Richer plots with *Bromion* vegetation, initially counting around 20 species per 1 m², needed more time, six seasons, to show an increase due to grazing, but the decrease in the control plots proceeded simultaneously (Fig. 4).

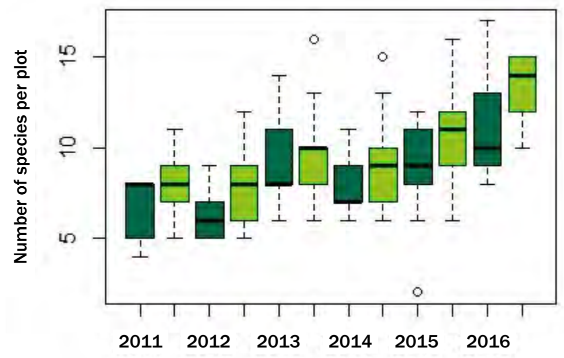


**Fig. 2.** Species richness of vascular plants (number per 1 m²) at Kotýz over six years (2011–2016) from the beginning of grazing (light green – grazed plots, dark green – control plots). Species richness significantly increases in time and there is a significant difference between grazed and control plots in 2016 (tested with analysis of variance).

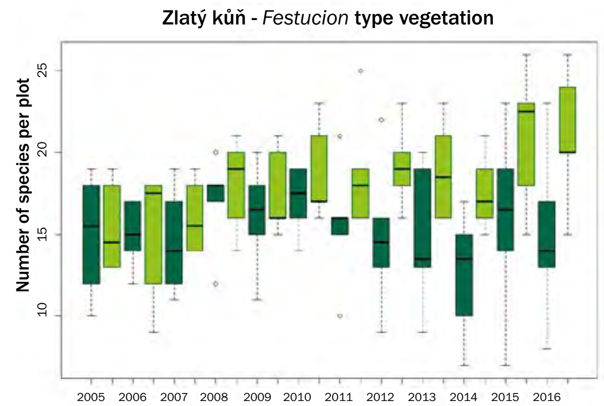


**Fig. 3.** Species richness of vascular plants (number per 1 m²) in *Festucion* plots at Zlatý kůň over 12 years (2005–2016) of grazing management (light green – grazed plots, dark green – control plots).

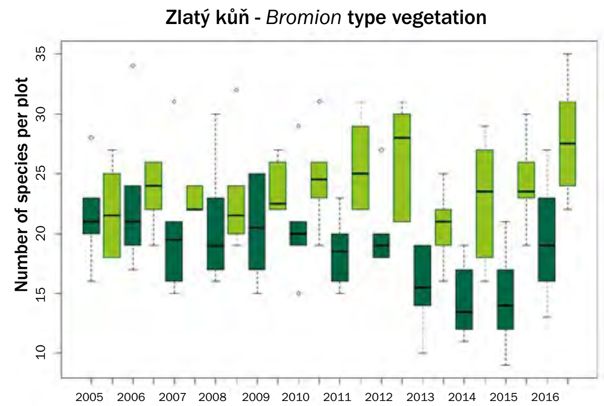


**Fig. 4.** Species richness of vascular plants (number per 1 m²) in *Bromion* plots at Zlatý kůň over 12 years (2005–2016) of grazing management (light green – grazed plots, dark green – control plots).

**Fig. 5.** Small pasque flower (*Pulsatilla pratensis* subsp. *bohemica*) in early spring at Paní hora in Karlštejn NNR. (H. Mayerová)

**Fig. 6.** Grazing should start after *Pulsatilla* flowering, so that the plants can produce seeds and the population does not decline. (H. Mayerová)

When comparing the results from different sites, it is evident that the observed effect of grazing on the vegetation clearly depends on the initial state, especially on species richness. At sites with lower species richness, grazing management allows for the coexistence of more species on a small scale by seed deposition and disturbances. Sites with higher species richness, on the other hand, are more vulnerable to abandonment (observed in control plots) and react with a decrease in species number, dominance of a few species and litter accumulation.

Overall grazing promotes typical steppe species sharing traits like small height, tussock or rosette forms, and annual life cycle (*Arenaria serpyllifolia*, *Carex humilis*, *Eryngium campestre*, *Festuca rupicola*, *F. valesiaca*, *Pilosella officinarum*, *Potentilla arenaria*, *Scabiosa ochroleuca*, *Thlaspi perfoliatum*, *Thymus praecox*, *T. pulegioides*, *Veronica praecox*). A few competitively strong species of grasslands with a dense sward prosper in the ungrazed plots, particularly grasses and taller forbs like *Arrhenatherum elatius*, *Brachypodium pinnatum*, *Bromus erectus*, *Galium album*, *Stachys recta* and *Teucrium chamaedrys*.

The grazing management re-introduced in 2005 and 2006 at the monitored localities has significantly contributed to the restoration and maintenance of dry grasslands and raised or maintained a high species richness by increasing microhabitat heterogeneity on a small scale. These conclusions agree with other studies from similar areas (e.g. Milchunas et al. 1988, Dostálek & Frantík 2008).

## New insights and recommendations

Long-term monitoring of the reintroduced grazing management shows how the effect on vegetation evolves with time and how it can be recorded. Based on statistical evidence and practical observations gained during management planning we have made the following recommendations which can be generalised to other sites.

- Results after just a few seasons are not statistically significant and show strong effects of interannual variability (Mayerová et al. 2010). The suitability or success of similar management cannot be evaluated without long-term data.
- It is necessary to consider each site separately with regards to its initial state, vegetation composition (especially presence of endangered and expansive species) and presence of notable invertebrate species, and then to adapt the planned grazing management. The objective is to ensure a maximum impact of grazing on degradation processes (expanding grasses or shrubs) and to avoid a negative impact on target species (grazing of flowers before seed ripening, or grazing at a time when vulnerable invertebrates are present).
- If more than just a few sites are involved, it is impossible to take all the above into account perfectly. In this case, experience and monitoring results show the importance of variability of grazing in time, intensity and space between seasons to ensure that possible negative impacts on target species are not repeated.

## Acknowledgements

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**Fig. 7.** Grazing herd on the slopes above Alkazar quarry. Sheep and goats can handle steep and difficult terrain. (H. Mayerová)

# Restoration of steppe communities in northern Bohemia

Roman Hamerský & Vlastislav Vlačiha

| | |
|---|---|
| Location | Central Bohemian Uplands (České středohoří): SAC Raná-Hrádek, 50°24'24.745" N, 13°46'16.839" E; SAC Oblík-Srdov-Brník, 50°24'17.262" N, 13°48'10.663" E; elevation 240–509 m |
| Conservation status | PLA, SAC, NNR |
| Restored area | 176 ha |
| Financial support | LIFE+, ME Landscape Management and Restoration Programmes, EEA grants, Rural Development Programme; average costs of shrub removal €950/ha, mowing €690/ha, sheep and goat grazing €730/ha |

## Abstract
The dry steppe grasslands at the sites of Raná and Oblík belong to the most valuable sites of the České středohoří PLA. Large parts have suffered from fast spontaneous encroachment of shrubs after management was abandoned and from the spread of tall grasses, especially in the 1990s. Species degradation of the grasslands has been stopped by removing trees and shrubs and reintroducing management (mowing, controlled sheep and goat grazing). Monitoring results show a shift from dominant tall grasses to short grassland with *Bromus erectus* and *Festuca* spp. At the same time, rare species from surrounding fragments of steppe grasslands have completed the vegetation. Through a suitable combination of grazing and mowing, the population of European ground squirrel (*Spermophilus citellus*) at Raná has considerably grown.

**Fig. 1.** Vegetation dominated by *Stipa pennata* at Raná. Grazing by a combined herd of sheep and goats supports shrub reduction and expansion of steppe species. (R. Hamerský)

## Site description
The occurrence of species-rich extrazonal steppe communities at SAC Raná-Hrádek and SAC Oblík-Srdov-Brník relates directly to the dry and warm climate of the Louny region. On mineral-rich, basaltic rocky slopes and sloping tracts made up of Mesozoic sediments (marlstones, claystones) at the foot of the hills, the occurrence of nearly a hundred threatened plant species included in the Red List of the Czech Republic have been recorded. *Helictotrichon desertorum* and *Stipa glabrata* are phytogeographically the most significant, as they occur in an exclave at the western boundary of their distribution area. The largest part of their population in the European Union grows in these two SACs.

Besides natural conditions, the steppe communities are directly linked to the long-time agricultural management of the Louny region landscape. The preserved clearance cairns, which form an entire system of more than 72 km long at Oblík (Machová 2010), are outstanding traces of the colonisation of the landscape. These mounds of agrarian origin used to divide tracts of farmland from the foot up to the steep hill slopes. Better accessible land was farmed until the 1950s.

## Initial state
The decline in the number of sheep since the early 20$^{th}$ century as well as the pressure of conservation measures (designation of Raná National Nature Reserve) moderated the grazing intensity on steep, rocky, nutrient-poor slopes where needle-grasses (*Stipa* spp.) prevail. The flocks were later moved to more favourable sites at the base, which had until then mostly been used for cattle grazing. According to botanists of that time, the very high farming pressure, 'devastation by grazing', was nevertheless the main reason for a botanical society to rent the most valuable parts with the aim of preserving rare steppe flora on e.g. the nearby Tobiášův vrch hill as early as the 1930s (Prinz et al. 1936). Also in Raná National Nature Reserve (first designated a Town Reserve in 1936, redesignated a State Nature Reserve in 1951) grazing was prohibited, as stated in the reserve regulations (conservation terms), because of the presence of rare plant species. This prohibition was sometimes violated: according to reports, cattle on Raná hill often escaped.

**Fig. 2.** Vegetation with *Stipa pulcherrima* and dispersed shrubs at Oblík, extensively grazed by sheep. (L. Sedláček)

In the following years, sheep and goat grazing intensity gradually decreased. In the 1970s and 1980s it settled down on ca 2500 sheep in the two SACs. This grazing pressure, currently considered optimal, supported a stronger generative spread of species formerly suppressed by grazing, e.g. *Stipa* spp., *Cotoneaster integerrimus* and *Anthericum liliago*. In that time, grazing rather successfully prevented shrubs from spreading to the relatively humid and nutrient-rich pastures at the foot of the rocks.

In the years 1991 to 1997, an exponential spread of shrubs (especially *Crataegus* spp., *Cornus sanguinea*, *Prunus spinosa*, *Rosa canina* and *Fraxinus excelsior*) caused by a lack of grazing was recorded on the most valuable needle-grass steppes. Only rocks, screes and sites on very steep, sunlit, desiccant and skeletal, south- to southwest-facing slopes often marked by landslides remained less affected. The encroachment speed of the most valuable sites was directly linked to the course of the weather in the vegetation season and the natural speed of shrub rejuvenation. During one season many up to 30–150 cm high shoots can grow out of *Prunus spinosa*, *Crataegus* and *Robinia* stubs (Kubát & Machová 2010).

In large pasture areas, overall degradation of steppe grassland was recorded caused by mesophytisation of the environment (nitrogen deposition, accumulation of biomass, increased humidity of the environment, change in species composition and vegetation height). When comparing the years 1973 and 2007, Zmeškalová (2009) found a decrease in pasture species and species of broadleaved grasslands but, conversely, an increase in nitrophilous species and weedy species of wood fringes and shrub communities. A general decline in area of steppe pastures (*Festuco valesiacae-Stipetum capillatae*) was recorded as well as a decrease in cover and abundance of steppe species *Stipa pulcherrima* and *S. pennata*, *Astragalus exscapus*, *A. austriacus* and *A. danicus*, *Adonis vernalis*, and *Pulsatilla pratensis* subsp. *bohemica*. These changes led to a spread of aggressive, tall grass species, particularly *Arrhenatherum elatius*, *Dactylis glomerata* and *Calamagrostis epigejos*. Expansion of com-

**Fig. 3.** *Astragalus austriacus* at Raná, reacting on restoration management with population increase. (V. Vlačiha)

mon shrubs also suppressed the occurrence of rarer shrub species like *Cotoneaster integerrimus* and *Cornus mas*. At the same time, populations of European ground squirrel (*Spermophilus citellus*) and some insect species, e.g. hermit (*Chazara briseis*) and Damon blue (*Polyommatus damon*), saw a radical decline.

## History of vegetation monitoring

Changes in vegetation have been monitored at both sites for a long time. The results of a series of theses from the 1970s was published in the monography on Oblík by Slavíková (1983). In 1993–1998 also the impact of an incidental fire (April 1993, fire area 3.5 ha) on the species composition of the *Stipa* grasslands of Raná NNR was monitored. After removal (burning) of the dead biomass, open spaces were occupied already in autumn, especially by ephemerous species like *Holosteum umbellatum* and *Erophila verna*. The following year, abundance of the species *Rapistrum perenne*, *Verbascum phoeniceum*, *V. lychnitis*, *Oxytropis pilosa* and *Astragalus exscapus* sharply increased. In the flowering time of *Rapistrum perenne* and *Verbascum phoeniceum*, a yellow-purple colour prevailed at Raná, seen from afar. After the fire, the first impression was that ca 20% of the *Stipa pulcherrima* and *S. pennata* plants had been burned and the rest of the population was stagnating. The year after saw a quick turn of events: abundance, plant height and culm density of *Stipa* tussocks had increased. The changes remained visible until five years after the fire, when old biomass gradually built up again.

Changes in vegetation and populations of threatened plant species at Oblík, caused by grazing, were monitored in the years 1999–2003 (Hamerský & Bělohoubek 2003). The gradually more intensive restoration of the steppe vegetation (concentrated and multiple shrub removal, regular mowing and additional grazing) had led to the need of monitoring the impacts of these measures.

## Restoration objectives

Restoring preserved open *Stipa* steppe sites (narrow-leaved dry grasslands of the *Festucion valesiacae* alliance) and 'white slope' areas (broadleaved dry grasslands of the *Bromion erecti* and *Cirsio-Brachypodion pinnati* alliances).

## Restoration measures

The restoration measures were carried out in three types of area:

**1**) Areas of relatively well-preserved narrow- and broad-leaved dry grasslands in large areas of the NNRs, their buffer zones, and sometimes mosaically also elsewhere. These areas were formerly only grazed at various intensities.

Treatments: multiple (3×) minor shrub reduction, higher grazing pressure in the first two years, lower grazing pressure in the following four years. The work was carried out carefully with regard to rare species.

**2**) Areas with partly degraded steppe grassland covered for up to 50% by dense scrub and with a high rate of tall grass species and low rate of preserved steppe species (former pastures, sometimes fields or fallows).

Treatments: annual major shrub removal (7× in total, two reductions in the first year), followed by annual mowing or additional grazing, in wet years two times a year.

**Fig. 4.** Large population of *Astragalus danicus* after reintroduction of grazing at Raná. (R. Hamerský)

**3**) Degraded areas with shrub and tree cover locally reaching up to 100%, almost without steppe species (former orchards, pastures, fallows and fields).

Treatments: multiple rigorous shrub removal or extraction, including surface levelling (two reductions in the first two years), followed by annual mowing or additional grazing, in wet years two times a year.

| Year | Restoration measures |
|---|---|
| 1984 | *Robinia* removal on southern slopes, Oblík |
| 1995 | Shrub removal and reduction, Raná |
| 1997 | Reintroduction of grazing, Oblík |
| 1998 | Reintroduction of grazing, Raná |
| 2008 | Successive purchase of most valuable tracts in both SACs |
| 2009–2010 | Shrub removal, realisation of EEA project for ground squirrel preservation |
| 2011–2016 | Integrated restoration of steppe grasslands, LIFE+ project |

## Monitoring methods

The influence of restoration on the habitats is monitored in several permanent monitoring plots according to the NCA methodology. In 6 fixed plots measuring 5 × 5 m, every year relevés are made and changes in dominance recorded. The records are then statistically evaluated by means of DCA or PCA analyses. In the relevés, the abundance of populations of the main target species (*Helictotrichon desertorum*, *Astragalus austriacus*, *A. danicus*, *Adonis vernalis*, *Stipa pennata* and *S. tirsa*) is counted, see Tab. 2.

At restored sites, the abundance of ca 20 diagnostic target species (e.g. *Stipa pulcherrima*, *S. pennata*, *Astragalus danicus*) is monitored in 5 selected plots of ca 0.5 ha in the first three years after shrub removal. Changes in abundance of *Stipa pulcherrima* are monitored in 2 permanent plots by precise counting of tussocks. The counting of ground squirrel populations is performed according to the method of the European Ground Squirrel Rescue Programme.

## Situation after intervention

In 2016, the monitored communities in both SACs – especially thanks to measures performed under the LIFE+ project – were in the desired condition. Removal of expansive scrub followed by grazing by domestic animals in combination with mowing of the grasslands had contributed to an expansion in area and general restoration of dry grassland communities. Results included a change in quality, particularly a marked increase in xerothermic species and a decrease in mesophilous species (suppression of aggressive spread of *Arrhenatherum elatius*). An example was the white slopes at the base, where the rate of broadleaved grasslands (*Scabioso ochroleucae-Brachypodietum pinnatii*) had increased.

Also historical cherry and pear orchards with a rich undergrowth of needle-grass (*Stipa pulcherrima*, *S. pennata*) and other rare xerophytic species were largely restored (removal of expansive shrubs, planting old varieties of fruit trees, grazing). Scrub was reduced less only at boundaries with intensively managed cultures, where it forms a barrier against the dispersal of pesticides and fertilisers. Another result of the measures is the growth of the European ground squirrel population (Tab. 1, Fig. 7). NCA gradually purchases tracts valuable for nature conservation and takes special care of them, including non-intensive grazing and mowing.

## Results

Restoration by mowing helped to reduce shrubs, especially resistant hawthorns (*Crataegus* spp.), but did not slow down the increase in *Ononis spinosa* plants. The main effect was a decrease in grass height by suppressing the aggressive *Arrhenatherum elatius* and an increase in cover and number of the target species *Bromus erectus*, *Festuca rupicola* and *Carex humilis*. Already in the second year, needle-grasses (especially *Stipa pennata*, more slowly also *S. pulcherrima*) started to spread over disturbed open places. The speed of spreading was directly proportional to the distance to compact needle-grass populations and their degree of fertility. In comparison to additionally grazed sites, however, the abundance of needle-grass is lower in the first years. The species *Veronica teucrium*, *V. prostrata*, *Dianthus carthusianorum*, *Sanguisorba minor*, *Agrimonia eupatoria*, *Stachys recta* and *Pilosella officinarum* were found to spread rapidly. Already three years after mowing was resumed, the amount of moss had increased (even on carbonate substrate), which prevents some species from germinating. Alternation of grazing (disturbing the sward and soil profile by animal movement) and mowing helped to reduce the growth of moss.

The impact of sheep and goat grazing on species composition was directly proportional to the chosen restoration intensity. Some species, e.g. needle-grasses, reacted better than others. Besides a generally lower vegetation, the grasslands saw a diversion from more mesophilous to xerophilous species. Clear population growth was recorded for the species *Festuca valesiaca*, *Astragalus danicus*, *Artemisia pontica*, *Salvia verticillata*, *Agrimonia eupatoria*, *Cynoglossum officinale*, *Nonea pulla* and *Erysimum repandum* (Tab. 1). Through more intensive grazing, *Arrhenatherum elatius* had almost disappeared after three years. Hardly grazed species like *Thymus praecox* and *T. pannonicus*, *Achillea pannonica* and *A. setacea* were supported very strongly. *Astragalus danicus* was found to decline to the benefit of *A. excapus* and *A. austriacus* (Fig. 8).

Decomposition of the dry, hard leaves of *Stipa pulcherrima* was only found at high grazing pressure. At the time, green plant parts were however also grazed, with lower generative production as a result. Hard-leaved needle-grasses were initially rarely grazed by sheep (the first flock needed three generations to get accustomed). Later, the flock structure was adapted to the conditions of the restored pastures after shrub removal by increasing the rate of Romanov sheep. Despite, the sheep had to accustom another three years before they started to graze the initially avoided needle-grass. This fact may be in contradiction to the aim of ensuring a natural spread of needle-grasses to restored tracts in the nearby surrounding.

More intensive grazing had a positive effect on the expansion of *Stipa tirsa*, *Vincetoxicum hirundinaria* and *Helictotrichon desertorum* (Fig. 6). It strongly reduced *Rosa canina* populations, but individuals of the rarer *Rosa elliptica* were not grazed much. A higher grazing intensity also supported spe-

**Fig. 5.** *Helictotrichon desertorum* in a needle-grass population after shrub removal and sheep grazing at Oblík. (V. Vlačiha)

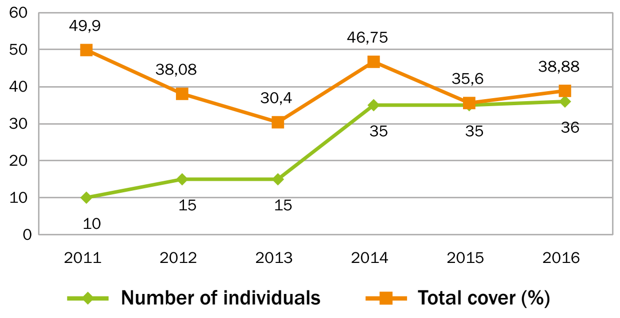


**Fig. 6.** Development of *Helictotrichon desertorum* abundance compared with total cover in a relevé with management at Raná. The optimal cover for high abundance of the species is a total cover of around 40%.

cies like *Linum tenuifolium*, *Teucrium chamaedrys* and *Sesleria caerulea*. Cover and abundance of *Bromus erectus* at the intensively grazed sites declined, while at the same time festues (dominated by *Festuca valesiaca*) grew in number. The abundance of *Astragalus excapus*, *Verbascum phoeniceum* and *Helictotrichon desertorum* increased while their cover decreased, because the vegetation is grazed and, on the other hand, new plants germinate more successfully in the opened vegetation. High grazing intensity led however to degradation of areas with sheep-folds. Here, and in other strongly disturbed places, ephemerous species like *Holosteum umbellatum* and some speedwells (*Veronica* spp.) expanded already in the second year.

The realisation of some specific measures evoked also other changes in the extent and way of spreading of selected species. At fire sites, *Buglossoides arvensis*, *Hyoscyamus niger*, and later *Cerinthe minor* and *Erysimum crepidifolium* were found to spread. In places where dry shrubs were retained (without being burnt or disposed for chipping) to support insects and other animals however, due to the more humid environment, even denser scrub of mostly *Prunus spinosa* and *Rosa canina* reappeared within a few months.

In regularly disturbed places along paths, *Sclerochloa dura* expanded and after having been missed for almost 40 years, *Glaucium corniculatum* was found. The increase in species diversity was certainly supported by the alternation of restoration management measures (plots intensively grazed after shrub removal, plots not grazed after mowing once or twice, alternated mowing and grazing, etc.).

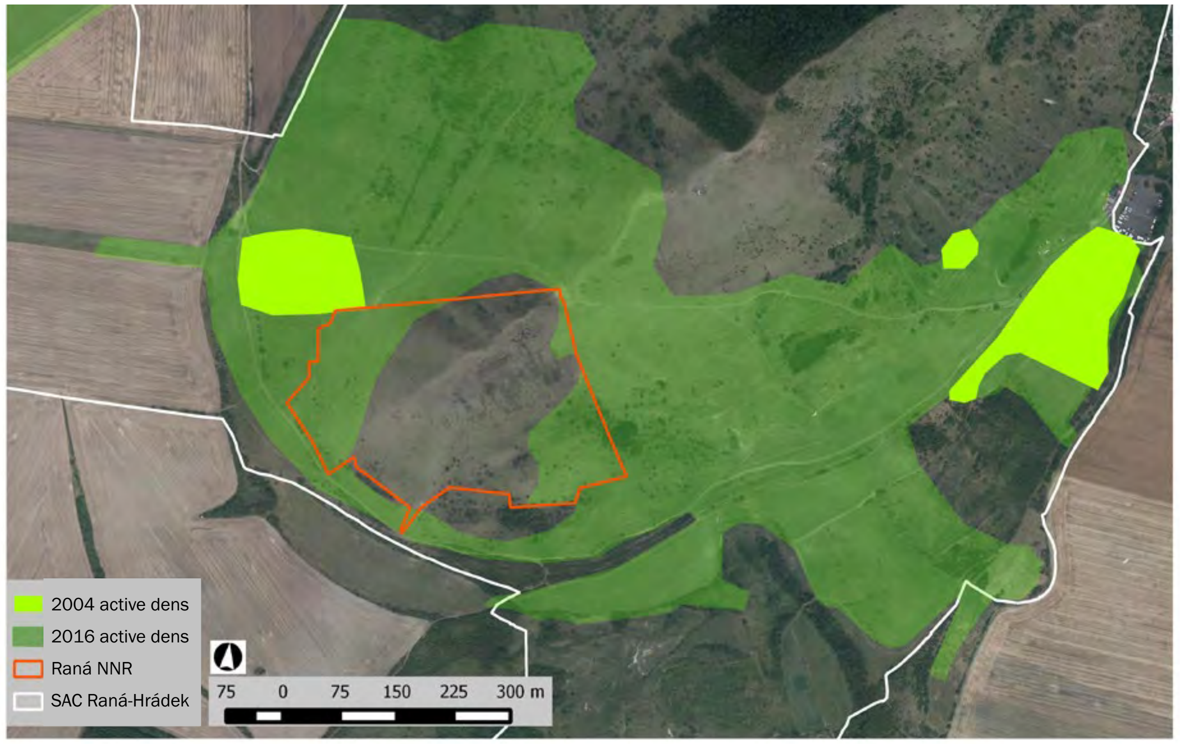


**Fig. 7.** Development of *Spermophilus citellus* population at Raná. (J. Ptáčková)

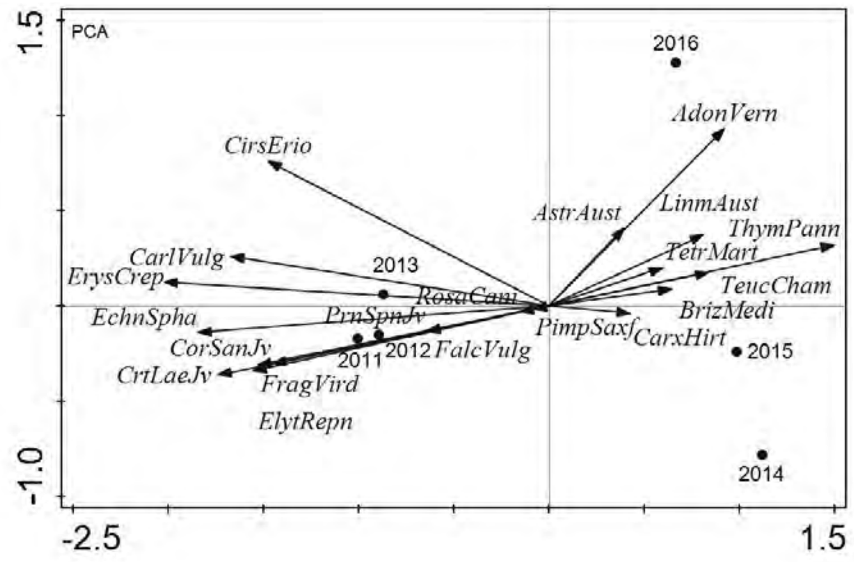


**Fig. 8.** Principal component analysis (PCA) of relevés with management realised in 2011–2016 indicates a shift in species representation. Shrubs, mesophilous and ruderal species (e.g. *Cornus sanguinea*, *Prunus spinosa*, *Crataegus laevigata*, *Fragaria viridis*, *Echinops sphaerocephalus*, *Cirsium eriophorum*) prevailing in the years 2011–2013 are gradually replaced by characteristic steppe species (e.g. *Adonis vernalis*, *Astragalus austriacus*, *Linum austriacum*, *Teucrium chamaedrys*, *Thymus pannonicus*) in the years following regular extensive grazing.

**Tab. 1.** Results of the monitoring of target populations of threatened species increased in number by restoration measures (period 2011–2016).

| Species | Location of expansion | Restoration type with essential impact on population size | Increase in population size (%) |
|---|---|---|---|
| *Spermophilus citellus* | W, SW and S slopes of Raná | shrub removal, mowing, extensive grazing | 300 |
| *Adonis vernalis* | SW and W slopes of Raná, S slopes of Oblík | shrub removal, extensive grazing | 5 |
| *Stipa dasyphylla* | top parts of Oblík and Brník | shrub removal | 3 |
| *Stipa pennata* | E slopes of Raná, foot of Oblík | shrub removal, extensive grazing | 10 |
| *Stipa pulcherrima* | E slopes of Raná, foot of Oblík | shrub removal, extensive grazing | 15 |
| *Stipa tirsa* | S slopes and foot of Oblík | shrub removal | 20 |
| *Stipa glabrata* | S slopes below Brník hill | shrub removal | 10 |
| *Astragalus exscapus* | along paths, esp. SW, S and E slopes of Raná | extensive grazing, rather intensive trampling | 20 |
| *Astragalus danicus* | E, SE and S slopes of Raná, S slopes of Oblík, along paths | extensive grazing, less intensive trampling | 30 |
| *Astragalus austriacus* | E, SE and S slopes of Raná | extensive grazing, rather intensive trampling | 5 |
| *Helictotrichon desertorum* | SE slopes of Raná, SSE slopes of Oblík | shrub removal, extensive grazing | 5 |
| *Achillea setacea* | E slopes of Raná, along paths | extensive grazing, mowing | 10 |
| *Erysimum repandum* | E slope of Raná, near the village, esp. along paths | extensive grazing, mowing | 50 |
| *Sclerochloa dura* | E slope of Raná, near the village, directly on paths | trampling, extensive grazing | 15 |

**Tab. 2.** Development of numbers of protected plant species in relevé with management at Oblík.

| Species | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| *Adonis vernalis* | 18 | 20 | 20 | 25 | 28 | 37 |
| *Astragalus austriacus* | 0 | 0 | 0 | 2 | 4 | 6 |
| *Astragalus danicus* | 10 | 10 | 8 | 10 | 10 | 12 |
| *Stipa pennata* | 30 | 26 | 26 | 13 | 17 | 18 |

## New insights and recommendations

- For dense shrub and tree stands, multiple rigorous interventions need to be planned, as new shoots reach heights of up to 1 metre per year in the Thermophyticum. Shoots need to be removed because without repeating the measure, scrub reaches a higher density than before the first intervention already after two years. Restored sites where shoots were removed every year and which were regularly mown or grazed showed a high species diversity already in the third year. Some *Stipa* species appeared already in the second year.
- Restoration management intensities made an essential difference as for impact on the development of steppe species. *Helictotrichon desertorum* was found to spread better after more rigorous disturbance of the soil surface.
- The ability of sheep to also graze dry, hard-leaved plants at these sites manifested itself after adapting the herd structure or in as late as the third generation of the original breed.
- The proximity of species-rich source sites and partly also older supplies of germinable diaspores of some species in the soil led to a rapid completion of the seed bank of steppe species at restored sites in a natural way.

## Public support

The primary objective of the LIFE+ project was restoration management of steppe vegetation, performed in collaboration with the NCA, concerned municipalities, landowners, NGOs and private individuals. The public was involved by promoting restoration management (e.g. organisation of a 'Steppe Festival' at Raná, publication of information materials, competitions at schools, a permanent exhibition on the steppes of the Louny Region in Louny Regional Museum). The restored sites are a destination for Czech and foreign scientific field excursions.


## Acknowledgements

We thank Jan Novák for analysing the relevés, and Vladislav Kopecký, Pavel Moravec, Jana Ptáčková, Pavla Staňková and other colleagues for providing information on the LIFE+ project and the development of populations of the European ground squirrel and invertebrates.


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# Restoration of heath vegetation at a serpentine site


Přemysl Tájek & Zdeněk Janovský


| | |
|---|---|
| Location | Slavkovský les, Mnichovské hadce, Křížky NNM; elevation 790–817 m |
| Conservation status | PLA, NNM, SAC |
| Restored area | 4,5 ha |
| Financial support | ME Landscape Management and Restoration Programmes |


## Abstract

The heathland and low grassland vegetation of Křížky NNM long suffered from expansion of tall grass vegetation due to a non-intervention regime introduced in the 1960s. Therefore, annual extensive summer sheep grazing of the site was started in 1996. Since 2008, the effects of this management have been assessed by making relevés of the vegetation in pairs of fenced and unfenced plots. Results of the monitoring show that this grazing method supports the targeted low grassland vegetation and suppresses tall grass vegetation. However, essential dwarf-shrub species were surprisingly more prosperous in the fenced controls. Further monitoring of the site has shown that this is probably caused by very strong winter grazing pressure of overbred sika deer, which graze on evergreen ericaceous dwarf-shrubs. Assessment of the performed sheep grazing methods has indicated several partial measures which have markedly increased its effectivity.


## Site description

Already since the late 19th century, Křížky has been a well-known botanical site, particularly perceived by scientists as one of the few sites of the endemic *Cerastium alsinifolium*. Recent deeper botanical knowledge of the region has however shown that the uniqueness of the site consists most of all in the exceptionally high concentration of a whole range of other rare vascular plants and lichens bound to heathlands and shallow soils in the surrounding of serpentine rocks. On the other hand, most *Cerastium* tussocks turned out to be hybrids of *C. alsinifolium* and *C. arvense* from adjacent pastures (the main distribution centre of pure populations of the endemic mouse-ear is presently situated in wet places of serpentine pine forests – Vít et al. 2014, Tájek et al. in prep.). Also the character of the heathland with a high cover of *Erica carnea*, *Polygala chamaebuxus* and *Vaccinium uliginosum* is exceptional in the Czech Republic.

The original vegetation of Křížky was probably open pine forest with dwarf-shrub undergrowth and rocky outcrops. It is not known when the site was deforested and secondary heathland developed, but the site belonged to the nearby village of Prameny, which was historically documented already in the 14th century. The oldest primary evidence of non-forest vegetation at Křížky is a Stable Cadastre map from the first half of the 19th century. In the first half of the 20th century (and probably also long before that) Křížky was an extensively managed sheep pasture. From an aerial photograph of the year 1952 it follows that heathland vegetation used to cover a much larger part of the area. After traditional farming at the site had gradually ceased after World War II, scrub started to encroach the area, and tall grasses gradually expanded to the heathland vegetation. These changes in vegetation led in the mid-1990s to the decision of resuming sheep grazing at the site to prevent further degradation of the local vegetation.

## Initial state

The absence of farming, lasting for decades, supported by the non-intervention regime of the reserve (since the

**Fig. 1.** Sheep grazing, 2008. (P. Tájek)

1960s), led to an undesired regression of heathland formations to the benefit of tall grasses, particularly *Calamagrostis arundinacea*, locally also *Arrhenatherum elatius* and *Molinia caerulea*. In the past decade, the number of flowering *Erica carnea* plants, whose pink-coloured populations used to be an important tourist attraction of the region in early spring, has moreover significantly declined.

## Restoration objectives

Preserving or expanding populations of rare plant species, particularly *Erica carnea*. Arresting the expansion of tall grasses. Enlarging the heathland area.

## Measures applied

1994 and 1996: removal of expanding scrub.

1996 to the present: extensive sheep grazing, usually 14 days to 1 month with a flock of ca 30 sheep, as a rule in July (June–August).

## Monitoring methods and data assessment

A total of 15 pairs of experimental plots 1.5 × 1.5 m in size were monitored. One of each pair was always fenced with chicken-wire mesh (since 2008). Relevés of the plots were made in the years 2008, 2011 and 2014 (always before sheep grazing started) in the standard way using the extended nine-value Braun-Blanquet scale. Cover was only recorded for vascular plants.

The species cover values from the relevés were analysed by means of redundancy analysis (RDA). Interactions of treatment (fencing/grazing) and time were used as explanatory variables of species composition. Identity of relevé pair, initial differences between plots at the time of fencing, and development trends shared by fenced and unfenced plots (main effect of time) were used as covariants. All calculations were carried out in the Canoco 5.04 programme (ter Braak et Šmilauer 2012).

## Results

The heterogeneous character of the site, where rocky outcrops alternate with deeper soils of variable humidity, was reflected in the differences between the plot pairs (ca 72% of variability in species composition of the relevés), which were greater than the differences within the pairs (ca 4.5% of variability). The actual effect of grazing management (treatment × time interaction) explained slightly more than 1% of the variability in species composition of the relevés ($p = 0.0002$), which is comparable to the general speed of change at the site (main effect of time explained ca 1.4%).

In fenced plots without grazing, the cover of the herb layer generally increased during six years of monitoring, just as the cover of *Molinia caerulea*, but surprisingly also of *Vaccinium vitis-idaea* shrubs and winter heath (*Erica carnea*), one of the most important target species (Fig. 3). As expected, the cover of tree saplings and leguminous species sensitive to grazing, *Trifolium pratense* and *T. campestre*, increased as well.

In grazed plots, the herb cover remained approximately the same or declined. The incidence or cover of a range of *Nardus* grassland species, e.g. *Galium saxatile* and *Briza media*, as well as some more valuable species bound to nutrient-poor pastures, such as *Antennaria dioica* and *Platanthera bifolia*,

**Fig. 2.** View of Křížky NNM, October 2010. (P. Tájek)

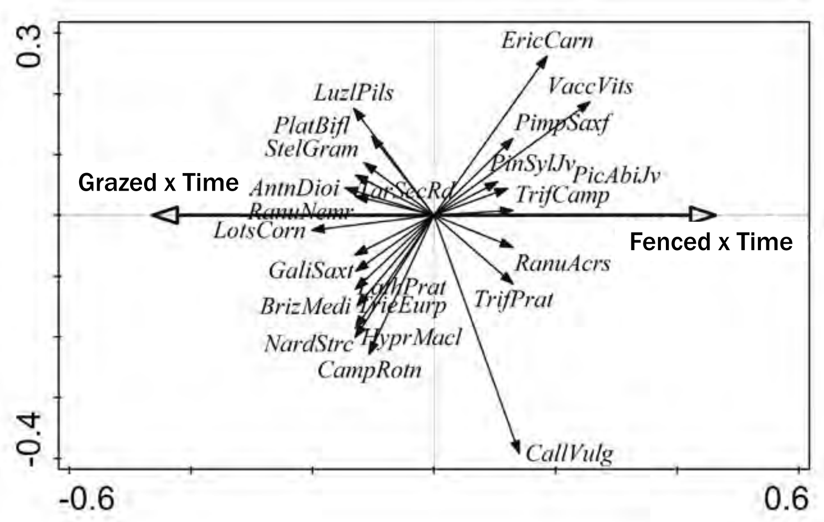


**Fig. 3.** Redundancy analysis (RDA) ordination diagram displaying the effects of treatment and time interaction (i.e. actual effect of the treatments) in the monitored permanent plots. The first axis explains 1.2% of variability in species composition of the relevés, the second axis 4.5%. Only species for which the interaction explained at least 1.5% of variability in cover (i.e. predominantly species frequently recorded in more plots) are shown. The species arrows indicate in which direction in the ordination diagram their cover grows. The longer the orthogonal projection of a certain species arrow on the arrow of one of the treatments, the more the cover of that species grows relatively to changes in cover in the other treatment (e.g., *Lotus corniculatus* strongly increases with time in grazed plots, whereas the number of pine saplings (*Pinus sylvestris* juv.) grows relatively less strongly in fenced controls).

increased here. All in all, we can conclude that sheep grazing in summer really reduces the cover of undesired grasses in the expected way and enables rare species and short grassland communities to survive.

Besides the systematic monitoring of presence and cover of each plant species in the middle of the vegetation season, the site was continuously checked, which has considerably completed the overall picture of local vegetation development. It revealed that the development of heathland vegetation in the area is fundamentally influenced by deer grazing in winter. Especially sika deer (*Cervus nippon*) is strongly overbred in the area. It concentrates in groups and larger herds in dry-blown places on the ridge of Křížky, where it browses the tops of evergreen dwarf-shrubs (*Erica*, *Vaccinium*, *Calluna*). We suppose that winter grazing by deer explains the unanticipated higher prosperity of evergreen shrubs in the ungrazed control plots.

The effects of winter grazing are particularly obvious in April, when the very early winter heath flowers in the fenced plots while it is hardly able to flower elsewhere (Fig. 5). The intensity of winter grazing by deer can be seen in the almost continuous layers of deer dung in some parts of the site by the end of winter.

## New insights and recommendations

It is important to drive grazing sheep out of the grazed area for the night (or another time of day when they do not graze), thus reducing the amount of dung, which enriches the site with nutrients in an undesirable way. Grazing should take place in a time when unwanted graminoids are still attractive for the grazing animals, i.e. in the second half of June and first half of July at our site. It is good to cut the grassiest places, so as to raise grazing pressure in worse accessible, rockier places. From a long-term perspective we consider it appropriate to alternate several years of grazing with no grazing, which helps dwarf-shrubs to regenerate. This can be achieved by e.g. dividing the site into 2–3 parts which are grazed in two- or three-year intervals. It is necessary to monitor the vegetation regularly (at least by experts casually visiting the site, ideally several times a year) and react to the situation flexibly when planning conservation measures.

**Fig. 4.** Unfenced permanent plot, 2011. (P. Tájek)

Although winter grazing is a common and desirable type of management in some parts of the heathland distribution area (e.g. most of the areas on the coast of the North Sea; Måren 2009), it has apparently a negative impact on the population biology of dwarf-shrubs and, by extension, on the long-term maintenance of heathland vegetation at the site in our winter conditions. In the winter of 2016–2017, a scent fence (on wooden poles at ca 1 m above the ground, at regular intervals of 3 m) especially made to repel deer was set up around the whole circumference. The dwarf-shrub communities had nevertheless been browsed very strongly after the winter. In autumn 2017, the entire site was therefore fenced with 2 m high chicken-wire mesh, which was found to work out very positively in spring 2018, given the number of flowering winter heath plants.

Winter grazing by overbred sika deer on the heathland seems to be part of a more complicated problem of altered landscape conditions, since a strong increase in selective grazing pressure on flowering plants of *Trollius altissimus* is observed at the same time, which leads to reduced rejuvenation of this legally protected species in the adjacent Upolínová louka NNM.

## Acknowledgements

We thank Tomáš Peckert for assistance with establishing the experimental plots.

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**Fig. 5.** Fenced permanent plots, not grazed by deer in winter, with richly flowering winter heath (*Erica carnea*), spring 2012. (P. Tájek)

# Restoration of open sand communities in southern Moravia

Klára Řehounková & Ivana Jongepierová

| | |
|---|---|
| Location | Váté písky NNM, both sides of the railway track between the stations of Rohatec and Bzenec-Přívoz, 48°54'–48°55' N, 17°13'–17°16' E; elevation 180–190 m |
| Conservation status | NNM, SAC, SPA |
| Restored area | Total of 11 sites covering 2.7 ha (until 2015) |
| Financial support | ME Landscape Management and Restoration Programmes |

## Abstract

In Váté písky NNM, restoration and monitoring of open sand communities have been carried out since 2010. In degraded places, the eutrophicated upper sand layer has been scraped off with heavy vehicles and disposed in reclaimed plots in the mining site nearby. Spontaneous vegetation development was monitored in 15 permanent plots situated at sites where this treatment had been carried out. It was found that the species composition of disturbed sites approaches that of the target vegetation at reference sites already after four years. Optimal management of these communities should consist in scraping off the eutrophicated layer on a large scale in a mosaic way combined with other small-scale measures (e.g. irregular local disturbance of the surface, removal of expansive scrub and non-indigenous species).

## Site description

The drifting sand area between Rohatec and Bzenec-Přívoz has been formed since the Late Ice Age (for 18 ± 2 thousand years) by sand blowing out of lake sediments (Kadlec et al. 2015). Sand layers reach a depth of 10–36 m here. During the Holocene, oak forests – apparently with Scots pine (*Pinus sylvestris*) – developed here. However, in the Middle Ages these were felled and intensively grazed, thereby releasing sand again, and sandstorms even started to occur. In the 19$^{th}$ century, the entire area was gradually purposely afforested with Scots pine. Open sands with Pannonic psammophytic steppe vegetation (*Festucion vaginatae* alliance, Natura 2000 habitat 6260) have to date been preserved at just a few small sites. One of them is a treeless fire-control zone along the Vienna–Cracow railway (presently Váté písky NNM), which was maintained open until the end of steam locomotive operation in the 1970s. After that, even if some patches occasionally caught fire, this did not hinder pine and locally also black locust (*Robinia pseudoacacia*) to encroach the site. Restoration of the open sands was introduced in the late 1980s, when full-grown pine trees were being cut and saplings pulled out with the help of state nature conservation authorities and NGOs.

## Abiotic conditions

The sand contains a large proportion of silica and is characterised by an acidic soil reaction (pH 4.5–5.5). Arenic cambisol and locally also arenic regosol have developed on them (Jongepier & Bezděčka 2002). The area is located in the warm climate region T4 (Quitt 1971). The mean annual temperature exceeds 9 °C, the mean annual precipitation does usually not exceed 500 mm (Tolasz et al. 2007).

## Initial state

On several hectares throughout the NNM territory, dense *Calamagrostis epigejos* populations used to occur. These were particularly places where shrubs and trees had been eliminated but humus and needle layers not been raked up. Furthermore, *Solidago gigantea* quite often grew at former fire sites used to eliminate the wood of felled trees.

## Restoration objectives

Restoring thermophilous open sand communities.

**Fig. 1.** Large-scale scraping of eutrophicated upper soil layer by means of heavy vehicles in 2014. (I. Jongepierová)

## Measures applied

**Restoration measures**

1987: start of felling Scots pine with the help of several CUNC LCs of the Hodonín District. After cutting down the trees, however, stumps and eutrophicated places with *Calamagrostis epigejos* and *Solidago gigantea* remained, particularly at fire sites. To a lesser extent, black locust spread from the surrounding stands.

2010 – present: renewal of initial succession by scraping off the eutrophicated upper sand layer to a depth of 10–30 cm (costs ca €7,700/ha, depending on scraping depth). The material was subsequently transported to a nearby sand quarry in plots with prescribed afforestation in accordance with a valid though inappropriate reclamation plan and national legislation.

**Management measures**

- Regular removal of saplings of undesired species like *Pinus sylvestris*, *Solidago gigantea*, *Populus tremula* and *Robinia pseudoacacia*.
- Regular disturbance of closed vegetation by means of e.g. compact disc harrows (supplementing the large-scale mosaic scraping of sites by irregular small-scale measures).

## Monitoring methods

In the years 2012–2016 the succession of vascular plants after scraping off the upper sand layer was monitored in 15 permanent plots measuring 5 × 5 m. During three years, five permanent plots were established annually, each time at newly scraped sites. In addition, relevés were made at degraded sites before scraping off the upper sand layer in the years 2012–2014 and also at representative sites with well-preserved psammophytic vegetation in the years 2014–2015, which served as reference sites.

## Results

Desirable plant species started to spread to the newly opened sites very quickly, since target psammophytic vegetation had remained in the immediate surroundings of the disturbed sites. The newly created sites were also colonised by a number of specialised psammophilous animals occurring only on the sand path leading along the railway track before the restoration of Váté písky NNM.

In the 15 monitoring plots with a removed eutrophicated layer, 97 vascular plant species were recorded during the years 2012–2016, of which 23 are included in the Red List of the Czech Republic (Grulich 2012). Within five years the number of species associated with dry grasslands tripled (i.e., the mean ± standard error of the mean (SE) increased from 3.8 ± 1.7 to 13 ± 3.5) and that of synanthropic species declined to half (from 8.2 ± 3.2 to 4.2 ± 2.95) as compared to the degraded plots. Already in the first year, the average number of target dry grassland species spontaneously colonising the treated plots was almost comparable to the reference plots with preserved psammophytic vegetation. Moreover, unwanted synanthropic species gradually declined. In the fifth year, the average numbers of synanthropic as well as dry grassland species of drifting sands were the same as in the reference plots.

The most successful species spreading spontaneously to the newly created sites included *Corynephorus canescens*, *Rumex acetosella*, *Trifolium arvense*, *Filago minima*, *Agrostis vinealis*, *Verbascum lychnitis* and *Artemisia campestris*.

The results of indirect gradient analysis (Fig. 4) show that the spontaneous vegetation development in disturbed plots rapidly directs towards psammophytic vegetation.

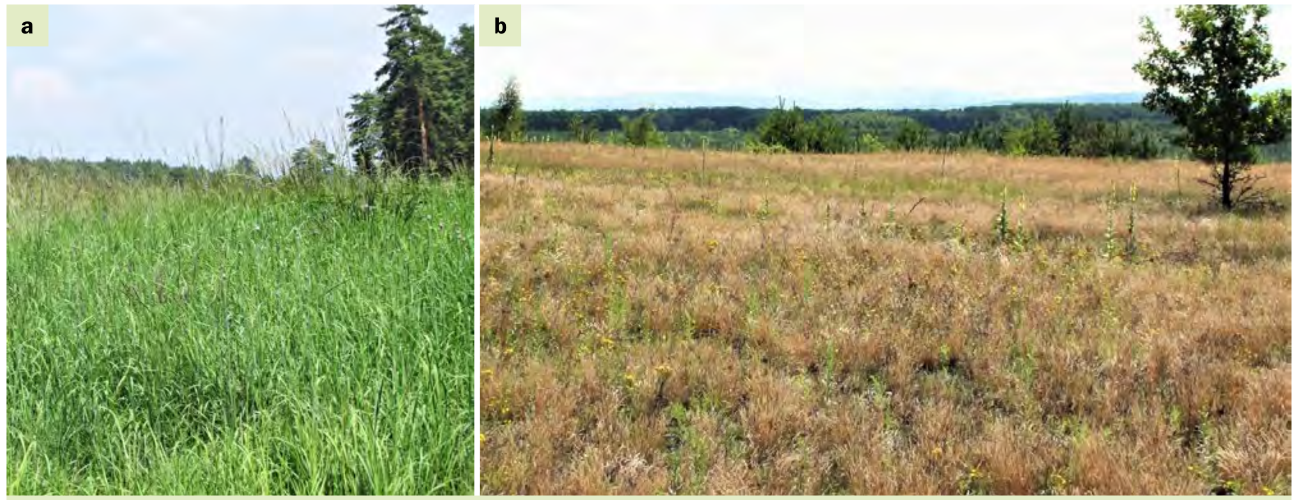

**Fig. 2.** Degraded site (a) and reference site (b) in Váté písky NNM. (K. Řehounková)

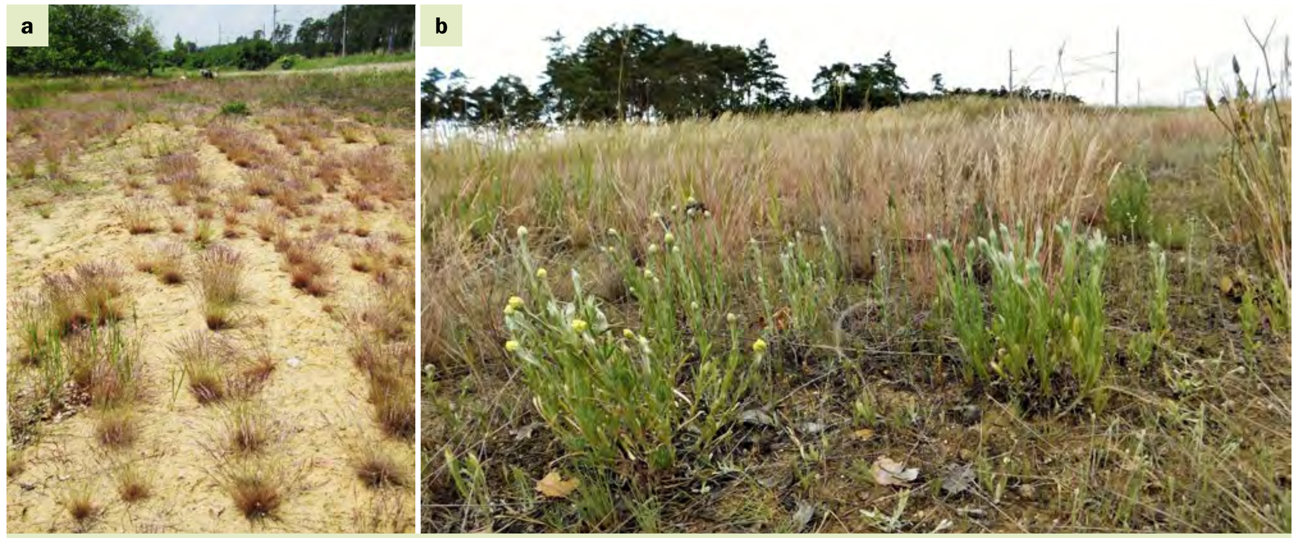

**Fig. 3.** Restoration of dry grasslands at disturbed sites: (a) first year and (b) fifth year after intervention. (K. Řehounková)

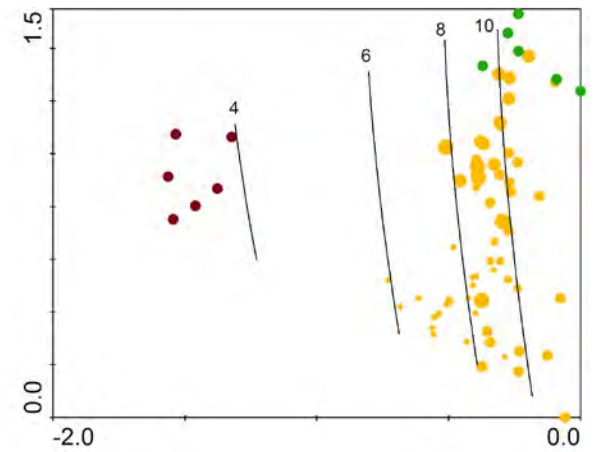


**Fig. 4.** Indirect gradient analysis (DCA) of plots with removed eutrophicated upper layer (yellow) compared to degraded plots before intervention (brown) and target psammophytic vegetation of sands (green). The size of the yellow symbols corresponds to the age of the plots (1–5 years after intervention). Isolines express the number of target species (i.e. associated with dry sandy grasslands) recorded in the permanent 5 × 5 m plots. The number of desirable species in the scraped plots increased gradually after site restoration, and within only four years the established vegetation corresponded to that at the reference sites.

**Fig. 5.** Monitoring of permanent plots, 2014. (I. Jongepierová)

## New insights and recommendations

The monitoring results have confirmed the effectiveness of the chosen restoration method, which can also be applied to similar habitats elsewhere in Europe.

The optimal way of restoring strongly eutrophicated sand areas is to combine mosaic large-scale scraping of the upper nutrient-rich soil layer with other small-scale measures (e.g. local irregular disturbance, regular removal of expansive shrubs and non-indigenous species).

## Acknowledgements

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# Restoration management of Molinia meadows in a military training area

Alena Vydrová & Vít Grulich

| | |
|---|---|
| Location | Boletice Military Training Area; elevation 570–940 m |
| Conservation status | SAC, two parts also in Šumava PLA |
| Restored area | 7 sites covering 17.9 ha in total |
| Financial support | Ministry of Defence, ME Landscape Management and Restoration Programmes |

## Abstract

In Boletice Military Training Area, reconstruction and maintenance management has been running at 7 Molinia meadow sites since 2008. Its aim is to stabilise the structure and species diversity of this vegetation. Special attention is paid to *Gentiana pneumonanthe*. Reactions on the measures are monitored in permanent plots and their annual assessment is taken into account when modifying the intervention regime.

## Site description

The geology of the Pošumaví region, in which metamorphosed rocks (gneiss and granulites) often play a role, has caused the formation of hard pseudogley soils during the Quaternary in many places (Albrecht et al. 2003). After deforestation, very suitable conditions arose at these sites for semi-natural vegetation in the form of intermittently wet Molinia meadows (*Molinion caeruleae* alliance), which must have covered vast areas in the time of extensive farming.

Molinia meadows are very sensitive to management and changes in it. In the time of extensive farming they seem to have benefited from shallow draining, which meant that the soil surface was not moistened permanently, but desiccated, and fluctuation in its humidity functioned well. By contrast, this vegetation strongly degrades when the soil is drained deep, which discharges water quickly.

The reduction in area has been caused by massive draining causing great damage to the water regime on the landscape level on the one hand and by cessation of traditional farming on the other. The draining of areas with Molinia meadow vegetation led to their mesophilisation. Such sites were moreover often ploughed, and if permanent grassland remained here, it was resown or at least supplemented with high-yield grass species, intensively fertilised and mown more times per year. These factors have fundamentally changed the species composition of these meadows.

At remote locations the opposite happened. Lacking maintenance of shallow drains led to their obstruction and thereby to permanent moistening of the vegetation. At such sites more productive species limited by intermittent desiccation often started spreading, to the detriment of species which tolerate this stress factor. Such sites were moreover often left unmanaged without hay removal, so more sensitive, especially low-yield species suffered from accumulation of dead biomass here. This mostly led to an impoverished species composition.

**Fig. 1.** *Gentiana pneumonanthe* at the site of Olšina. (A. Vydrová)

The threat to Molinia meadows has gradually led to the designation of some sites as nature reserves, especially if some rare and attractive, legally protected species had persisted in growing there. These sites were included in the list of protected habitats mentioned in the appendix of Council Directive 92/43/EEC or Habitats Directive. During the habitat survey in the Czech Republic in the years 2001–2005, the present acreage of Molinia meadows was found to amount to 8,570 ha (Härtel et al. 2009).

In Boletice Military Training Area a rather large area (406.5 ha in total) of Molinia meadows has remained preserved (Bodnár et al. 2015) thanks to the following reasons.

a) The Armed Forces took possession of the area soon after expatriation of the German population, who had lived and farmed traditionally here until that time (Roušar 2006).

b) All farming was conformed to the needs of army training, therefore larger draining projects were not realised here and large-scale fertilising did not take place either.

c) Abandonment of the settlements also meant a stop to nutrient contamination by local sources of sewage water.

d) Many sites were mechanically disturbed, but this happened irregularly and importantly, it was not accompanied by eutrophication.

These factors had a fundamental influence on the relatively large area of Molina meadow habitat in comparison to the regular cultural landscape.

In 2005, the Special Area of Conservation (SAC) Boletice was demarcated in Boletice Military Training Area, by which the habitat of intermittently wet Molina meadows became one of the objects of protection. Both Molina meadow types known from the Czech Republic (Chytrý 2007) appear in the area. Species-rich vegetation (*Molinietum caeruleae*) was mostly found at lower elevations in the NE part of the military training area, especially in the part where the bedrock contains a so-called Varied group, part of which is formed by crystalline limestone. The other type (*Junco effusi-Molinietum caeruleae*) is slightly poorer in species and associated with more acidic bedrock mostly in the central part of the area and occurs at higher elevations.

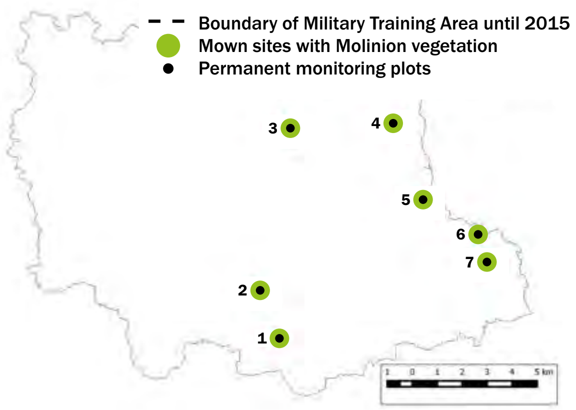


**Fig. 2.** Monitored Molinia meadows in Boletice Military Training Area: 1 – Olšina - louky, 2 – Loutecký, by the bridge, 3 – Strouhy, by the chapel, 4 – Mokřady u Okrouhlíku, 5 – Mokřady u Osí, 6 – Louky u Podvořského rybníka, 7 – Podvoří - louky.

## Initial state

The continuous monitoring of the state of Molinia meadows in SAC Boletice has shown that sites with this vegetation have gradually deteriorated after 2000 (when the Armed Forces left the area). The main reason was absence of farming because there was no longer interest in hay. The degradation was particularly evident at more remote and moistened sites. Decline of several rare species was recorded, e.g. *Gentiana pneumonanthe*, for which (initially not annual) records of abundance at the sites of Podvoří and Osí are available since 1995 and which Pavlíčko (1998) monitored at the site of Olšina. Other declining species are *Dactylorhiza majalis*, *Laserpitium prutenicum*, some rare sedges and dicotyledonous plants. On the other hand, grasses were found to have spread.

**Fig. 3.** Permanent plot at Podvoří - louky: mown variant. (A. Vydrová)

Fig. 4. Permanent plot at Podvoří - louky: unmown variant. (A. Vydrová)

The initial state of the vegetation at the sites was rather varied. Only part of the site Podvoří - louky had been mown regularly until 2000. However, this management used to be rather intensive (cut twice annually, apparently also occasional fertilisation) because of the easy access. The other sites had already been lying fallow for several years before 2001. At these, degradation through accumulation of dead biomass or excessive moistening was recorded. Both these factors had led to a rapid decline in species diversity and retreat of more sensitive species, mainly diagnostic species of Molinia meadows. Vegetation succession had in some parts directed towards wet Cirsium meadows. Moreover, in unmown vegetation at several sites, *Iris sibirica* had strongly expanded, suppressing almost all other meadow species.

## Restoration objectives

Stabilising the structure and species diversity of various types of Molinia meadows and proposing methods of managing them on a regular basis. Maintaining populations of *Gentiana pneumonanthe* at sites where it grows.

## Measures applied

Valuable Molinia meadow sites were identified and ways to implement suitable management were searched for in collaboration with Újezdní úřad Boletice (national nature conservation authority in the Military Training Area). The necessary consent of the Czech Armed Forces to performing the management was a certain restriction; therefore no sites in target areas of military 'polygons' could be selected. In the course of the year 2008, a total of seven partial sites were selected, including both types of Molinia meadow vegetation as well as different positions on the moisture gradient. In three of them also *Gentiana pneumonanthe* occurred.

For the approved sites, projects of reconstruction and maintenance management have been elaborated. The main measure is regular mowing.

### Reconstruction management

Two cuts per vegetation season have been proposed for reconstruction. Its aim is to suppress expansive dominants, especially *Filipendula ulmaria*, *Alopecurus pratensis*, *Dactylis glomerata*, *Scirpus sylvaticus*, but also *Iris sibirica* and *Calamagrostis epigejos*. In part of the site of Mokřady u Osí, shallow drains have been restored.

### Maintenance management

Suppression of dominants is a basic condition for the transition of reconstruction management to maintenance management, i.e. to one cut in the second half of the vegetation season.

The relatively drier parts of the sites Podvoří - louky and Olšina - louky are mown at least partly with a mowing machine, whereas wetter sites, e.g. Mokřady u Okrouhlíku and Mokřady u Osí, are mown with a brushcutter. Permanent plots are mown manually with scythes.

After the intervention, the sites are carefully raked and the mown biomass is taken out of the area. *Gentiana pneumonanthe* and partly also *Dactylorhiza majalis* plants are individually marked and exempted from intervention.

Based on yearly assessment of the state of the vegetation at each site, the management methods for the following year are adjusted as needed. Reason for this is the reaction of the vegetation to the course of the weather each year, but at particular sites also different reactions to the measures performed.

## Monitoring methods

The quality of the performed management and its impact on the vegetation is assessed yearly at each site. In 2009, permanent plots 4 × 4 m in size were established at 5 sites, always in pairs (plots with management and unmown control plots). In these, relevés are recorded yearly. At the sites of Mokřady u Osí, Podvoří - louky and Olšina - louky, where *Gentiana pneumonanthe* grows, moreover flowering stems of this plant are counted every year.

## Results

It is hard to interpret the changes in dominant species in the permanent plots (mown and unmown) over the monitoring period. Changes in vegetation are influenced by several factors, from the course of the weather to the quality of the management work. In the graphs (Figs. 7–9), changes in dominant species of the vegetation and in the numbers of species are captured for the plots at model site Podvoří - louky. These graphs unequivocally demonstrate that the number of species in the mown plot is higher than in the unmown one. The changes in dominants are probably still most dependent on the local course of the weather (rainy spring, dry period, etc.). Changes in vegetation have proceeded gradually and very slowly so far. We have recorded similar trends also at the other sites. While changes are not very distinct in the relevés, changes in the appearance of mown and unmown plots are conspicuous. In unmown plots, the vegetation is taller and has clear dominants, whereas mown plots show a greater differentiation in species and most often lack real dominants.

The monitoring of *Gentiana pneumonanthe* provided surprising results (Figs. 5 and 6). After the start of the intervention, its abundance at the sites increased, even though it did not manage to reach the numbers recorded here in the 1990s (as long as management continued), not even in years with the highest number of flowering plants recorded. Mowing caused a thinning of *Iris sibirica*, but mosses strongly expanded in the open patches.

At the site Podvoří - louky, the gentians reacted negatively to the high temperatures and extreme drought of 2015; in the same year, the site was not mown in spring (reconstruction management has been carried out here until today) and the vegetation had become much denser. By contrast, in the same year at the site of Olšina, gentians flowered very well and the extreme drought did not manifest itself at all. In 2016, the number of *Gentiana pneumonanthe* plants in the monitoring period was the highest. This increase had probably been caused by measures performed in a superior way. The *Gentiana* plants had in the two previous years very carefully been exempted from mowing, the moss layer had thoroughly been raked up, so plants were able to seed in fully open patches without dead biomass, grass or moss.

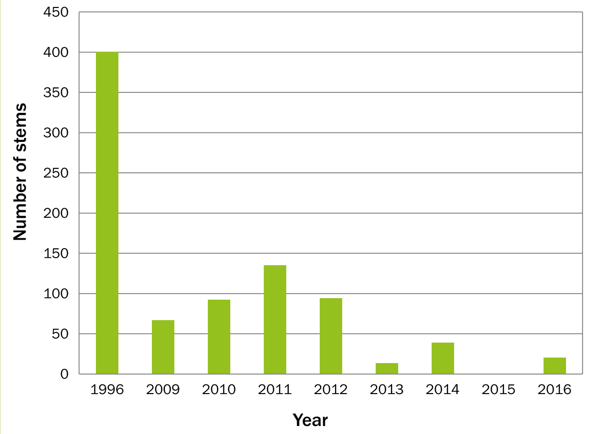


Fig. 5. Flowering of *Gentiana pneumonanthe* at Podvoří - louky in the years 1996–2016.

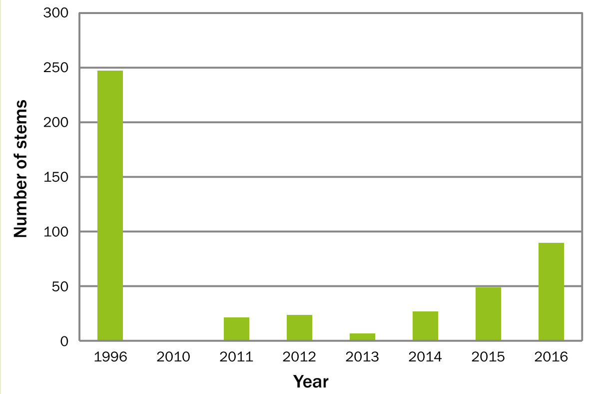


Fig. 6. Flowering of *Gentiana pneumonanthe* at Olšina - louky in the years 1996–2016.

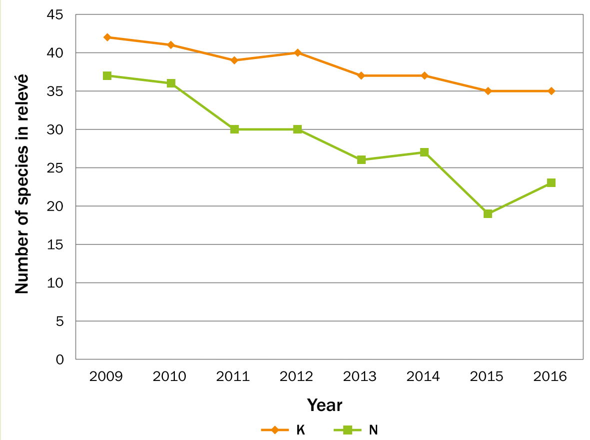


Fig. 7. Changes in species numbers of permanent plots at Podvoří - louky: K – mown variant; N – unmown variant.

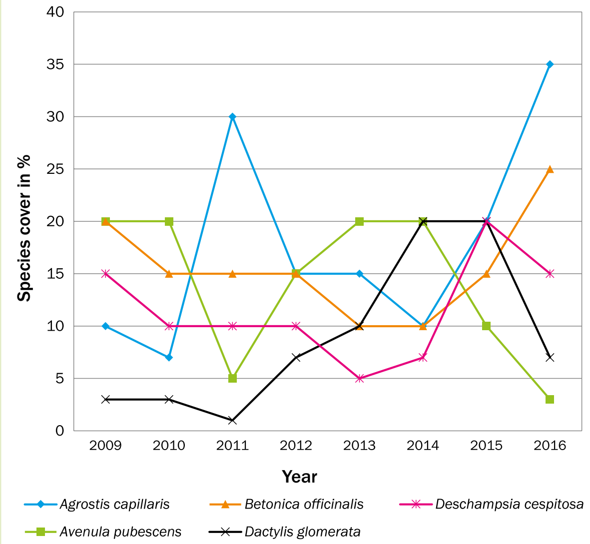


Fig. 8. Changes in cover of dominants, permanent plot at Podvoří - louky: mown variant.

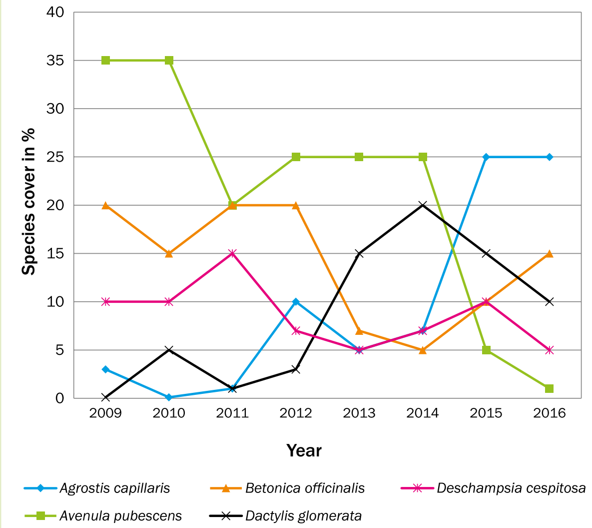


Fig. 9. Changes in cover of dominants, permanent plot at Podvoří - louky: unmown variant.

## New insights and recommendations

The monitoring of permanent plots at Molina meadow sites has provided very important information for the planning of further measures. Based on the hitherto performed activities the following conclusions can be drawn.

- Management leads to regeneration of the moss layer, which is evident especially at wetter sites.
- *Gentiana pneumonanthe* clearly dislikes a higher moss cover.
- Populations of sensitive species producing little biomass, especially *Carex davalliana*, *C. pulicaris*, *Eriophorum latifolium* and *Parnassia palustris*, regenerated at wetter sites.
- Management at the wettest sites led to a suppression of diagnostic species of the *Molinion* alliance and supported successional change towards minerotrophic types of the habitat of acidic moss-rich fens: low sedges prevail in the vegetation at present, at the site of Mokřady u Okrouhlíku the measure has strongly supported the vitality of *Carex davalliana*.
- At the site of Mokřady u Osí, where shallow draining was realised in the first intervention, expansive productive species indicating a rather stable water regime were successfully suppressed: *Filipendula ulmaria* reacted very distinctly, whereas *Scirpus sylvaticus* retreated very slowly; some of the diagnostic species of the *Molinion* alliance, e.g. *Molinia caerulea* and *Sanguisorba officinalis*, have gradually started to enter the vegetation.
- Diagnostic species of nutrient-rich Molinia meadows, particularly *Serratula tinctoria*, *Betonica officinalis* and *Laserpitium prutenicum*, retreated markedly at mown sites. We have not been able to explain this phenomenon clearly to date; it may have been caused by the fact that the timing of the measures was different from the era of historical farming.

It has been demonstrated that measures have a high chance of success if the management is carried out by one organisation over a longer period of time, during which it learns to understand the specificities of the measures. Yearly alternation of firms performing the assigned work as a result of selection procedures meant that not all specified management principles were always respected. The result of this system was that the measures were not always timed optimally (these problems even arose due to the need of repeating the selection procedure for administrative reasons!). It also happened that unmown permanent plots as well as *Gentiana pneumonanthe* plants were mown by mistake, even though everything had been clearly marked with wooden sticks in the field.

We can learn from the management of the Molinia meadow habitat in Boletice Military Training Area that it is necessary to monitor the success of management measures permanently, to assess them and to implement the monitoring results in management plans where needed. The instability of Molinia meadow habitats is another topic for monitoring in order to know how to protect these valuable, very species-diverse plant communities.

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**Fig. 10.** Vegetation with *Iris sibirica* at Podvoří - louky. (A. Vydrová)

# Heathland restoration by means of controlled burn


Bohumil Fišer, Hana Mayerová, Martin Adámek & Jan Hora


| | |
|---|---|
| Location | Target areas in Brdy PLA, altitude 726–794 m |
| Conservation status | PLA, planned NNM, SCI |
| Restored area | 1 ha by controlled burn, 20 ha by incidental fires during military training |
| Financial support | Fire Rescue Service of the Czech Republic, NCA |


## Abstract

Extensive heathlands are among the most valuable habitats in the Brdy PLA. Their existence is the result of military training in target areas during the past 90 years. When military training ceased at some sites in 2015, it became necessary to find an alternative to preserve the heathlands. Because of the presence of explosive loads from military training, prescribed burn is probably the only management option. A controlled burn experiment was carried out in May 2016 in the former target area of Jordán in cooperation with the NCA and the Fire Rescue Service of the Plzeň Region. The experiment involved temperature monitoring and recording phytosociological relevés, including comparison with phytosociological relevés from plots burned in the past during military trainings.


## Site description

In 1926, the government of the Czechoslovak Republic approved the creation of an artillery shooting range in the Brdy hills. After 1930, three target areas were gradually felled, each with an area of almost 500 ha – Brda, Jordán and Tok (Čáka 1998). Continued military training then led to the creation of open heathland with *Calluna vulgaris*, *Vaccinium myrtillus*, *V. vitis-idaea*) and acidophilic grasses which is unique in the Czech Republic. Artillery shooting kept the heathland open through soil disturbances and incidental fires. There were almost 100 fires of varying extent in the three target areas in the last 10 years of military activity, most of them in May and April due to suitable weather conditions (Fig. 2).

The heathland ecosystem depends on the life cycle of heather (*Calluna vulgaris*). Heather plants grow old in about 25 years, lose their ability of vegetative reproduction and the heathland then degenerates gradually (Gimingham 1971). Heather seedling germination requires bare soil (Equihua & Usher 1993) and may be induced by heat and smoke in the top layers of the soil (Thomas & Davies 2002, Mallik et al. 1984). On the other hand, long exposure to high temperatures can reduce germination rates (Schimmel & Granström 1996).

The heathland in the Jordán target area is approximately in the middle of its life span, with few seedlings, located mainly in craters created by ammunition explosions. Keeping the ecosystem in a favourable state requires active management (Pešout & Fišer 2016). The Brdy PLA management plan recommends prescribed burn of target areas as a suitable measure for the present Natura 2000 habitats.

## Initial state

In the last years of the Brdy Military Training Area, Jordán was the least used target area of the three. There were several incidental fires, located in the SW part used for air force training. Large areas of Jordán are therefore overgrown by birch (*Betula pendula*), and explosive ammunition loads are found all over the area. Since the cancellation of the Brdy Military Training Area on 31 December 2015, disturbance methods other than the side-effects of military training need to be found.

**Fig. 1.** Burning *Calluna vulgaris* in target area Jordán, 2016. (B. Fišer)

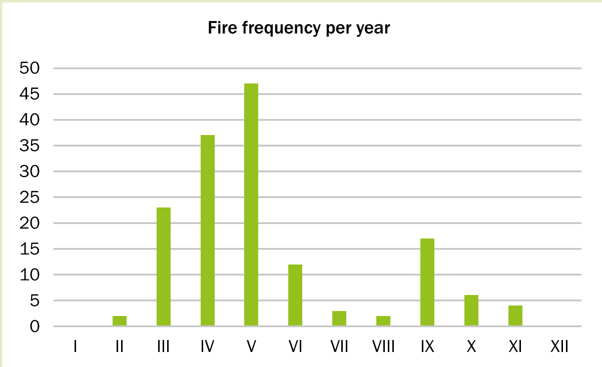


**Fig. 2.** Fire frequency in the target areas Brda, Jordán and Tok in particular months during military trainings in 2006–2015. (Sedláček 2015)

Current Czech legislation forbids burning of vegetation. For this reason, the described experiment was part of a fire drill of Fire Rescue Service units. Heather burning served as a model situation for uncontrolled heathland fire.

## Restoration objectives

Restoring heathlands in former military target areas by prescribed burn.

## Management measures

April 2016. Two separate plots (1 ha in total) were chosen for a controlled burn test.

May 2016. Both plots were searched for bird occurrence and nesting two weeks before experimental burning, with a negative result. Ornithologists repeated the monitoring twice on the day of the experiment (in the morning and just before the intervention) to exclude nesting in the area and to alarm all other animals possibly present.

18 May 2016. A number of security measures taken included closure of the area, sufficient water supplies and felling of shrubs and trees near selected areas. A special remote-controlled initiation technique was used enabling instant ignition of the entire plot in order to ensure fast burning, minimal heat exposure of the soil and minimal risk of ammunition explosion. For a detailed description of the methods, see Fišer et al. (2016).

## Monitoring methods

Monitoring was targeted at both fire behaviour and the course of vegetation succession afterwards, including heath regeneration.

Ten measurement points were established to measure temperatures above the ground, on the surface and in the soil during the fire. Data from these sensors were collected each 10 s.

**Fig. 3.** Controlled burn at Jordán, 2016. Curtain hoses, visible in the background, are suitable for remote fire control in areas with ammunition load. (B. Fišer)

Before the experimental fire, 9 permanent plots (5 × 5 m) were established for vegetation monitoring. Phytosociological relevés were made before burning, repeated two months after, and will be collected again. Based on records of the Fire Rescue Service and aerial mapping, parts of heathland in the neighbourhood of the experiment with known fire history were localised. In these, permanent plots were also established and the vegetation in them recorded. Overall, data from 25 plots aged 0 to 15 years after fire were obtained. For the analyses, data collected in the experimentally burned plots before the fire were not used.

The cover of each species was estimated in percentages and the data was analysed using R (R Core Team 2012).

## Results

### Fire measurements

The maximum temperature reached was 800 °C. Above the ground, flame burning lasted 1 to 4 minutes. Increased heat exposure on the soil surface was recorded to last 4 to 6 minutes. The maximum soil temperature at a depth of 2.5 cm was 55 °C at one point, but did not exceed 30 °C at the other points. The maximum soil temperature at a depth of 5 cm was 30 °C at one point, but did not exceed 15 °C at the other points. At a depth of 10 cm heat exposure was negligible. Fire spread rate averaged 1–2 m.min$^{-1}$.

### Vegetation succession

In total 38 vascular plant species (including 8 tree species) and 26 bryophytes and lichens were recorded in the permanent plots. To evaluate the changes in vegetation composition in time since the fire, the percentage covers of dominant species and important groups of species were plotted (Fig. 4): *Calluna vulgaris*, *Pteridium aquilinum*, *Vaccinium* (*V. myrtillus* and *V. vitis-idaea*), graminoids (*Poaceae*, *Cyperaceae* and *Juncaceae*, 12 species), herbs (14 species) and mosses.

Results show that slow-growing species (*Calluna vulgaris*, *Vaccinium myrtillus* and *V. vitis-idaea*) reach a maximum cover around 10 years after the fire and decline later. This corresponds with the heather life cycle. Around the same time, 10 years after the fire, moss cover rises and suppresses generative spread of heather. On the other hand, *Pteridium* cover, which at first peaks around the same values as heather cover, declines with time.

## New insights and recommendations

The experimental prescribed burn of the heathland in the Jordán target area during a fire drill and the results of vegetation monitoring have resulted in several basic premises for future use on a large scale:

- The course of a carefully prepared fire can be fast and does not cause long heat exposure of the soil profile, so both humus layer, containing the major seed bank, and heather roots remain untouched. In addition, animals can find refuge in the soil. Another evidence of the speed of such a fire is that heather plants in craters caused by ammunition explosions remained unburnt, because the flames spread around the depressions.
- It is necessary to keep clear paths around former target areas to prevent fire from spreading from the heathland to surrounding forests.

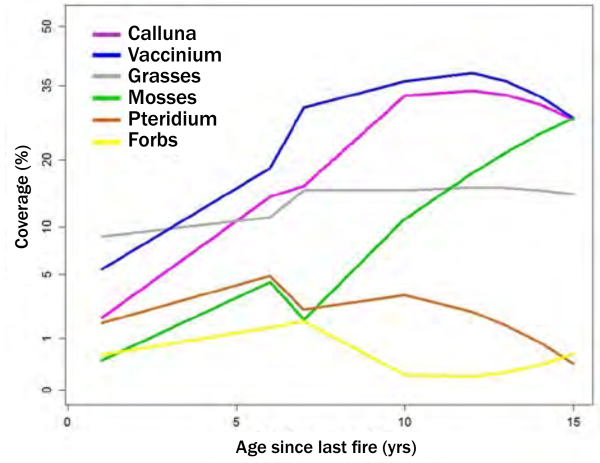


**Fig. 4.** Average percentage cover of different plant ecological groups in a sample. Number of samples in age categories since last fire: 2 months 9×, 6 years 2×, 7 years 3×, 10 years 5×, 12 years 1×, 13 years 1×, 14 years 3×, 15 years 1×. Square root transformation on y-axis.

**Fig. 5.** *Cicindela campestris* two days after controlled burn. (B. Fišer)

**Fig. 6.** Seedlings in old explosion craters remain untouched during fire. (B. Fišer)

- Paths should also divide the target area itself, so that the heathland can be burned in parts and the risk of uncontrolled fire of the entire area is decreased.
- Mainly for safety reasons, curtain hoses are convenient for use during prescribed fires in the Brdy target areas. Their main disadvantage is the higher cost.
- Vegetation relevés in areas with a relatively long fire history show that heather can be a successful dominant species 10 to 15 years after fire. That makes grazing management after fire redundant (grazing in target areas is a complicated issue due to explosive loads). On the other hand, it is necessary to repeat burning in a certain cycle to prevent heathland degradation.

## Acknowledgements
The authors want to thank all firefighters who were actively involved in the fire drill of May 18, 2016 and the directorate of the Fire Rescue Service of the Plzeň Region for their courage and energy before and during the test. Thanks for measuring temperatures and heat exposure go out to the Technical Institute of Fire Protection, Faculty of Safety Engineering, Technical University of Ostrava. We are grateful to Karolína Pánková of the Faculty of Science, Charles University, Prague for recording phytosociological relevés.

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**Fig. 7.** Regeneration of *Vaccinium myrtillus* two weeks after controlled burn. (B. Fišer)

# Restoration of a dry heathland in Prague: comparing the effects of grazing and sod-cutting

Jiří Dostálek & Tomáš Frantík

| | |
|---|---|
| Location | Zlatnice NM, Prague, elevation 250–280 m |
| Conservation status | NM |
| Restored area | 0,2 ha |
| Financial support | Prague Municipal Authority |

## Abstract
In Zlatnice NM to the north-east of Prague, the effects of extensive grazing and sod-cutting on the regeneration of a dry heathland was monitored. The results of the experiment have shown that extensive grazing is a suitable means of restoring lost dry heathlands on shallow, nutrient-poor soils. In some cases however, grazing can be combined with sod-cutting, which is also an effective method. Using sod-cutting alone is however technically more demanding.

## Site description
The restored dry heathland is situated on a steep south-facing slope above the Šárecký potok stream. The bedrock is mainly made up of proterozoic slate, on which a shallow layer of protoranker and ranker soils have developed. For more detailed information on site and vegetation conditions, see Dostálek & Frantík (2015).

## Initial state
A considerable part of the site used to be extensively grazed by cattle (especially goats and sheep), thanks to which heathland developed (Kubíková et al. 2005). After cessation of extensive farming, the site became gradually encroached by shrubs and trees. Already in 1980, the heathland was almost completely covered by shrubs or replaced by vegetation dominated by *Avenella flexuosa* and *Festuca ovina*. For more details, see Kubíková (1982).

In connection with its active approach to nature reserve management, the Department of Environment Conservation of the Prague Municipal Authority decided in 2008 to restore the heathland vegetation, which is the main reason for its conservation. In that time the heathland had completely vanished as a result of long-time absence of the original grazing regime, which had led to senescence and gradually dying of the heathland vegetation. The degradation was also supported by invading scrub and gradual restoration and development of the surrounding woodland, shading the site of plants of the heliophilous heather (*Calluna vulgaris*). Instead of the vanished heathland, vegetation dominated by *Avenella flexuosa* and mosses had developed.

**Fig. 1.** Vanished heathland in 2008. (J. Dostálek)

Restoration of the heathland was decided on after field research, in which young heather plants had been found to grow in places where the soil was disturbed by trampling. Based on this fact it was assumed that the soil seedbank contained viable heather seeds, as is indicated for this species (see e.g. Kubíková 1999). Restoration of the heathland seemed therefore to be prospective.

## Restoration objectives
Restoring heathland at a site where it used to occur in the past, but had vanished by a change in management and subsequent succession.

## Monitoring objectives

The aim of nine-year monitoring was to compare the effects of grazing and sod-cutting on the regeneration of dry heathland.

## Measures applied

In early 2008, expanding scrub was cut at the site and at the same time treated with a herbicide. According to need, more shrubs and trees were eliminated in the course of the entire period of heathland restoration monitoring.

Simultaneously with shrub and tree removal, the effectivity of the following two main management measures recommended for heathland restoration are being tried out (grazing and sod-cutting; see e.g. Háková et al. 2004; for more details, see Dostálek & Frantík 2015).

1. Since 2008, part of the area is yearly grazed for a short time (one week) in early spring by a herd of 25–35 sheep and 2–5 goats.

2. In the early spring of 2008, in 5 randomly selected plots of 1 m² in size, the sod was scraped off down to the mineral soil in the ungrazed part of the area. Germination of the seeds on the raw humus is namely inhibited. They only germinate on mineral soil (e.g. Kubíková 1979, Sedláková & Chytrý 1999, Diemont et al. 2013, Henning et al. 2017).

Note: controlled burn, which is regarded to be one of the most effective ways of restoring heathland (e.g. Sedláková & Chytrý 1999), has not been applied because it is strictly prohibited on the territory of Prague. Moreover, the vegetation lacks a sufficient amount of dry mass for burning.

## Monitoring methods

Data was collected using a system of square permanent plots 1 m² in size, which were fixed in the field by driving large nails into the ground. The squares were divided into 9 square subplots with a net. In each of the nine subplots, the complete species composition as well as the estimated percentage cover of each species, including the total cover of all bryophytes, were recorded. Thus an estimation (average and standard deviation) of the cover of each species was obtained for the entire plot. For heather (*Calluna vulgaris*) also the number of individuals was recorded. In this way each year in July, from 2008 to 2016, the state of the vegetation cover was captured (incl. numbers of heather plants in 2008–2010) in 5 grazed plots, 5 plots with removed sod, and 4 plots without intervention, serving as a control. Since 2011, it has been impossible to count the number of heather plants, because when a heather population expands, it is hard to determine exactly which plant is a sapling and which is just a rooted part of an expanding polycormon.

The data on cover and number of heather plants was statistically evaluated using the Statistica v. 9 programme. Changes in cover of the other species groups over 2008–2016 were also subjected to a multiple factor PCA analysis (ter Braak et Šmilauer 2012).

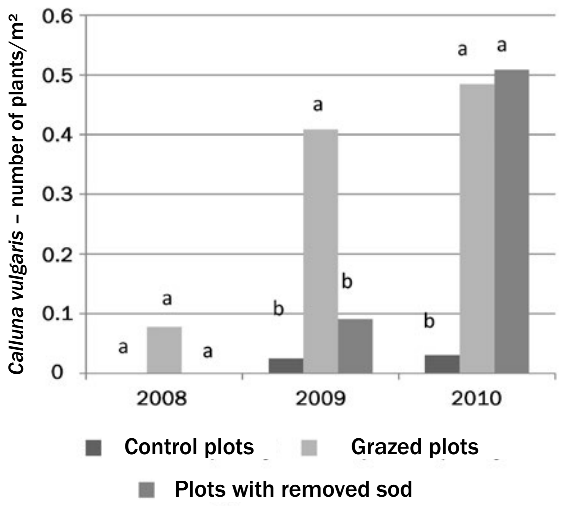


**Fig. 2.** Numbers of heather (*Calluna vulgaris*) plants in relation to management measure in the monitored plots over the period 2008–2010. Values in one year indicated with different letters are statistically significantly different.

## Results

### Changes in numbers of heather plants and their cover

Changes in cover of heather related to the type of treatment which should lead to regeneration of the vegetation are illustrated in Fig. 3. Until 2015, heather cover increased most prominently in the grazed plots. Its increase was linear, and from the second year after grazing was introduced, it was statistically significant in all subsequent years in contrast to the control. In 2016, however, heather cover in the grazed plots markedly declined to values not significantly differing from the cover in plots with removed sod.

The cover of heather in the plots with removed sod also started to rise considerably, especially in the years 2010–2013. In 2011 it had reached such a level that from that year onwards it did statistically not differ significantly from grazed plots. Since 2014 the total cover in these plots has rather stagnated. In the period 2008–2016 the absolute increase in heather cover in plots with removed sod was the same as in grazed plots and was statistically significantly higher than in the control plots. During the nine-year monitoring also the cover of heather in the control plots, which had been left without intervention, increased slightly. This increase was however observed only in parts of the plots which had been accidentally disturbed by trampling by people or wild animals.

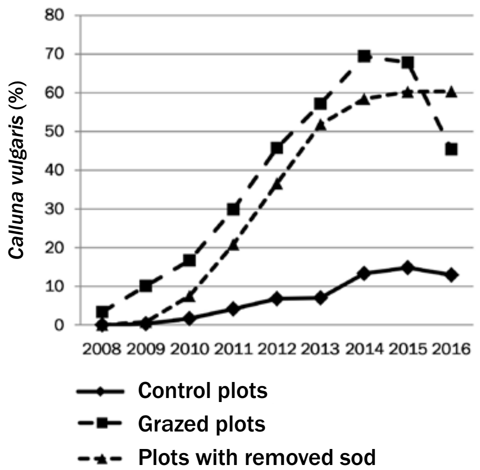


**Fig. 3.** Cover of heather in plots with different types of treatment in particular years.


**Fig. 4.** Plot with removed sod in 2008 and 2015. (J. Dostálek)

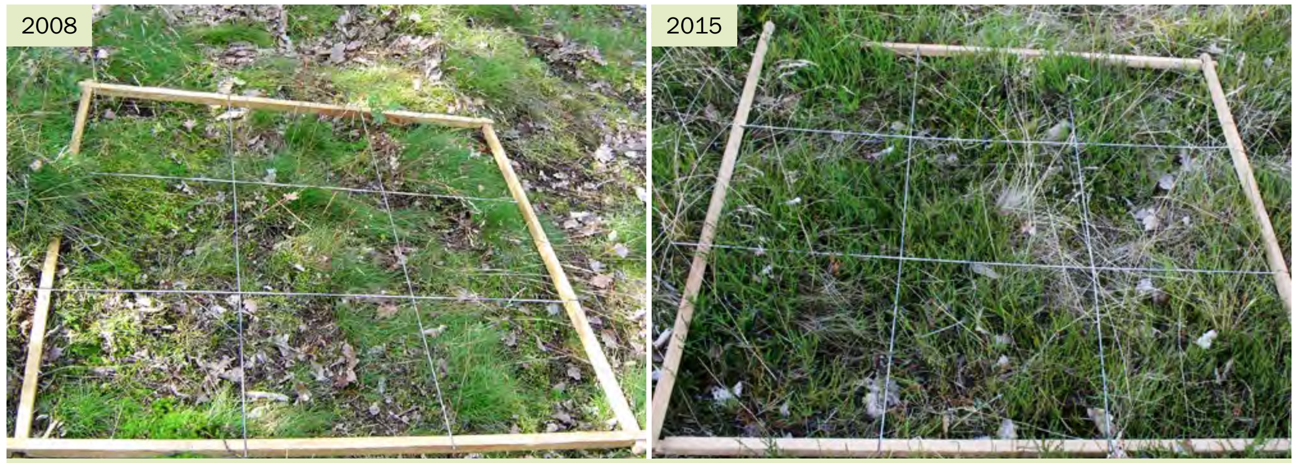


**Fig. 5.** Annually grazed plot in 2008 and 2015. (J. Dostálek)


**Fig. 6.** No heather developed in the plot without intervention in the period 2008–2015. (J. Dostálek)

The influence of grazing and sod-cutting on the prosperity of heather seedlings is illustrated in Fig. 2. In the grazed plots, as compared to the plots with removed sod and those without intervention, the number of heather plants increased already from the second year after grazing was introduced. In the third year (2010) however, the number of heather plants in the plots with removed sod rose so significantly that it became practically equal to the number of heather plants in grazed plots.

**Changes in cover of other plant species**

The results of assessing the influence of the heathland restoration measures on the cover of distinctive species groups in the years 2008–2016 is shown in Fig. 7. The diagram shows that regular grazing and one-shot sod-cutting considerably inhibited an increase in herb cover, which prospered better in the control plots without management measures. Mosses and shrubs (except for heather) locally increased their cover, especially in the grazed and control plots, which relates (just as with herbs) to the regeneration of dominants of the original vegetation.

## New insights and recommendations

The results of nine-year monitoring have shown that heathlands regenerate successfully after the management interventions. The removal of full-grown trees from the surrounding, which took place in the winters of 2010–2011 and 2011–2012 also contributed to the prosperity of the heathland. Regeneration of the heather population is further supported by grazing and sod-cutting. Sod-cutting alone is however technically demanding, although it could be appropriate to combine both measures, which is confirmed by the results of the present monitoring. Grazing seems to be a suitable way of regenerating and managing heathlands on nutrient-poor, skeletal soils. Grazing however needs to be supplemented with cutting and removing scrub from the heathland.

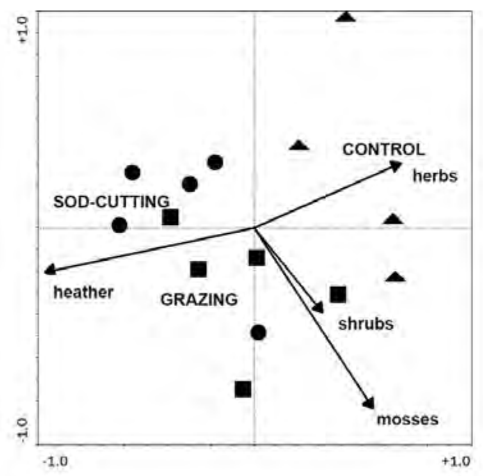


**Fig. 7.** Result of indirect gradient analysis (PCA) of all studied plots, showing an increase in the cover of heather (*Calluna vulgaris*) and distinct species groups related to management measures in the period 2008–2016. The differences in cover between the years 2016 and 2008 were ordinated; circles – plots with removed sod, squares – grazed plots; triangles – plots without intervention.

**Fig. 8.** Restored vegetation in regularly grazed plot, 2015. (J. Dostálek)

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# Restoration of heathlands in Podyjí National Park

Lenka Reiterová & Robert Stejskal

| | |
|---|---|
| Location | Znojmo District, heathland at Kraví hora (48°50′50″ N, 16°02′19″ E), Havranické vřesoviště (48°49′09″ N, 16°00′41″ E), Popické kopečky (48°49′42″ N, 16°01′12″ E); elevation 308 m |
| Conservation status | NP, SAC, SPA |
| Restored area | 80 ha |
| Financial support | ME Landscape Management and Restoration Programmes, Rural Development Programme; €115–580 per ha and year, depending on applied method |

## Abstract

The heathlands in Podyjí NP are a substitute community at sites where dry oak forests potentially grow. Their creation as well as conservation are conditioned by at least occasional grazing. The state of these communities was in the 1990s affected by long-time absence of any management. In the past 25 years several procedures of restoration and long-term management of the heathlands have been tried out: grazing, mowing, cutting shrubs and trees, sod-cutting, and burning. Grazing can be regarded the most effective method in the long term. However, in the present conditions of increasing atmospheric nitrogen deposition, it is necessary to supplement grazing with more rigorous disturbance methods, preferably burning and sod-cutting.

## Initial state

The heathlands are substitute communities at sites where dry oak forests or, in extreme positions, pine forests potentially grow. They mostly form a mosaic of the *Euphorbio cyparissiae-Callunetum vulgaris* association (*Euphorbio cyparissiae-Callunion vulgaris* alliance) with dry steppe grasslands of the *Potentillo heptaphyllae-Festucetum rupicolae* association (*Koelerio-Phleion phleoidis* alliance). They arose by long-time extensive grazing, apparently by groups of cattle consisting of different species. Grazing however gradually declined already during the 19th century, but especially from the early 20th century onwards. After World War II and the retreat of the population from the border region it was practically not resumed anymore.

On the steep slopes of the Dyje (Thaya) river valley, woodland spontaneously returned quite rapidly. The communities on the plateau, however, showed considerable persistence, so that in the early 1990s, despite the significant degree of degradation, still more than 100 ha of heathland and steppe fallows was registered. At the same time, the heathlands had reached a certain breakpoint, because very fast developing of scrub as well as tall grasses were observed during the following decade, even at sites which had been preserved until that time.

In 1991, most populations were in an advanced stage of degradation: partly converted to spontaneous and planted shrub and tree stands, partly encroached by aggressive tall grasses such as *Arrhenatherum elatius* and *Calamagrostis epigejos*. An exception was the ca 25 ha large area of well-preserved populations at the site of Kraví hora near the town of Znojmo, where a military training area had existed until the 1960s. The traversing of heavy vehicles and building of trenches had proved to be a very suitable type of heathland management.

The newly established Podyjí NP Authority did not have the means to perform the necessary management, therefore it searched for other possibilities to rescue the unique xerothermic communities.

In order to set the optimal management, also the results of studies dealing with the impact of atmospheric nitrogen deposition on heathland and dry-grassland communities and with the dynamics of the nitrogen cycle in the communities are significant (e.g. Fiala et al. 2011, Záhora et al. 2016).

**Fig. 1.** Sod-cutting – site before intervention. (R. Stejskal)

**Fig. 2.** Sod-cutting – site shortly after intervention, 27 March 2008. (R. Stejskal)

The environmental conditions are currently, due to increasing nitrogen concentration in the atmosphere and, by extension, in the precipitation, namely considerably different from the time when the heathlands were formed.

## Abiotic conditions

The subsoil under the heathlands near Znojmo consists of acidic rock, predominantly of granodiorites of the Carpathian Foredeep. The soil horizon is generally very shallow. A low nutrient soil content and water deficiency are limiting factors. The area of the Znojmo heathlands are located in the warm climate region, having a mean annual temperature of 8–9 °C and a mean annual precipitation of around 500 mm (Portál ČHMÚ). Black frosts in winter and overheating of the surface in summer are typical phenomena. Thanks to the usually low or lacking snow cover and intensive insolation, the vegetation season often starts very early.

## Restoration objectives

Preserving and restoring heathlands over an area registered before the establishment of the National Park, i.e. roughly 150–180 ha.

## Monitoring objectives

Identifying a suitable type of management which makes it possible to permanently preserve the communities in a favourable state and which prevents them from diminishing in area.

## Restoration measures

Several types of measures have been applied in the restoration of heathlands and dry grasslands in Podyjí. The type of management was selected according to the state of the treated area on the one hand and the availability of methods at the site on the other. Also the development of the community in areas where accidental disturbances had occurred was evaluated.

**Burning**

Empirical observation of the development of areas affected by occasional fires according to historical records, and experience with traditional management of Western European heaths (Gimingham 1994) indicate that regeneration of heather (*Calluna vulgaris*) is significantly supported by burning. This information could not be used for regular heath management in Podyjí to date, especially because of legislative obstacles. In spring 1997, an area of ca 5 ha accidentally burned at Kraví hora near Znojmo. The fire was of medium intensity: aboveground parts of herbs and most heather shrubs burned off, just as nearly all litter on the ground, but trees and shrubs were basically not damaged (only bark in the basal part of stems was affected by fire). The development of the vegetation after burning has been monitored in only three plots as part of a research project (Sedláková & Chytrý 1999).

Besides this fire, unintended fires have also occurred at several other heathland sites over an area of 0.5–5 ha.

**Grazing**

The most suitable method of restoring and managing xerothermic grasslands and heaths is regarded to be extensive grazing (Chytrý et al. 2001). In Podyjí NP this management was experimentally resumed in 1993, when an area of ca 2 ha was grazed by a temporary herd of 7–10 Cameroon goats. These were in 1995 replaced by a temporary flock of approx. 250 sheep. In the following year, at another site, the first ca 15 animals were kept in sheepfolds (in periodically translocated enclosures). Gradually, at least occasional grazing has been introduced on heaths with a total area of 150 ha. Kraví hora near Znojmo has been grazed by a mixed herd of sheep and goats at an intensity of ca 5 animals per hectare daily from April to September, whereas the site of Havranické vřesoviště by sheep at an intensity of only 3 animals per hectare for ca 3–5 hours daily (depending on the season), mostly from June to September.

**Tree and shrub reduction**

A range of sites was strongly encroached by scrub, mostly *Rosa*, *Prunus spinosa*, *Ligustrum vulgare*, *Populus tremula* and *Pinus sylvestris*. Although these are important as shelter and food for birds, small mammals and insects, the shading and litter accumulation gradually leads to degradation and extinction of the original oligotrophic xerothermic community. The most applied method of shrub reduction in Podyjí has been felling, initially in winter time, later also in the second half of the vegetation season, followed by treatment of the stumps with a herbicide. In 1997, a complete area of ca 3 ha, encroached with mainly *Rosa canina* shrubs at a cover of ca 50%, was treated by pulling out shrubs with mechanic hands. During the work, underground parts of up to several metres long were pulled out without causing any major undesired disturbance of the topsoil.

**Reduction of trees and shrubs followed by grazing**

A stand of full-grown black locust trees of approximately a hectare large on the heath of Kraví hora near Znojmo was felled and was, without subsequent herbicide treatment, fenced in the following season, after which a herd of sheep and goats was locked up in the enclosure.

**Mowing**

Grazing has not been carried out every year in all heath areas. Some areas have only been grazed for a short time in part of the season. Moreover, in some years the grazing was started later, particularly owing to granting terms of national subsidies without which the grazing could not have been funded, or because of difficulties in finding farmers willing to tend cattle on the heaths. Ungrazed areas had to be managed in an alternative way, concretely mowing. Particularly for reasons of capacity, the areas were mown mostly once a year. In some areas mowing was carried out in spring as a preparation for grazing in the second half of the season. In the years 1998 and 1999, repeated mowing 10× annually was tried out in five experimental plots at Kraví hora with a high dominance of *Calamagrostis epigejos* measuring 20–100 m², to prevent this grass from flowering.

**Sod-cutting**

In 1992, as part of a research project, the sod in a plot of 4 × 4 m was experimentally removed using a machine; in 1999 this was carried out in another plot of 10 × 25 m, in both cases in vegetation where heather occurred. These experiments were followed up by further sod-cutting already as management measures to support heather and competitively weak species or as a method to reduce *Calamagrostis epigejos* at Kraví hora (Figs. 1, 2, 4 and 5). These measures were carried out in the years 2008, 2009, 2014 and 2016. Every year, 6 to 13 plots were scraped on a total area of 170 to 1600 m² annually.

## Monitoring methods

Permanent plots established after burning, mowing and sod-cutting have since 1992 been monitored by Iva Keizer-Sedláková and various collaborators (Sedláková & Chytrý 1999, Keizer-Sedláková et al. 2015).

In spring 1998 also counts of heather seedlings were carried out once-only at Kraví hora near Znojmo, at the site of a fire which had occurred in the previous year. The seedlings were counted in randomly located plots 1 m² in size. The effectivity of grazing, just as the development of plots after tree and shrub reduction, has been monitored solely empirically, by visual estimation of the state of the habitats at Kraví hora and at Havranické vřesoviště.

The development of sod-cutting plots and plots where mowing has long been the main type of management has been monitored similarly extensively.

## Results and discussion

**Burning**

Results of the monitoring show that regeneration of the dwarf-shrub part of the vegetation (*Euphorbio cyparissiae-Callunetum vulgaris* association) can be supported by burning at medium intensity, which not only burns the aboveground necromass, but also removes covering mosses, lichens and litter, and exposes the mineral soil. At low burning intensity, moss and lichen layers hinder the germination of heather seedlings (Fig. 3) and after some three to four years, grasses start to spread strongly here. The monitoring has also confirmed that burning does not have a negative effect on *Pulsatilla grandis*: its cover remained the same all the time and it was observed to flower richly. This finding has been confirmed by empirical observation of plots developing after occasional medium-intensity fires, in which heather seedlings drastically increased in number (after the fire at Kraví hora, their number was around 50 plants/m²). Such a fire occurs, for example, when dead biomass starts burning in a dry period. It leads to incineration of the aboveground biomass including mosses and lichens as well as litter on the soil surface, but full-grown trees or underground plant parts are not seriously damaged.

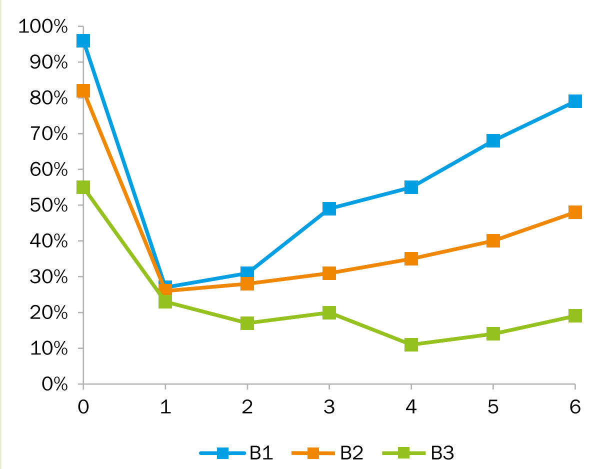


**Fig. 3.** Development of percent frequency of heather (*Calluna vulgaris*) in plots after burning: B1 – Kraví hora, medium fire intensity, B2 – Havranické vřesoviště, low fire intensity, B3 – Popice, low fire intensity, 0 – state before burning, 1–6 – state in the 1st to 6th year after burning. (Sedláková & Chytrý 1999)

#### Grazing

Aggressive tall grasses are reduced only by high-intensity grazing. In Podyjí a rate of 3–5 animals per hectare has caused an expansion of grasses, not only short species like *Festuca* but also *Arrhenatherum* and *Calamagrostis*, in areas which are yearly grazed during the entire season. Not only the intensity is important (minimum 5 animals, in productive regions like Podyjí rather 7–10 animals per hectare), but also the daily and yearly grazing period. It is especially important to start grazing as early in the season as possible. When grazing is started by mid-April, ended not earlier than late September, and the animals remain on the pasture for at least 8–10 hours daily, aggressive grasses are suppressed and heather regeneration is supported. A lower grazing intensity is not sufficient to suppress tall grasses. Especially a later start of grazing significantly reduces its effectivity. It is appropriate to add goats to the herd in order to control the expansion of shrubs and trees. In order to diversify the vegetation, other animals can be added (horses, cows, poultry etc.), however always in a minority. In Podyjí, the vegetation at sites with horse or poultry grazing has namely always developed towards other communities than heathlands or dry grasslands of the abovementioned associations.

Experience from Podyjí thus supports the acknowledged theory that regards grazing by smaller animals to be the most reliable method to manage heathlands in the long term. An intensity of 3–5 animals per hectare, recommended for submontane regions, however, needs to be raised in warmer regions and particular attention should be paid to starting the grazing as early in the season as possible (already in February if the weather proceeds favourably). On the other hand, grazing cannot be applied successfully in areas which are strongly degraded either by shrub and tree encroachment or by expansion of aggressive grasses. In areas encroached by shrubs and trees it is necessary to carry out intensive thinning, in some cases to uproot the shrubs and trees, before grazing is introduced.

In accordance with experience from the former military grounds of Milovice, grazing by Exmoor ponies could be a suitable alternative for Podyjí, but their grazing at Milovice has only been running for a short time, so it is hard to judge its long-term impact on the communities. In Podyjí, an experimental project with a herd of 11 horses started only in the year 2018, so that we will have to wait some time for an evaluation of this management method.

#### Reduction of trees and shrubs

Cutting shrubs and trees alone is insufficient to achieve their reduction. In the following seasons a large number of shoots were found to reappear and had to be removed again. If not, the area would have been encroached by shrubs and trees completely. Neither the application of herbicides at the treated sites led to a noticeable restraint in shoot development in the following years.

After uprooting shrubs and trees, establishment of woody plants was minimal in the first seasons, but within five years shoots started to branch out, and the entire area was encroached again very rapidly. Repeating the measure had a similar result.

#### Reduction of trees and shrubs followed by grazing

Intensive grazing of felled areas effectively prevented development of shoots after cutting black locust, even without herbicide treatment of the trunks. It was also significantly beneficial for the composition of the herb vegetation. Although the undergrowth initially consisted almost exclusively of *Rubus* species, *Calamagrostis epigejos* and nitrophilous herbs like *Chelidonium majus* and *Ballota nigra*, these aggressive species strongly declined during one season of forced grazing, starting steppe grassland regeneration. If grazing is introduced after shrub and tree removal in time and at sufficient intensity, restricting shrub regeneration with other methods (herbicides, cutting etc.) is not necessary.

#### Mowing

During mowing, the vegetation unequivocally directs towards classical *Arrhenatherion* grassland. Very intensive mowing (min. 10× per season) helps reducing the abundance of *Calamagrostis epigejos*. If a site is mown every time *Calamagrostis* reaches a height of max. 25–30 cm (i.e. before flowering), the cover of this species decreases from more than 50% to less than 10% within two seasons. At the same time, species of short grasslands regenerate.

**Fig. 4.** Sod-cutting – site 3 months after intervention, 12 July 2008. (R. Stejskal)

**Fig. 5.** Rejuvenating heather 3 months after sod-cutting, 12 July 2008. (R. Stejskal)

Mowing can certainly not be recommended as a method of long-term heathland maintenance. It can be applied successfully as additional management in combination with grazing, to a limited extent as a temporary defence against accumulating of dead biomass at sites where grazing is not carried out for more years. However, not later than 5–10 years after that, grazing or sod-cutting (or other soil disturbance) needs to be introduced, otherwise there is a risk that the heathlands and steppe grasslands gradually convert to meadow communities. Short grassland of the *Koelerio-Phleion phleoidis* alliance could be locally managed by mowing (4–6× per season), but this method has not been investigated purposefully in Podyjí. Nevertheless, from the long-standing state of grasslands located close to villages or towns (where frequent mowing is secured), we assume that it may work. Intensive mowing can be used to reduce *Calamagrostis epigejos*. This method is however very labour-intensive and costly for the necessary frequency of applying the measure.

#### Sod-cutting

Sod-cutting in vegetation dominated by *Calamagrostis* led to an essential reduction in cover of this grass. Even at sites where *Calamagrostis* almost formed monocultures, a number of target species, e.g. *Genista pilosa*, *Pilosella* spp., *Agrostis capillaris* and also seedlings of *Calluna vulgaris*, appeared in the first years after the intervention. It is however necessary to scrape off a sufficiently thick soil layer (at least 5–10 cm) in order to remove most underground *Calamagrostis* tillers. Sod-cutting also gives good results in hitherto preserved heather populations, where not only seedlings germinate but also old shoot tussocks regenerate from the roots. Sod-cutting leads to a removal of the topsoil layer, where the accumulation of available nitrogen is the strongest. It can thus partially and temporarily solve problems caused by atmospheric nitrogen deposition. Disturbance of the surface with other methods, e.g. by vehicle traversing, appears to be functional as well, but it always has to be temporary, i.e. the traversing route needs to be changed after one or a few years.

## New insights and recommendations

Our results so far indicate that the most reliable type of heath management is grazing, ideally by a herd with different species dominated by sheep and goats. The impact of grazing by wild horses has not yet been tested. To secure permanent existence of dwarf-shrub communities, grazing apparently needs to be combined with one-shot rigorous disturbances (burning or sod-cutting). Disturbance by burning and also sod-cutting must be carried out with sufficient frequency, repeating it once every 10–20 years. In both cases, sufficient intensity is also important: burning at medium intensity, sod-cutting to a depth of several centimetres under the soil surface. It needs to be said that the burning of large areas of standing vegetation – except for scientific experiments – is still restrained by legislative obstacles.

Practice shows that principally any measure leading to a limitation of aboveground biomass accumulation can prolong the existence of a heathland and its ability to restore. Therefore no available management approaches need to be rejected, whether cutting, raking, vehicle traversing or other ones. However, it is always desirable to remove as much biomass from the heath as possible, and the intensity of the measure must always be indirectly proportional to the frequency of its application.

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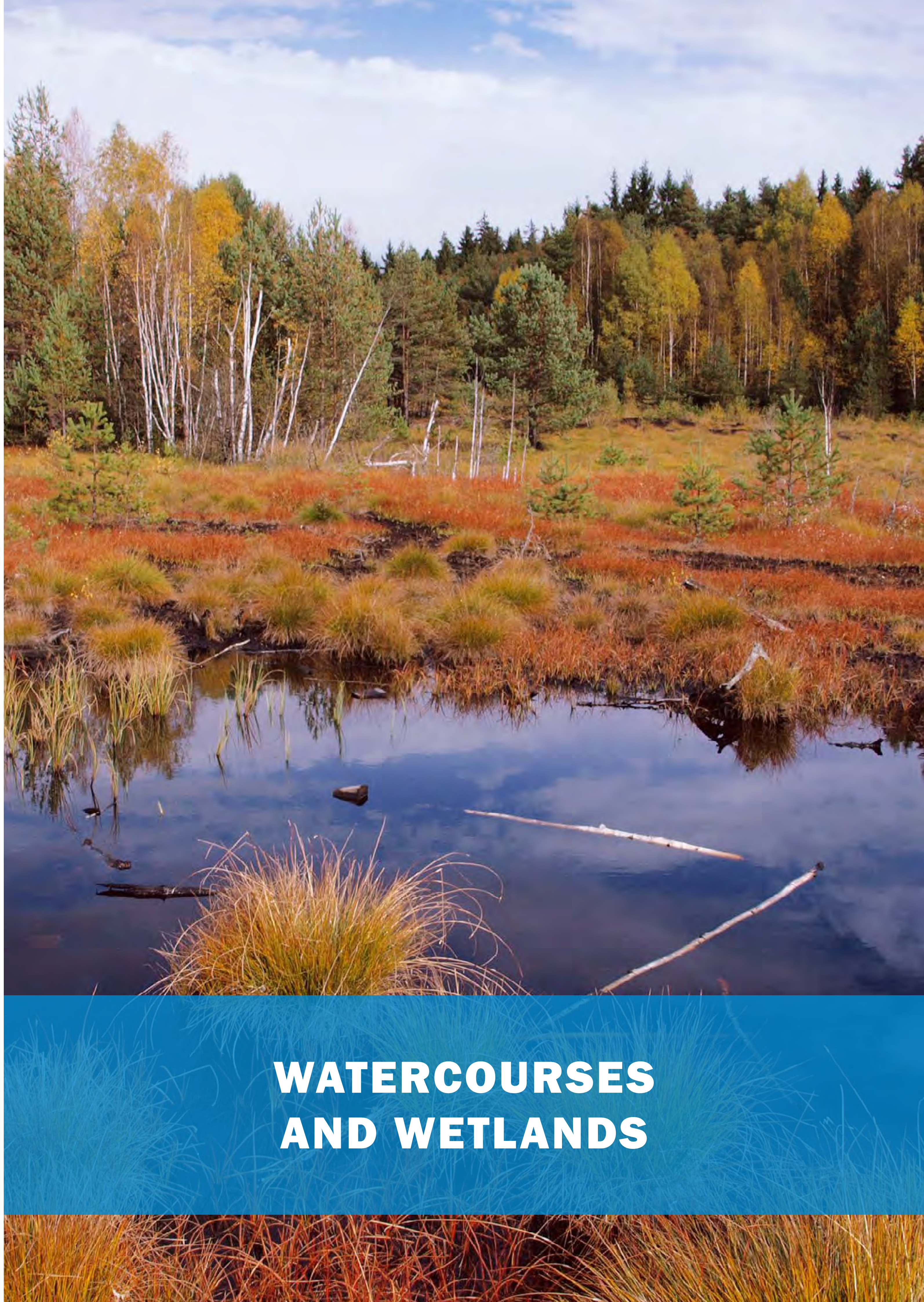

# WATERCOURSES AND WETLANDS

# Introduction

Tomáš Just & Pavel Pešout

Wetlands have an irreplaceable function in the water retention of a landscape and in improving the water balance. Besides these vitally important functions for nature and humans, they host a high biological diversity. In recent years, due to the more and more frequent manifestations of climatic extremes, wetland restoration is deservedly coming to the forefront of people's interest.

## A century of hydrological adjustments in the landscape

In the past, streams, rivers and their floodplains were subjected to technical adjustments serving land use intensification and industrialisation of the landscape. This happened in an effort to obtain as many fluvial areas as possible for agriculture, forestry and building. Their capacity was increased and riverbeds were deepened so that the surrounding land would be less frequently affected by even minor inundations and could be drained more easily. The unnaturally geometrised, enlarged and deepened riverbeds had to be fortified to resist the erosive effects of flowing water. For purposes of energy production, navigation and water inlet, watercourses were inflated by means of lateral constructions in the form of weirs or cascades.

Technical watercourse adjustments in the Czech Republic obtained an industrial character and significant extent after 1890. Regional floods were a strong motive for the need to 'improve' the hydrological conditions in the country. These took place just in the time when steam-powered building and transport machines started to be used. All of a sudden, large volumes of soil material could be transferred much more easily than before. The negative effects of the technical adjustments we see today were not known then and the prospects of business activities in construction, agriculture and elsewhere seemed to be unlimited.

In the interwar time, large canalisation projects continued, including improvements of river navigability. Technical watercourse adjustments of all sizes became an important phenomenon on the landscape scale. After the war, the countryside was socialised and the increasing industrialisation of agriculture supported the extent and range of large-scale draining and watercourse adjustments. These activities, simply referred to as 'land amelioration', have destroyed the fundaments of hydrological stability of the landscape to an exceptional extent (Just et al. 2005).

The century of hydrological adjustments in the landscape, which we consider to have taken place from 1890 to 1990, has drained at least a quarter of the farmland area, i.e. over a million hectares (Kulhavý et al. 2007, 2010), according to some experts even up to 1.5 million ha (Vašků 2011), and a considerable area of woodland. Also the area of wetland habitats has decreased dramatically (Richter & Skaloš 2016), out of 1300 thousand ha of wetland registered in the 1950s, only 350 thousand ha have remained today (Just 2005). A third to a half of the length of our wa-

**Fig. 1.** Revitalised streambed of Loděnický potok stream near Nenačovice, Beroun region, after finishing construction and tree planting, 2015. Activity by Povodí Vltavy, s.p., financed from the Operational Programme Environment. (T. Just)

Revitalised peatbog, Soumarský most, Šumava NP. (L. Vlková)

**Fig. 2.** A demanding restoration of wetland habitats in Bohdanečský rybník NNR was realised by the NCA in 1999–2015. (J. Rusňák)

tercourses, including minor streams, have been technically adjusted, which has caused their total length to be reduced by about a third. The extent of capillary watercourses, minor surface waters and springs which are completely occupied with large-scale draining facilities is actually not known, but it undoubtedly represents a significant contribution to the deficit in hydrological accumulation and water retention of the landscape and to the decline in biodiversity of water and wetland environments as we see it today. The water retention of the landscape has also been damaged by other major changes in the agricultural landscape, resulting in considerable erosion risk and faster discharge of precipitation. From 1948 to 1990, a total of 270 thousand ha of meadows and pastures, 145 thousand ha of baulks (corresponding to a respectable length of min. 800 thousand km), 120 thousand km of field roads, and 35 thousand ha of rural hedgerows were ploughed up and 30 thousand km of linear green elements eliminated in the Czech Republic (Klápště & Franková 2015).

## Brighter days ahead

Since 1990, major changes in water management paradigms have taken place. The massive destruction of water-related ecosystems caused by hydrotechnical and 'amelioration' adjustments is today identified and described. Drainage as a factor deteriorating water accumulation conditions is felt in times of drought. The increased and accelerated surface discharge distinctly deteriorates the water retention of the landscape, which we feel during floods. Especially the present occurrence of more frequent and stronger weather extremes force us to perceive these facts better.

In 1992, with the aim of supporting wetland restoration and renaturalisation of watercourses, the Ministry of the Environment set up a system of national subsidies in the form of the River System Revitalisation Programme and after that the Landscape Management Programme. This positive idea had however already received some kind of organisational and financial basis before it actually became effective in the water management world. Many projects ended up in failure for many years and at high costs. Only around the year 2000 the first credible watercourse revitalisations and wetland restoration projects appeared (for more details, see Just et al. 2012).

## Hesitative restoration of water retention of the landscape

The item of water retention restoration was included in a number of conceptual documents and strategies, also adopted at the governmental level, especially in connection with the current flood prevention and struggle against drought (Klápště & Franková 2015). Also the value of ecosystem services provided by wetlands is well-known and ever more exactly quantified (see e.g. Pithart et al. 2012, Mc Innes 2013, Hátle 2013). Despite this, and in spite of the fact that our water management, agriculture and forestry accept the targets of improving the water balance in the landscape, the prevailing approach to this problem is still inconsistent. In the agricultural landscape, erosion is hardly being reduced, the state of our soil is not improving, and the organic soil content is often still decreasing. Forestry reacts to climate change only slowly. Not even the large-scale decay of spruce and pine monocultures in a number of regions in the Czech Republic is leading to systematic pressure leading to an improvement in species, age and spatial composition of forests. Although watercourse authorities endorse the need to improve the morphological-ecological state of watercourses and are already realising various revitalisations, they rather often deal with them in the old-fashioned way. Until today, sediments

**Fig. 3.** Revitalised wetland habitats in Bohdanečský rybník NNR require further maintenance, which is yearly secured by NCA. In the photo: winter mowing of an islet. (Z. Koberová)

**Fig. 4.** A shallow sunlit depression with sandy bottom, created in the littoral of Dolanská zátoka inlet during the revitalisation of Bohdanečský rybník lake, is used for reproduction by *Bombina bombina*, a species protected at this SAC. (Z. Růžičková)

are removed from the riverbed, and bank breaches are landed up even in places where this is unnecessary. Drain systems and other river structures, which lost their function long ago, are cleaned and repaired.

Only recently, minor wetlands are slowly being conserved (with agricultural subsidies) and restored (in integral land consolidation projects). Important projects improving the water balance in the landscape have however been realised thanks to the first (as of 2007) and the (current) second Operational Programme Environment, which provides sufficient finances to support all high-quality projects. Minor measures (mostly costing up to €25 thousand) are mainly realised with support of the ME Landscape Management and Restoration Programmes. Annually several dozen major and minor projects for the restoration of pools, wet grasslands and small surface waters and for the revitalisation of streams, peatbogs and springs are supported (Anon. 2015, Limrová 2015).

A large number of pools and wetlands have been restored or created in the Vysočina region, eastern Bohemia, southern Moravia, the Ostrava, Liberec and Podblanicko regions and a range of other regions. Peat restoration projects are running successfully in the Šumava NP and PLA (Bufková 2013), in the Slavkovský les PLA, Jizerské hory PLA, Krkonoše NP, the Krušné hory Mts, etc. Pools are an integral part of the revitalisation of quarries, e.g. in the Třeboň and Most regions (Řehounek et al. 2010, Lhotský 2013). Recently also extensively managed fish lakes aimed at biodiversity support are being restored. Examples are the extensive revitalisation of Bohdanečský rybník lake (Franková & Peřina 2014) and the restoration of Lake Kojetín in the Polabí region (Trnka et al. 2014). Attention is also paid to the restoration of meadow marshes, fen meadows and salt marshes (Lysák 2016, Dedek 2016). Successful projects improving the morphological-ecological state of watercourses include the revitalisation of the Bílovka and Sedlnice rivers in the Poodří PLA (Birklen & Jarošek 2014; Jarošek & Legindi 2016) and the Jizera river (Holeček & Pácl 2016). The revitalisation of the Kněhyně stream in the Beskid Mts, including the subsequent elimination of a river structure, was ground-breaking also from the administrative point of view (Nevšímalová & Poloha 2015).

## Outlines of solutions to the main problems of wetland restoration and stream revitalisation

### Inaccessible plots

Wetland restoration is impossible without consent of the landowner. Also, full stream revitalisation needs space for the restoration of broad natural riverbeds and river zones. It is not easy to acquire the necessary land, but if those preparing restoration projects are sufficiently motivated, they manage to find various ways leading to at least partial success.

- Active negotiations with the landowners. A well-motivated 'revitaliser' conceives negotiations with the owners as a (sometimes even long-term) process in which he should be able to convince them of the well-elaborated plan and to react to justified objections by making appropriate corrections.
- Collaboration with municipalities. If a municipality is interested in realising a plan, it will be able to use some of its competences in land questions better than e.g. a national watercourse authority. Municipalities usually have their own land, which can be used for exchange. When purchasing land, a municipality is not strictly bound to official prices. And mainly, if the local government is trusted by the citizens, it can convince them to sell or exchange land parcels much more easily.

Fig. 5. In the revitalisation of the Barovka stream in the Železné hory PLA, a migration passage was created in the place where the stream flows into the Doubrava river. Already in 2015, a year after realisation, *Cottus gobio* was found to occur in the revitalised section. This species has a strong population in the Doubrava river, but did not occur in the stream before revitalisation. (V. Peřina)



Fig. 6. In the restoration of Lake Kojetín (Rožďalovice region) in Rybník Kojetín NM, realised by the NCA, adjacent wetland communities were supported by creating by-pass ducts and flow-through and stagnant pools. As the latter are not directly connected with a larger surface water body, they can serve as a site for amphibian development without the threat of predation by fish. Revitalisation of wetland habitats also included the creation of an islet covered with river gravel, which immediately became attractive for birds. (J. Tylš).

- Active involvement of people interested in wetland restoration and stream revitalisation into the process of land consolidation. This has hitherto been used to a small extent and passively by watercourse authorities and other possible investors in restoration projects.

### Missing connection of stream and floodplain revitalisation with flood prevention

In this field already positive changes are going on, especially in urban revitalisations supported by the Operational Programme Environment. As a whole however, we still strongly lag behind more advanced European countries, where morphological improvements of watercourses, restoring the natural character of floodplains, are commonly connected to flood protection. In the Czech Republic, barriers in education, attitude and organisation still persist. The latter problem is most evident from the way in which water management planning and subsidy programmes are still made. Especially the flood prevention programmes of the Ministry of Agriculture have traditionally concentrated on technical solutions only.

### Persisting conservative planning practice

The restoration of wetlands, peatbogs, springs and pools is still a neglected activity. Similarly, the knowledge is unfortunately insufficiently spread among planners, who are moreover not much inspired by river morphology and floodplain ecology. This is to a considerable extent the fault of their education: wetlands, lake and river morphology and ecology are mainly studied by natural scientists, who hardly come in contact with designers, whereas hydraulic engineers traditionally rather learn about conservative approaches to watercourse and wetland adjustment.

In the Czech practice of watercourse revitalisation design one already deals with general shapes and dimensions of near-natural riverbeds in the right way. Greater shortcomings remain in the details, which are essential for the development of a revitalisation and for its persistence in unfavourable situations. This may concern the substrate of the river bottom, important for various aquatic animals, or structures of so-called river wood as a habitat and shelter for biota (also for fish to hide from fish-eating birds). The importance of pools, shallows and temporary floodplain inundation, nor that of passages for natural migration or natural cadences in watercourses, is well appreciated. Timely collaboration during the elaboration of wetland restoration projects with scientists is not yet frequent.

### Problems with restoration project permittance

Water management authorities see revitalisation as a steady, more or less firmly fixed structure in the field. They may find dynamically developing revitalising riverbed something unusual and hard to deal with. A solution can be found in the elaboration of a project which proposes a stream or ri- ver zone, or at least the shape of a wide flood riverbed, as a fixed construction. The project defines limits to riverbed de-

**Fig. 7.** In the waterlogged floodplain of the Jasénka stream near Hlučín, financed from the Landscape Management Programme, several pools of various sizes have been restored in an extensive reed bed. The aim was to increase the number of wetland habitats, which had strongly declined in the past decades by direct elimination or draining. The pools are only filled with groundwater or precipitation. Since they do not contain any fish, amphibians are provided an appropriate environment. (F. Šálek)

velopment, which – according to the operating regulations – should lead the authority to carry out corrections in case the limits are exceeded. Water management authorities should not have problems with approving such a revitalisation concept. It is good to use the possibilities which are provided by the current Water Act, stating that a revitalisation object will not be regarded as a construction, but as a natural riverbed. Correct definition of permissible limits to the spontaneous development of a riverbed in a revitalisation project is also important for setting the conditions of consequent maintenance.

Equally, in the case of creating wetlands, pools or peatbogs, water management authorities try to categorise a restoration project and then demand various more or less needless measures.

## Securing subsequent wetland management

Realising wetland restoration and watercourse revitalisation evokes to a certain extent questions about the subsequent management, which is basically not supported by subsidies. Landowners and investors ask which maintenance will be carried out and how much it will cost. The expenses of maintaining a wetland or a near-natural riverbed or floodplain are in principle lower than e.g. the maintenance of a canalised watercourse.

## Let nature do its work

Every successfully realised wetland restoration or creation project is a plus. Nevertheless, as mentioned above, the total area of wetlands has been reduced to just a quarter in the past century. It is not easy to compensate this decline and it is clear that this cannot be realised before long without broad involvement of landowners. A certain chance is offered by the progress made under the Agri-environmental Programmes, in which registered wetlands enjoy protection from destruction and, conversely, farmers are motivated to preserve them. In any case we need to value enlightened landowners and farmers who restore or create wetlands as part of their work and without subsidies (e.g. forest company Vojenské lesy a statky s.p., Plumlov Dept.) or who tolerate spontaneously restored wetlands (Richter & Belušová 2011, Němec et al. 2012).

Similarly, roughly half of the adjusted watercourses cannot be covered by investments in revitalisation activities alone for their high costs and demands for land. To achieve a really significant improvement on the landscape scale, collaboration with ecologically oriented watercourse authorities is needed. A principal phenomenon which we should learn to work with is spontaneous renaturalisation processes, i.e. changes caused by natural forces which lead technically adjusted riverbeds back to a natural state. Partial processes include disintegration of reinforced embankments, erosion of geometrised riverbeds, riverbeds filling up with sediments or encroaching by vegetation, diversification of the shape and hydraulics of floodplains by trees and shrubs. Changes may be very quick if caused by floods. Watercourse authorities, led by conservative ideas, have however destroyed the results of renaturalisation. Therefore, in order to improve the state of thousands of kilometres of watercourses which have been technically adjusted in a doubtful way, it is protection, utilisation and initiation of processes of spontaneous renaturalisation which are absolutely indispensable (Just 2016).

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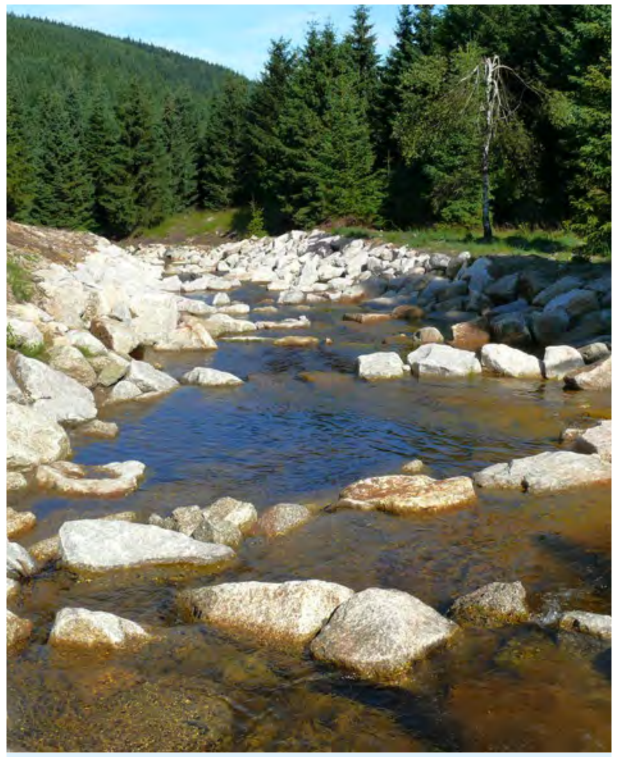


**Fig. 8.** A boulder chute on the Smědá stream in Jizerské hory PLA, completed in 2015, has replaced the former impassable weir of the local limnographic station. (P. Marek)

# Restoration of a drained mire in Šumava National Park

Ivana Bufková & František Stíbal

| | |
|---|---|
| Location | Open valley in upper Zhuřský potok stream (Křemelná), NW part of Šumava National Park, 49°11’10” N, 13°18’55” E; elevation 925 m [name also abbreviated to Zhůří] |
| Conservation status | Šumava NP (Zone I), SAC Šumava |
| Restored area | 31 ha, total of 7.4 km of blocked drainage channels |
| Financial support | Operational Programme Environment; €200 thousand |


## Abstract

Restoration of drained mires has been implemented in the Křemelná basin since 2014. The main restoration methods include damming and filling of drainage ditches and reconstructing natural capillary streams. The impact of the restoration measures on the water table and the hydrochemistry of both underground and surface water has been monitored to evaluate restoration success.


## Site description

Mires in the Zhůřský stream valley are part of a large complex of mires and wetlands in the Křemelná basin, a lower part of the Šumava plains. They represent one of the most valuable areas of the Šumava National Park. These wetlands consist of small ombrotrophic peat bogs with vegetation of low shrubs (*Vaccinium uliginosum*, *Calluna vulgaris*) and expanding graminoids, shrubs and trees at degraded sites, in a diverse mosaic with transitional mires, fen meadows and other types of wet meadows covered by *Deschampsia cespitosa* and rushes (*Juncus* spp.). Dry sites are occupied by *Nardus stricta* and vegetation of mown mountain meadows of the *Polygono-Trisetion* alliance. At the foot of the slopes, spruce mires appear in rather small areas, mostly related to groundwater welling up in the form of many springs.

The entire valley was traditionally farmed until the mid-20th century. Many mown meadows and pastures occurred here. Wetlands were drained by a dense network of shallow ditches. After World War II, the area became part of the Dobrá Voda Military Training Area. The drainage network was deepened, which resulted in ditches of up to 1.5 m deep at many sites (Fig. 1). A number of small tributaries were regulated and then strongly deepened because of spontaneous erosion of the sloping terrain.

The area in the Zhůřský potok valley is important for its species and habitat diversity. It is characterised by the presence of rather nutrient-rich fens, which are relatively rare in the Šumava range. These habitats typically possess a high species diversity and host many endangered and rare species (e.g. *Carex dioica* and *Trichophorum alpinum*) and plant assemblages.

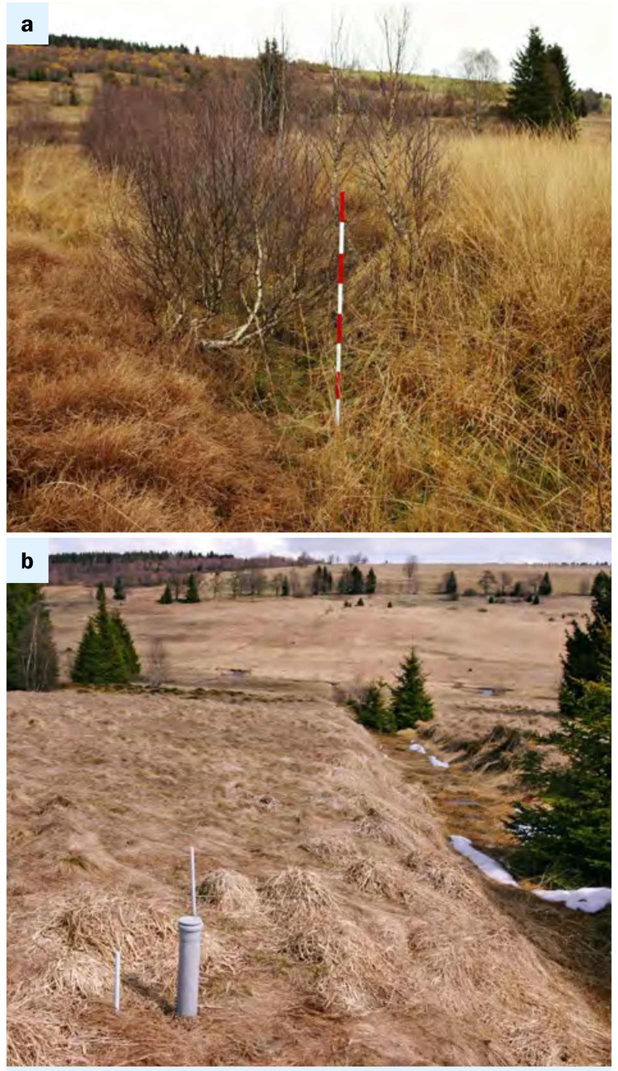



**Fig. 1.** Drainage ditches at Zhůří before restoration. (I. Bufková)

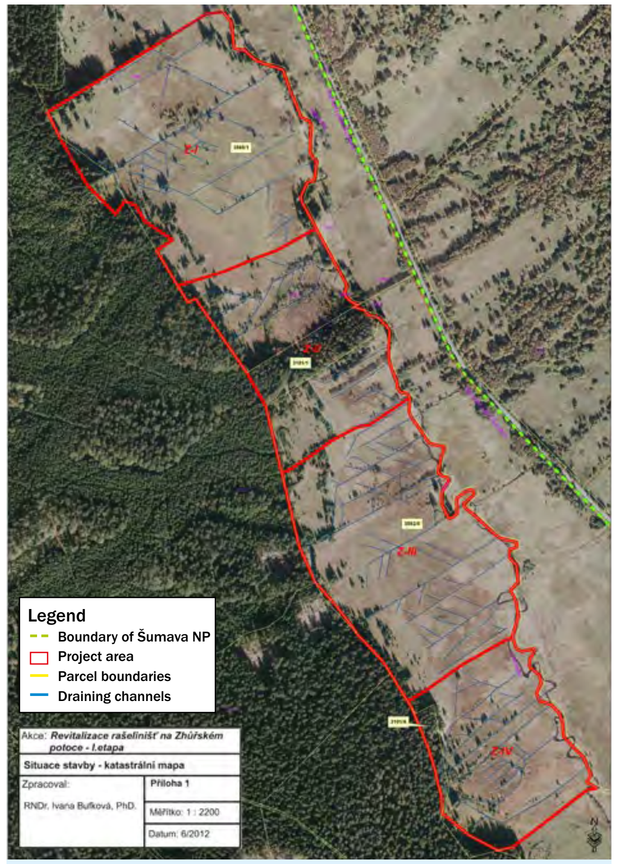



**Fig. 2.** Drainage network at Zhůří, geodetically surveyed and visualised in an orthorectified aerial photograph from the year 2013.

**Fig. 3.** Reconstructed natural course of capillary stream in wetland after restoration. (I. Bufková)

## Initial state

The wetlands were historically drained by a network of open channels with a total length of almost 8 km (Fig. 2), causing a disturbed water regime, reduced peat formation, and degradation of mires, followed by biodiversity loss. Drainage of the mires had caused a drop in the water table, increased its fluctuation amplitude and raised aeration and decomposition of the peat. The lower water table and nutrients released through the higher peat decomposition had led to an expansion of competitively strong species adapted to drier conditions. Peat-forming species (especially *Sphagnum* spp.) had declined, the peat formation process had been suppressed and induced a subsequent degradation or decline of valuable mire ecosystems.

As a result of drainage, three of the four raised bogs located in the area are almost collapsed and one bog is strongly degraded. There is a massive expansion of grasses, especially *Molinia caerulea*, *Nardus stricta* and *Avenella flexuosa*, which can locally reach up to 80% of the total cover. Approximately ¾ of fen meadows and transitional mires are in a severely degraded state. Places where the cover of peat mosses (*Sphagnum* spp.) is reduced to 5%, are common. These degraded minerotrophic fens are mainly overgrown by *Carex brizoides*, *Juncus filiformis* and *Carex nigra*. Drainage has caused a total destabilisation of the water regime, significantly accelerated the outflow of surface water and reduced water retention in the landscape.

The method of drained peatland restoration is based on the concept of a target water table (Bufková et al. 2010), i.e. the level of groundwater that would have been at the site before drainage and corresponds to the situation in intact mires of the same type. The target water table is of course different for various types of mire. For raised bogs, it was set at 5–10 cm below the surface, for transitional mires at 5 cm and for spruce mires at ca 15–20 cm below the surface.

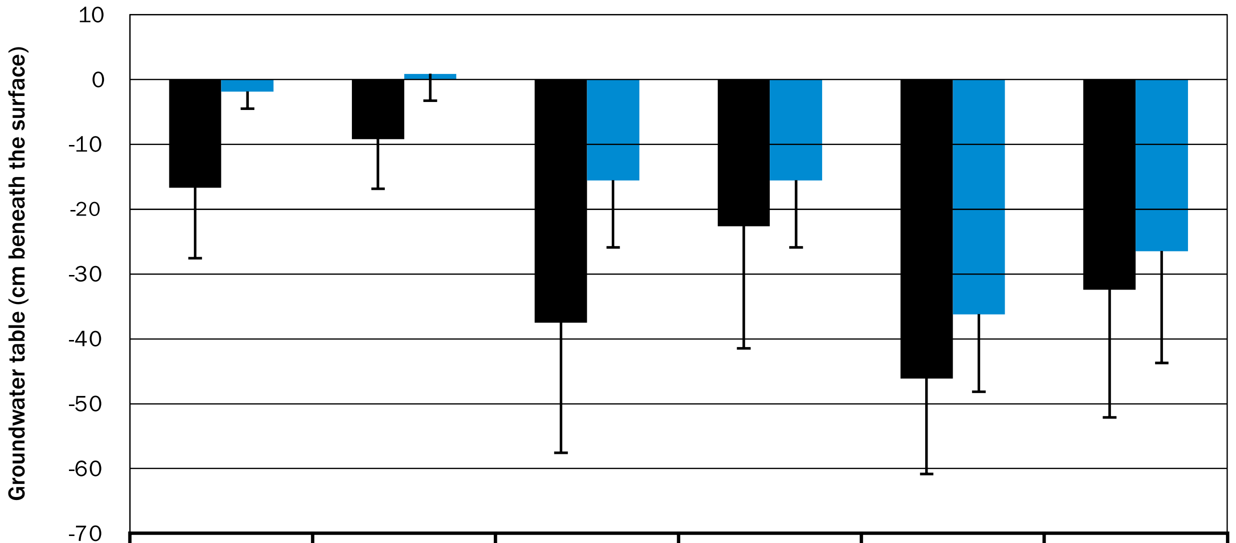
## Restoration objectives

Restoring the natural hydrology and ecological functions of wetlands in the landscape; protecting valuable mire communities and supporting rare species; restoring natural outflows and increased water retention in the landscape.

Regarding hydrology, the main aim of restoration is a water table rise to a level corresponding to the natural (pre-drainage) state and a reduction of water table fluctuation to retain enough water in the mire habitat, especially in critical periods of drought.

Another important aim is the restoration of natural water movement in the wetlands, especially with regard to slope gradient, water infiltration, movement of water just below the surface, and surface outflow in the form of the original small capillary streams.

All measures are aimed at stopping or significantly slowing down degradation processes leading to a positive impact on the re-establishment of peat-forming vegetation and wetland ecology.




| | PR-r | PR-p | V-r | V-p | LR-r | LR-p |
|---|---|---|---|---|---|---|
| ■ 2009-2013 pre | -17 | -9 | -38 | -23 | -46 | -32 |
| ■ 2016 post | -2 | 1 | -16 | -16 | -36 | -27 |

**Fig. 4.** Mean groundwater table in various mires at Zhůří in pre-restoration (2009–2013) and post-restoration (2016) time. V – raised bogs, PR – transitional mires, LR – collapsed fen meadows; r – borehole 1–2 m from the ditch, p – borehole 15 m from the ditch. Numbers of boreholes: PR-r 3, PR-p 3, V-r 4, V-p 4, LR-r 4, LR-p 4.

## Restoration measures

The restoration was implemented in 2014–2015.

The main restoration methods included blocking of drainage ditches by a cascade of wooden dams (Figs. 6 and 8) and in the next step their partial filling with natural material. Values of target water table and surface gradients were key parameters in the determination of the number of dams and their distribution along the various ditch sections. The target water table was determined by the type of mire which the ditch crossed. Waterbodies between dams, particularly in deep sections, were then filled (up to ⅔ of the volume) with peat, soil, branches or fascines. Finally, clusters of peat mosses and sedges were spread to support terrestrialisation of ditches and establish appropriate wetland vegetation. Shallow ditches, especially under good light conditions, usually started to revegetate spontaneously from the banks.

Due to the high vulnerability of restored mire habitats, most measures were carried out manually without the use of heavy machines. Light machines (like excavators weighing up to 1.5 t) were only used in selected, already heavily desiccated and damaged sections.

The restoration project included blocking of a total of 7,371 m of surface drainage channels with a total of 1,200 wooden dams. Fascines made from branches and remnants of peat or soil from the banks and adjacent surroundings were used to fill the blocked channels. Approx. 2000 $m^2$ of expansive shrubs were removed along the ditches. At three sites, surface water was diverted from the drainage channels to the original capillary stream courses or freely to wetlands (Fig. 3). The implemented restoration measures were one-off, aiming at re-establishment of natural conditions inducing a subsequent spontaneous regeneration of target habitats. Subsequent maintenance is not necessary except for some local corrections.

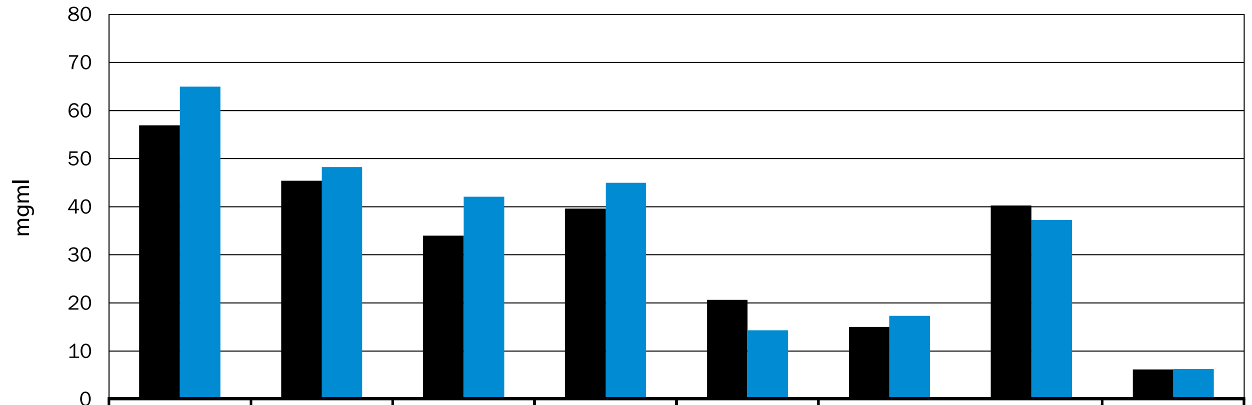
## Monitoring methods

Water table, groundwater hydrochemistry, precipitation, microclimate and vegetation have been monitored at the site since 2009. In total, 26 permanent vegetation plots with adjacent boreholes for recording water table data were established here. Boreholes and permanent plots were installed in the following types of mires: degraded transitional mires (6 boreholes), degraded raised bogs (8 boreholes), collapsed fen meadows (8 boreholes), and collapsed raised bogs (4 boreholes). The boreholes were installed in pairs, one on the bank of the drainage channel (1–2 m from the channel) and one in the mire at ca 15–20 m (perpendicular) from the channel. The water table was measured manually in all boreholes at approximately two-week intervals in 2009–2016 except for the year 2014, from which no data are available. Groundwater samples from selected boreholes (in raised bogs and collapsed fen meadows) and samples of surface water from the Křemelná stream were collected monthly for chemical analysis (measuring concentrations of $SO_4$, $NO_3$, $NH_4$, $PO_4$, Ca, Mg, Al and Fe, pH, electrical conductivity and DOC (amount of dissolved carbon)).

## Results

Fig. 4 shows the average water table in the monitored mire types for pre-restoration (2009–2013) and post-restoration (2016) periods. The restoration years 2014 and 2015, during which the damming was performed and hydrological conditions changed continuously, were not included in the average values. It can be seen from Fig. 4 that the average water table figures after restoration are higher than before restoration in all types of mires. The most significant shifts occurred in degraded transitional mires and degraded raised bogs (especially in boreholes adjacent to the ditch). As expected, the effect of the raised water table near the drainage ditches was greater compared to boreholes at greater distance. Although these data only show the immediate impact just after restoration (first year), the hydrological response of the habitats appeared to be relatively rapid and positive.

The fluctuation of the water table in various types of restored mires over the whole observed period is shown in Fig. 7. The water table well reflects the impact of dry weather in 2013 and, in particular, the extreme drought in 2015. In this year, the water table in raised bogs and fen meadows was at its minimum for the entire monitoring period and in some places dropped to more than 80 cm beneath the soil surface. This is an extreme value particularly for ombrotrophic raised bogs. On the other hand, the water table remained near the




| | V-r | V-p | LR-r | LR-p | PR-n | LR-n | V-n | KREM |
|---|---|---|---|---|---|---|---|---|
| ■ 2009-2013 pre | 57 | 45 | 34 | 40 | 21 | 15 | 40 | 6 |
| ■ 2016 post | 65 | 48 | 42 | 45 | 14 | 17 | 37 | 6 |

**Fig. 5.** Mean values of dissolved organic carbon (DOC) in groundwater of monitored mires at Zhůří, in control mires and in the Křemelná stream in profile below the restored area in pre-restoration (2009–2013) and post-restoration (2016) time. V – raised bog, PR – transitional mire, LR – collapsed fen meadow, KREM – Křemelná stream; r – borehole 1–2 m from the ditch, p – borehole 15 m from the ditch, n – undisturbed control mire.

**Fig. 6.** Dammed drainage ditches at Zhůří after restoration. (I. Bufková)

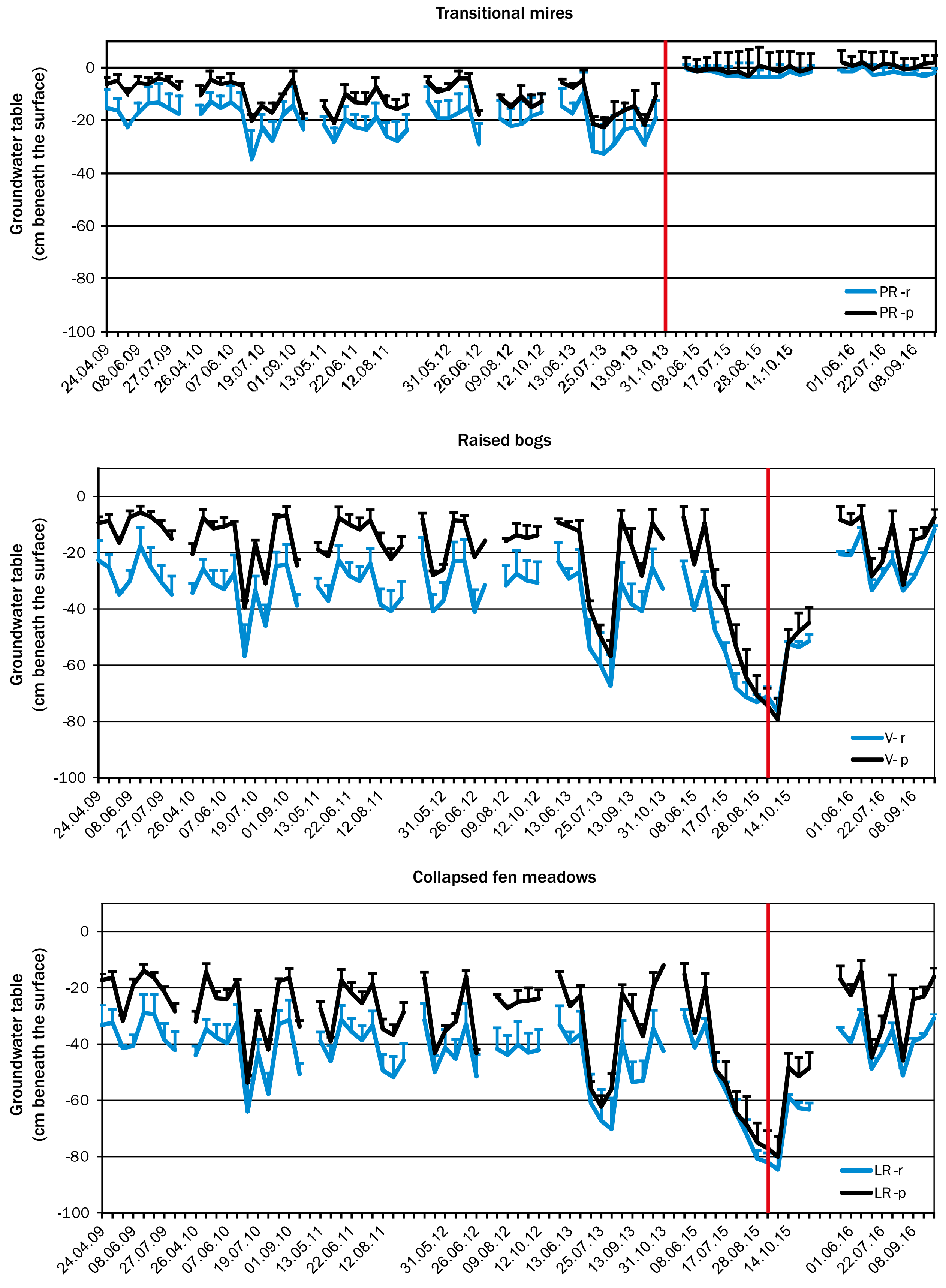



**Fig. 7.** Water table fluctuations in various types of mires at Zhůří during the entire monitoring period (2009–2016). Water table values on the vertical axis are in cm beneath the surface. The red line indicates the date when the restoration work was finished. For captions, see Fig. 4.

surface and very stable in transitional mires (restoration performed in 2014) even in 2015, despite the extreme drought. The hydrological response of the monitored transitional mires to restoration is probably so pronounced because the implemented measures included, in addition to the damming of ditches, also a reconstruction of the small capillary flow, which had been artificially redirected into a channel in the past.

Changes in the chemical composition of the groundwater in mires and the Křemelná stream before and after restoration are interesting, too. For example, the content of dissolved organic carbon (DOC) was slightly higher (a few milligrammes per ml) in raised bogs and fen meadows (Fig. 5) after restoration. The difference between mean DOC values before and after restoration was more pronounced in water samples from boreholes adjacent to the dammed ditches. In the Křemelná stream, however, this slight increase in DOC values was not observed. Higher DOC values were probably due to earthworks in the ditches and some soil disturbances caused during restoration which could not be avoided. These changes represent a typical immediate response of the habitats to the implemented measures and are expected to disappear after a certain period of time. In the future, DOC values after restoration should be lower than during the drainage period.

## New insights and recommendations

The target water table concept has proved to provide an appropriate methodological framework for the restoration of sloping mountain mires at the site studied. The obtained results show an immediate positive hydrological response of the mires to rewetting. A long-term response will only appear after another 5–10 years of measuring. The implemented measures and the monitoring data also show the hydrological importance of the reconstruction of the original capillary streams, formerly directed into drainage channels. Also new and harmless ways of transporting material across the vulnerable surface of mires, using a mobile wooden pathway and lightweight machines have been tested.


## Acknowledgements

This contribution was supported by the Programme of Transboundary Collaboration Czech Republic – Free State of Bavaria, Goal EÚS 2014–2020 (Project 26).


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**Fig. 8.** Blocked draining channel after restoration. (I. Bufkova)

# Restoration of an extracted peatbog – reintroduction of two target species

Ludmila Vlková & Karel Prach

| | |
|---|---|
| Location  | Šumava, part of Vltavský luh wetland and peatbog complex, 48°54'45" N, 13°49'33" E; elevation 745 m |
| Conservation status | NP Zone III, SAC |
| Restored area | 53 ha |
| Financial support | ME Landscape Management and Restoration Programmes, budgets of Šumava NP and PLA Authorities (restoration); Czech Science Foundation project P505/11/0256 (partly covering species reintroduction) |

## Abstract

The peatbog species *Andromeda polifolia* and *Vaccinium oxycoccos* were experimentally sown and planted in Soumarský most peatbog in the Šumava NP, formerly industrially exploited but revitalised since 2000. Both species used to occur here formerly, but did not re-establish spontaneously. The results showed that sowing as well as transplanting relevant target species may locally contribute to the restoration of peatbog vegetation. Transplantation of vegetative parts is more effective than seeding, and moisture is decisive for establishment and growth of both species.

## Site description

Soumarský most is a degraded raised bog with a total area of 90 ha, situated in a valley. The original dominant vegetation of the central part of the bog used to be bog pine forests belonging to the *Pino rotundatae-Sphagnetum* association of the *Oxycocco-Sphagnetea* class (Zýval 2000), which has been preserved in a small unexploited area. In the first half of the 20th century its north-western part was exploited in the form of turf digging (15 ha). In the 1970s, large-scale industrial mining by means of so-called milling was initiated on an area of 53 ha. The peatbog was thus drained to a great depth and its original vegetation removed. During the 1990s, the exploitation was gradually slowed down and in 2000 stopped with the consent of the Šumava NP and PLA Authority (Horn 2009). The process of restoration until 2011 was described by Horn and Bastl (2012).

## Initial state

The first stage of the restoration project was carried out in the years 2000–2004. The main measure was raising the groundwater level by means of a system of wooden dams blocking draining channels. As a result, extensive inundated areas were gradually created and these were successfully colonised by vascular plant and moss species of wetlands, mainly peat mosses (*Sphagnum* spp.). In order to accelerate the colonisation of exposed areas in the peat bog, *Carex rostrata* and *Eriophorum angustifolium* were locally planted. Within a few years these plants colonised a large area of wet depressions. Further, fragments of the mosses *Sphagnum flexuosum* agg. and *S. cuspidatum* agg. (Horn 2009; Horn & Bastl 2012) were spread over the area; these also established well. Another important measure was depositing mulch layers from the surrounding minerotrophic peat bogs on bare peat in order to prevent the surface from desiccating and to improve conditions for bryophyte and vascular plant diaspores to germinate. The most successful (spontaneous) colonist of exposed peat was *Eriophorum vaginatum* (see Fig. 1).

**Fig. 1.** *Eriophorum vaginatum* is the most successful colonist of the extracted peat bog. (L. Vlková)

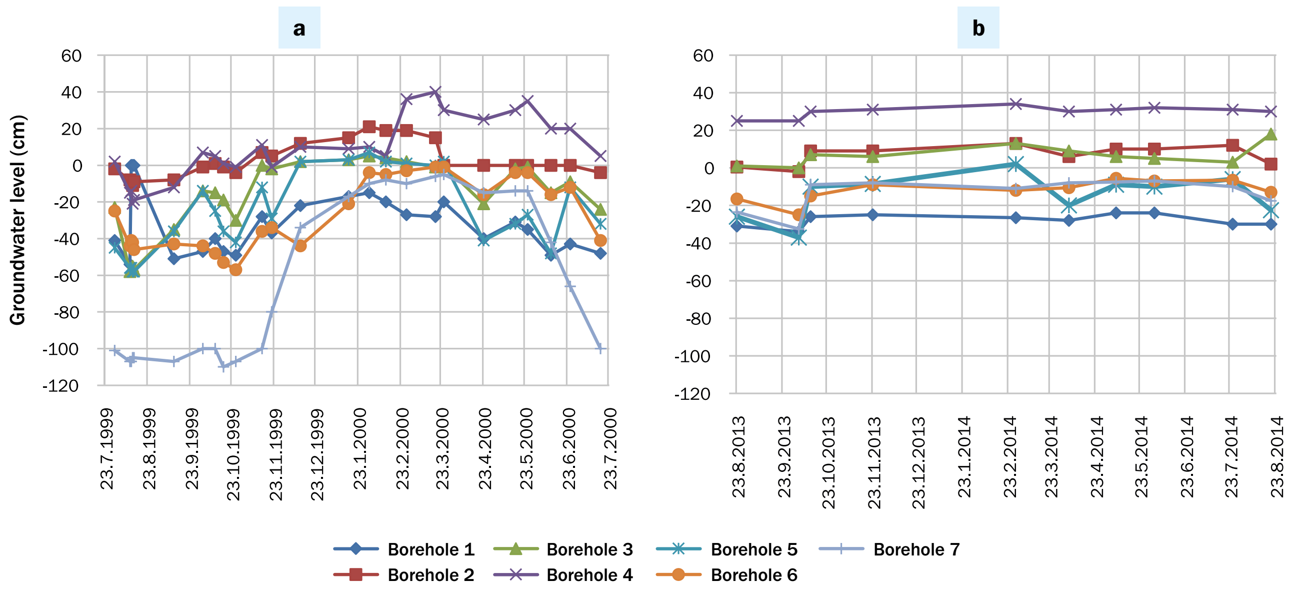


**Fig. 2.** Comparison of annual fluctuations in groundwater level for the same boreholes (Nos. 1–7) before (a) (Zýval et al. 2000) and after (b) peat bog restoration. Symbols indicate different measurements. (Note: in both compared periods measuring was performed only for some boreholes.)

In 2007, approximately 50% of the restored area was covered with vegetation, a total of 40% was taken in by bare peat and the remainder by surface water. In five years' time, peat moss cover increased from 1–2% to 8%. Drier places were mainly colonised by the trees *Betula pubescens*, *B. pendula* and *Pinus sylvestris*. In 2016, an estimated 70% of the area was covered with vegetation. The restoration process to date has shown that peat bog vegetation can be restored after raising the groundwater level, but the habitat lacks some typical peat bog species, e.g. *Vaccinium oxycoccos* and *Andromeda polifolia*, which grow predominantly in closed peat moss vegetation. Both species were selected for an experiment, since they are suitable for transfer thanks to their vegetative spreading and the relatively easy collection of their seeds.

## Restoration objectives

The aim of experimental planting and sowing of two typical bog species was to verify whether their absence hitherto is the result of inappropriate environmental factors (habitat limitation) or if the diaspores of the respective species have just not reached the site (dispersal limitation).

## Monitoring objectives

Determining if targeted sowings or plantings can accelerate the process of peat bog regeneration in a restored peat bog, at the same time assessing changes in water regime and vegetation connected with it.

## Measures applied and monitoring methods

Shoots and seeds of *Vaccinium oxycoccos* and *Andromeda polifolia* were transferred to 25 sites. At each site, boreholes were installed and the groundwater level was measured in approximately monthly intervals in the years 2011–2015. Survival of the plants was monitored mainly on the groundwater level gradient, but also temperature, soil moisture, pH and water conductivity were measured and the approximate depth of remaining peat was determined in the vicinity of the boreholes. Simultaneously the vegetation in the vicinity of the boreholes was recorded by means of phytosociological relevés (in 2 × 2 m plots in the years 2011 and 2015).

## Results

When comparing water levels before and after peat bog restoration, the hydrological regime was shown to have stabilised after restoration measures (Fig. 2). This was confirmed by calculations of the standard deviation of groundwater level fluctuations. The strongest fluctuations were recorded before restoration, while the water level fluctuation after peat bog restoration approached that of the nearby unexploited Malá niva peat bog.

The main environmental factor determining the restoration process as well as the establishment and survival of species is the groundwater level. Depending on water level but partly also pH and depth of remaining peat, typical plant communities develop, creating a mosaic of different types of environment in the restored peat bog (participating species are evident from Fig. 4). The successional changes are however slower than we had expected. The repeated relevés do not show any unambiguous and unidirectional change after four years, but just an indication of certain differentiation in the vegetation towards the drier and to the wetter end of the gradient.

The survival of both transplanted species mainly depends on the groundwater level (Fig. 3). *Andromeda* was more successful than *Vaccinium*, because it is probably able to adapt to water stress better. Seed germination and thus generative establishment of both species was always relatively low, even though the former was tested under various conditions. Transplantation and sowing experiments demonstrated that both species germinate and survive at the following ground-

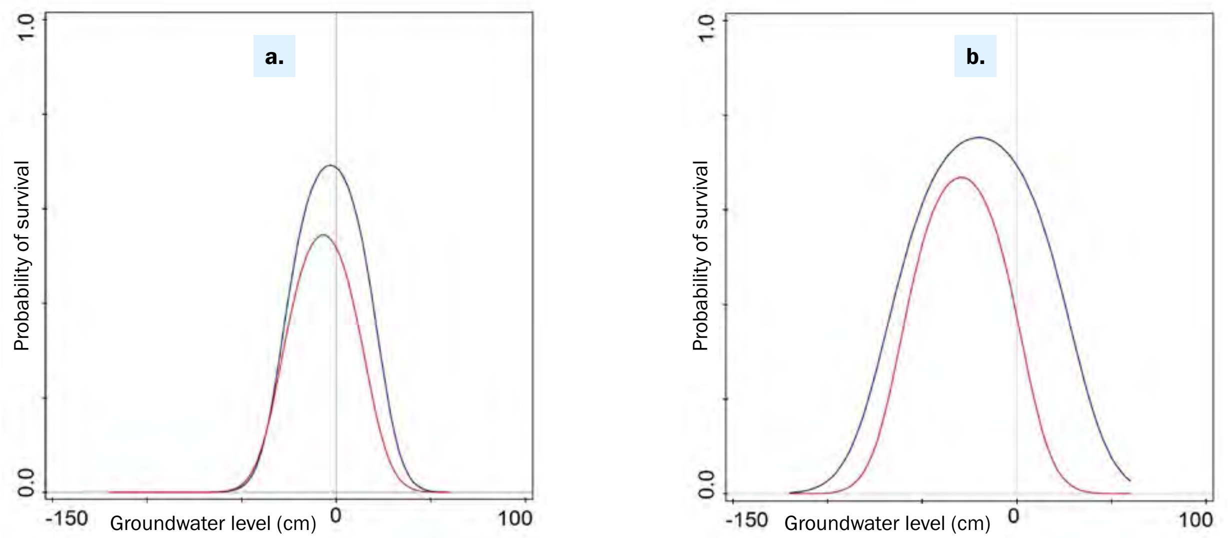


**Fig. 3.** Comparison of the survival of planted *Vaccinium oxycoccos* (a) and *Andromeda polifolia* (b) on groundwater level gradient a year after planting (blue: *Vaccinium* in summer 2012, *Andromeda* in summer 2013) and in the year 2015 (red) using the method of generalised linear models.

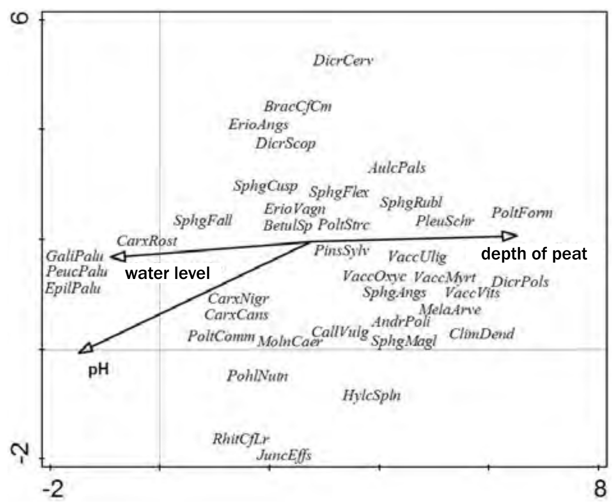


**Fig. 4.** DCA ordination of species recorded in 2015 with passively projected environmental variables. Species abbreviations are generally composed of the first four letters of the genus and the species name. The groundwater level rises with declining peat depth. Minerotrophic sites (having a higher pH, high water level and a shallow peat layer) are represented by e.g. *Carex rostrata*, *Peucedanum palustre* and *Galium palustre*. On the other hand, at sites with a low pH and a deeper remaining peat layer (unexploited bog margins) *Vaccinium vitis-idaea*, *V. oxycoccos*, *V. myrtillus* and *V. uliginosum* typically grow.

water level optima: *Andromeda polifolia* at −29.4 cm, *Vaccinium oxycoccos* at −6.9 cm (Vlková 2016). The strongest reduction in seedling survival was found in the summertime, when many plants on peat and in sphagnum dried up.

## New insights and recommendations

It is better to use adult plants (shoots) than their seeds to spread both species to a restored area. Logically, shoots have a lower mortality. A large amount of seed is needed to achieve a vital population. The described experiment has shown that sowing as well as transplanting target species may locally contribute to restoration of peat bog vegetation. However, the plants grow and survive only at a certain groundwater level optimum. It has been demonstrated that both species can grow in suitable habitats as well as in extracted and then restored peat bogs if their diaspores reach them – in other words, their absence hitherto is explained by dispersal limitation.

## Acknowledgements

The project was partly supported by grant GA ČR 31-19-15031S.

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# Restoration of rich-fen bryophyte populations

Ester Ekrtová, Eva Holá, Jan Košnar & Táňa Štechová

| | |
|---|---|
| Location | South-western and central part of Vysočina Region, 49°15'–49°27' N, 15°16'–15°27' E; elevation 575–665 m |
| Conservation status | NM, NR (6 sites), SAC (3 sites) |
| Restored area | Ca 1.5 ha |
| Financial support | Operational Programme Environment, Vysočina Region; €15,000 |

## Abstract

A project of restoring populations of rare rich-fen bryophytes in the Vysočina area was aimed at supporting microstructures of rich-fens in which rare bryophyte species occur. Mosaic sod-cutting and moss layer removal were performed in order to restore minor waterlogged depressions in areas as affected by expansion of competitively stronger wetland bryophytes or having very dense vascular plant vegetation in the most valuable part of the sites. The treatments were monitored by means of permanent plots measuring 1 × 1 m. The obtained data unequivocally showed that the performed measures had an impact on the structure and species composition of the moss layer. In most cases the number of bryophyte species in the monitored plots increased. A decline in strong acidophilous competitors was recorded. In a range of plots, the frequency of target bryophyte species increased. Also a number of important vascular plant species reacted positively.

## Initial state

Bryophytes are an integral and essential part of wetlands, where they prevail in quantity of biomass and often daringly compete with vascular plants in number of species. The species composition of the moss layer and the frequencies of the species in it are to a great extent determined by character, quality and preservedness of the wetland sites. Bryophytes namely react to only small environmental changes, like disturbance of hydrological conditions, chemical changes, changes in land use and subsequent succession, in a sensitive way. The presence of rare bryophytes in rich fens fully guarantees the occurrence of rare vascular plants, however the reverse is not true. We can often find a rich fen with a number of large populations of important vascular plants but a moss layer formed by just a few common species. If we investigate the history of such sites, we find that they were affected by a number of negative factors, partly resisted by the herb layer but not by the bryophytes. Rare bryophytes are namely competitively very weak species. Their most important competitors are not only vascular plants, but often also other bryophyte species, particularly some common sphagnum species like *Sphagnum teres*, *S. flexuosum* and *S. palustre*.

Due to their low competitiveness, occurrence of rare bryophytes depends on periodical mechanical disturbances of particular rich-fen sites. By disturbance, the fine mosaic of wetter and drier patches with open vegetation is repeatedly recreated. Rich fens then become a network of small gullets and open waterlogged springs. This structure used to be maintained by the traditional exploitation of wetlands, but its decline in the second half of the 20th century led to a dramatic change in the quality of wetland sites. The hay from litter meadows always contained a significant portion of moss thanks to the mowing and careful raking as men-

**Fig. 1.** Final stage of performed treatments in 2013 (deepening of restored waterlogged patches by means of rakes with steel teeth). The mosaically performed work in the most valuable part of Na Oklice NR was concentrated in places of nearly vanished open springs. (V. Kodet)


**Fig. 2.** Monitoring of effects of treatments at Chvojnov NR. (a) **October 2013.** Small part of cleaned, long-time unmown terrestrial reed bed, where all litter was raked up. The plot on the left was mown and raked and is much more waterlogged than the part which was only mown (on the right), although it was mown carefully. (b) **July 2014.** Waterlogged part of reed bed mulched with moss layer obtained from preserved part of the same site by small-scale sod cutting as part of treatments to support rare bryophytes. (c) **September 2014.** The moss layer is regenerating well. (d) **May 2015.** *Pedicularis palustris* regenerating massively from diaspores present in the mulch. A varied rich-fen is restoring, while the abundant hemiparasite *Pedicularis palustris* is strongly reducing the vitality and cover of the initially dominant reed. Plots without mulch only regenerate very limitedly and are formed by open, strongly waterlogged reed beds. (L. Ekrt, E. Ekrtová)

tioned below. In dry parts of the year, fen sites were occasionally also grazed. Plain mowing, which is today the most frequent type of conservation management of valuable rich-fen vegetation, mostly fails in disturbing the surface of the moss layer, causing a loss of small-scale heterogeneity. If we want to preserve a population of rare and threatened species, it is necessary to carry out special measures which simulate the former mosaic disturbance (as in traditional management) and natural dynamics of these communities.

For the presented project, the most important rich fens in the Vysočina Region were selected: Chvojnov NR, Jezdovické rašeliniště NM, Rašeliniště Kaliště NR, V Lisovech NR (SAC), Šimanovské rašeliniště NR (SAC) and Na Oklice NR (SAC). These are rich fens with mainly communities of the *Sphagno warnstorfii-Tomentypnion nitentis* and *Caricion canescenti-nigrae* alliances. Although these sites had been regularly mown for a number of years, the populations of significant bryophytes stagnated and some species were at the brink of extinction. Also the populations of some competitively weak vascular plant species were very small and their decline could not be stopped despite regular maintenance.

## Restoration objectives

Restoring the heterogeneous structure of sites with the most valuable sedge-moss communities and supporting populations of rare bryophyte species.

## Restoration measures

Before the treatment, plots in the most valuable parts of the sites close to the last remnants of rare bryophytes were selected. Target species included particular representatives of so-called brown mosses, e.g. *Messia triquetra*, *Hamatocaulis vernicosus*, *Calliergon giganteum*, *Campylium stellatum*, *Tomentypnum nitens*, and rare sphagnum species, e.g. *Sphagnum obtusum*, *S. contortum* and *S. platyphyllum*. The treatment was to create small open waterlogged microhabitats, which could be recolonised by not only rare and competitively weak bryophytes but also strong although declining vascular plant species. Therefore, places with at least partly noticeable remains of shallow channels and waterlogged depressions were selected: either places with dominating expansive sphagnum species or plots with very dense vascular plant vegetation. The size of one treatment plot varied from 2 to 25 m². The number of plots depended on the acreage of the site and the area of preserved rich-fen vegetation. The treatments covered 5–15 % of these areas on average.

Before realisation of the measure, places with the most significant bryophyte, vascular plant and mushroom species were marked with wooden pegs, so that they would not be eliminated in the treatment. The treatment itself was carried out by means of short hand scythes, with which the plots were first mown as close to the soil surface as possible. By cutting the sod or moss carpet, shallow depressions were created. Thinning of the moss layer and, where applicable, deepening of the depressions were carried out using rakes with steel teeth. Conspicuous mounds were cut with a hoe. The measures were always carried out in a mosaic way to create higher spots with islets of original vegetation as well as lower places with a perfectly removed moss layer (Fig. 1). Where possible, the biomass obtained from moss removal at species-rich sites was used to restore strongly degraded sites prepared in advance (Fig. 2b).

## Monitoring methods

A total of 31 permanent quadrats 1 × 1 m in size were established in the selected plots. Before the treatment, relevés of the moss layer were made in the quadrats and micromaps were drawn of the location of particular bryophytes (Fig. 3). This was repeated 3–4 months after the treatment (summer – autumn 2014) and in the spring and summer time of the following year (2015). For organisational reasons no exact record was made of the composition of the herb layer before the treatment, but the development of the herb layer after it was documented with a relevé and detailed notes on the occurrence of significant vascular plant species, also outside of the fixed quadrats.

## Results

The data obtained to date clearly shows that the treatments have had significant impact on structure and composition of the moss layer. In most permanent quadrats, the number of bryophyte species increased immediately after the treatment (see Fig. 4). New, especially competitively weak species appeared, which had apparently survived under the prevailing sphagnum moss layer but rapidly regenerated after removal of the sphagnum species. These were common species like *Calliergonella cuspidata* and *Straminergon stramineum* as well as less common species like *Pseudocampylium radicale* and *Plagiomnium elatum*. In some plots even the rare species *Hamatocaulis vernicosus*, *Calliergon giganteum* and *Campylium stellatum* appeared.

The frequency of various species monitored in the quadrats before (spring 2014) and after the treatment (summer 2015) changed significantly in favour of the target species (Fig. 5). This trend was clear in the case of e.g. *Philonotis caespitosa*, *Plagiomnium elatum* and *Pseudocampylium radicale*. Their massive occurrence is associated with relatively early successional stages in which they colonise newly created waterlogged plots quickly, but later most of them are replaced by other bryophytes. In a number of quadrats however also the cover of rarer species increased considerably. This concerns e.g. *Sphagnum contortum* and 'brown mosses' *Hamatocaulis vernicosus*, *Calliergon giganteum* and *Campylium stellatum*, which colonise permanently wet terrain depressions. Also the species *Tomentypnum nitens* and *Breidleria pratensis*, which often occur in partly wet microhabitats at the boundary between hummocks and hollows, showed a distinct increase.

A decline was recorded for strong acidophilous competitors, particularly *Sphagnum flexuosum* and *S. palustre*, which is explained by the fact that these species formed the highest percentage of biomass removed in the treatments. The reaction of *Sphagnum teres*, also forming a considerable part of the removed biomass, is interesting. Its cover decreased in a number of quadrats after treatment, but in some of them this peat moss replaced the initially dominating *Sphagnum flexuosum*. Another distinctly declining group of species was formed by common hummock mosses, e.g. *Polytrichum*

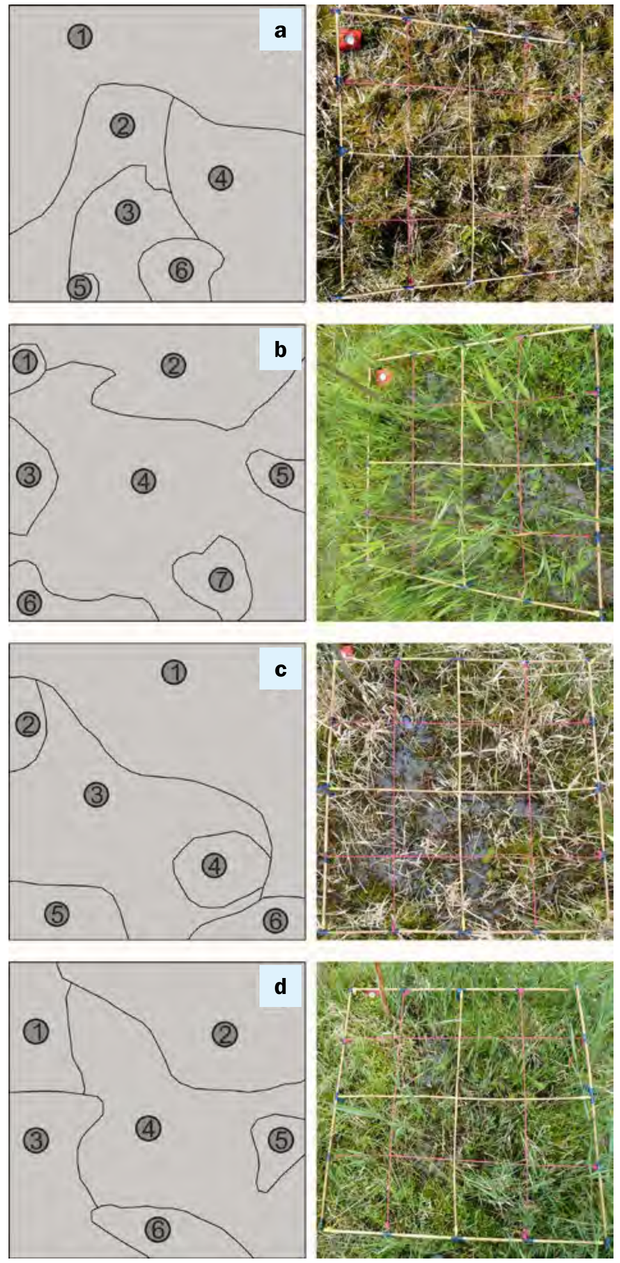


**Fig. 3.** Examples of micromaps of the moss layer in permanent plot Chvojnov 4; (a) before treatment, spring 2014. After treatment: (b) summer 2014, (c) spring 2015, (d) summer 2015. For a detailed description of micromaps, see Tab. 1. (E. Holá)

**Tab. 1.** Cover of bryophytes in different quadrats (A, B, C, D), see Fig. 3. The increase in cover of *Hamatocaulis vernicosus* is well visible.

| | Quadrat segments | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | | | | | B | | | | | | | C | | | | | | D | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| *Bryum pseudotriquetrum* | . | 3 | 10 | 30 | . | 90 | . | . | . | . | 5 | . | 80 | 20 | . | 1 | 80 | 30 | 70 | . | . | 30 | 5 | . | . |
| *Calliergon cordifolium* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | . | . | . |
| *Calliergonella cuspidata* | . | 3 | 20 | 30 | . | 10 | . | . | . | . | . | . | . | 20 | . | . | 3 | . | 10 | . | 60 | 10 | 3 | . | . |
| *Hamatocaulis vernicosus* | . | r | . | r | 30 | . | . | + | r | r | 3 | + | 5 | 3 | . | . | 10 | 40 | 3 | . | 5 | 5 | + | 90 | 90 |
| *Plagiomnium elatum* | . | . | . | . | . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | . | . | 3 | . | . | . | . |
| *Sphagnum teres* | 95 | . | 40 | . | . | . | 1 | 5 | 60 | 1 | . | 1 | 1 | 5 | 60 | . | . | . | . | 80 | . | . | 1 | r | . |
| *Straminergon stramineum* | 5 | 90 | 5 | 30 | . | . | 80 | . | . | . | . | . | . | . | 5 | . | . | . | . | 5 | 1 | 10 | . | . | . |

*commune*, *P. strictum* and *Aulacomnium palustre*. Partial reduction was also recorded for the relatively rare species *Dicranum bonjeanii*, which rather colonises drier and higher microhabitats as well. However, this species often spread to marginal parts of the sites outside the permanent plots, where it benefited strongly from scrub cutting, so its populations at the sites were not threatened by the treatments.

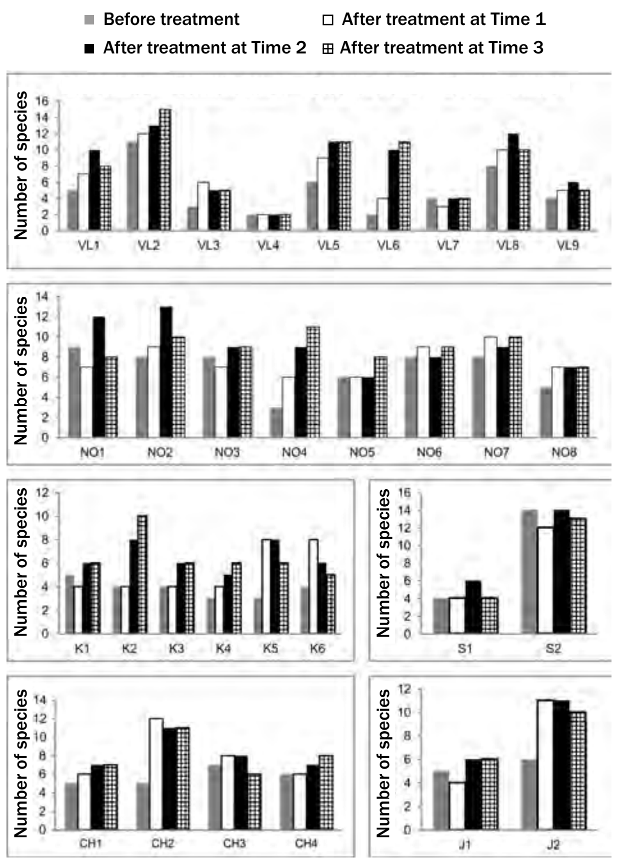


**Fig. 4.** Numbers of species recorded at the different sites (VL – V Lisovech, NO – Na Oklice, K – Rašeliniště Kaliště, S – Šimanovské rašeliniště, CH – Chvojnov, J – Jezdovické rašeliniště) before (spring 2014) and after treatment in summer 2014 (Time 1), spring 2015 (Time 2) and summer 2015 (Time 3).

Significant results of the project were also reached outside the permanent monitoring plots. Thanks to the treatment in Rašeliniště Kaliště NR, the local population of the critically threatened moss *Meesia triquetra* was restored after more than 50 years. Soon after a compact sphagnum layer had been removed, ca 40 stems of this moss were discovered. Two years later, the population already consisted of 100 stems (Fig. 6).

The positive effects of the treatments on a range of vascular plants were surprising. As expected, competitively weak species of open, waterlogged patches were supported, e.g. *Triglochin palustris*, *Utricularia minor*, *Drosera rotundifolia*, *Eleocharis quinqueflora* and *Pedicularis palustris* (Fig. 7). The positive reaction of *Carex limosa* to the treatments, at several sites creating nearly subdominant populations from initially sporadic stems, was also interesting. Further, populations of *Trichophorum alpinum*, *Eriophorum latifolium* and *Carex pulicaris* regenerated well. In Chvojnov NR, thanks to a reduction of the deep sphagnum layer, a large *Epipactis palustris* population, which had been missing here for several years, was regenerated.

The use of removed moss biomass in the regeneration of strongly degraded plots at the sites had a completely unexpected success. After spreading it on terrestrial reed beds and filled draining races prepared by mowing and removing old biomass, fen vegetation immediately regenerated, including a range of significant plant species (Fig. 2).

## New insights and recommendations

The performed treatments have had a very positive influence not only on the moss layer composition, but also on the fen vegetation structure as a whole. We managed to restore the fine microstructure of wetland communities, which are not only important for rare, competitively weak bryophytes and vascular plants, but also create habitats for a number of significant animal species.

Based on our experience with this pilot project, several general recommendations can be formulated:

- Treatments must be carried out by experts or personally supervised by them.
- For maximum effectivity, treatments need to be located in the immediate proximity of standing target species populations. Their extent should vary from 2 to 25 m².

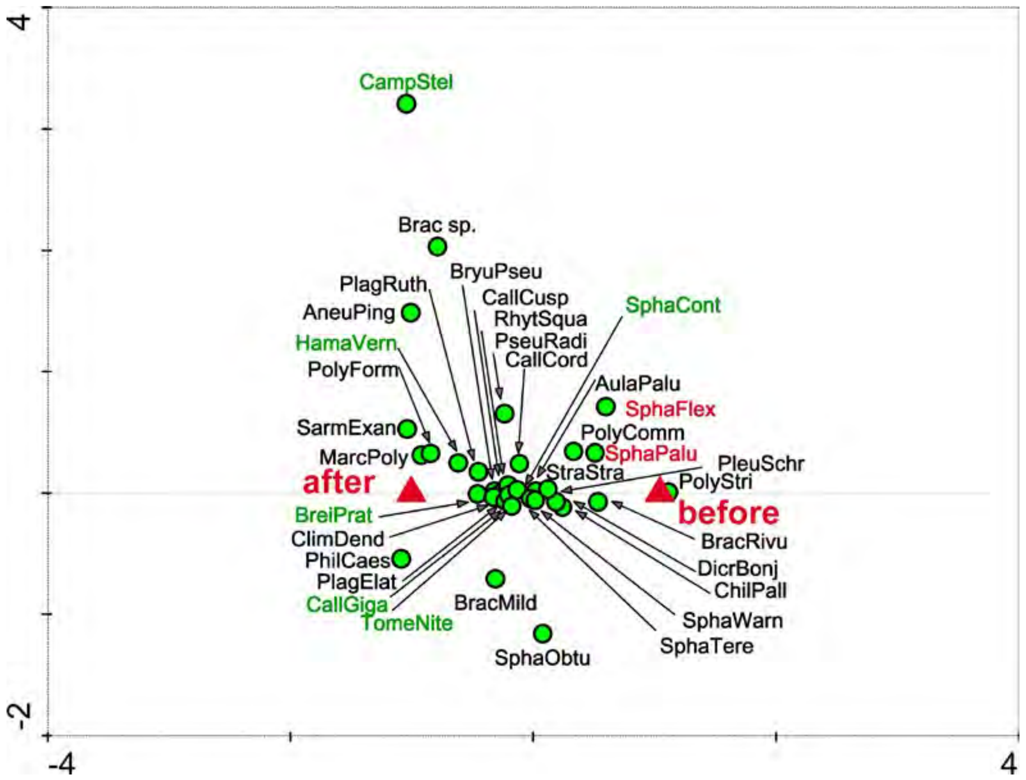


**Fig. 5.** Ordination diagram illustrating changes in species composition of the plots before (spring 2014) and after treatment in summer 2015 (Time 3) – CCA: F = 2.7; p = 0.002. Treatments limited the growth/cover of strong acidophilous competitors (*Sphagnum flexuosum*, *S. palustre* – species indicated in red) and raised the cover of rarer species (*Breidleria pratensis*, *Campylium stellatum*, *Calliergon giganteum*, *Hamatocaulis vernicosus*, *Sphagnum contortum*, *Tomentypnum nitens* – species indicated in green)

- When realising a measure with the aim of restoring the heterogeneity of fen communities, possible conflicts with other designated species (e.g. insects, molluscs, birds) must always be minimalised in advance.
- It is good to carry treatments out gradually, in one- to three-year periods depending on the state of a site, always in just a small part of the most valuable plots.
- It is desirable to concentrate the work outside the bird nesting season (especially if the treatments are large-scale) and in wetter times of the year. In a dry period, it is harder to estimate the depth of the treatment. In dry weather, target bryophyte species regenerate badly.
- When planning a treatment, it is good to select and prepare a plot for mulch deposition in the surrounding degraded vegetation in advance (mowing, thorough raking and removing of old biomass, in some cases cutting of the sod down to the humolithic layer). It is valuable material which can be used for very effective regeneration of strongly degraded sites.

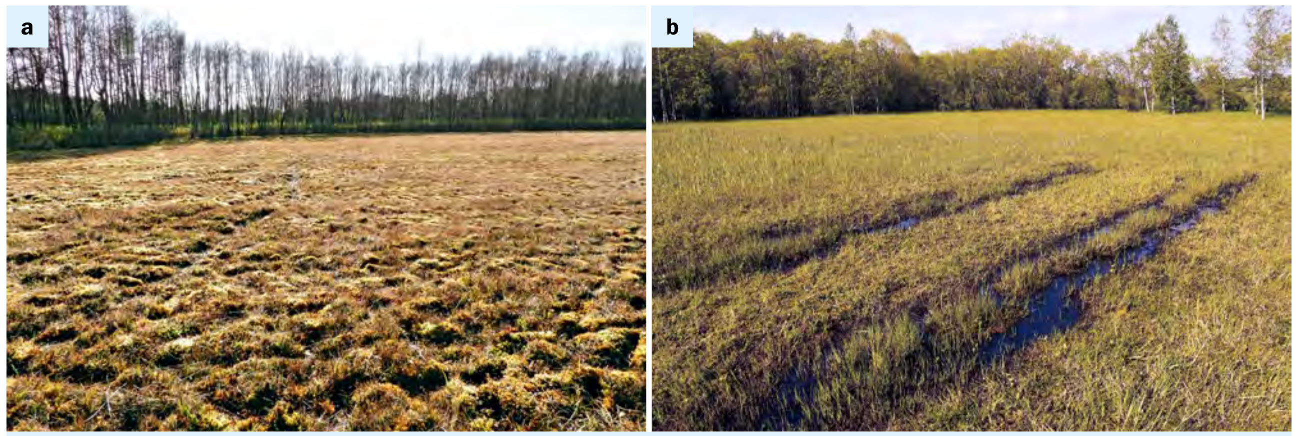


**Fig. 6.** Rašeliniště Kaliště NR: (a) compact bryophyte vegetation with prevailing peat mosses before treatment, (b) state of the area after local removal of bryophytes in places of nearly vanished waterlogged depressions. After the operation, *Meesia triquetra*, not found here for decades and regarded to be extinct, started to regenerate spontaneously. (V. Kodet, L. Ekrt)


**Fig. 7.** Plots in the most valuable part of Na Oklice NR: (a) immediately after sod cutting, (b) two months after treatment. The operation did not disturb valuable vegetation and important plant species unwantedly. On the contrary in closed sedge vegetation, open waterlogged patches were created, significantly increasing the heterogeneity of the site. *Triglochin palustris* is becoming a subdominant plant in the vegetation, while *Pedicularis palustris* and *Parnassia palustris* are richly regenerating. *Utricularia minor* is appearing in the wettest patches. (E. Ekrtová)

**Fig. 8.** V Lisovech NR. Terrain microstructure restored in a mosaic way by means of small waterlogged depressions in rich-fen vegetation. (L. Ekrt 2014)

## Acknowledgements

We thank all those who made the realisation of this relatively innovative activity possible, in particular J. Janová, A. Hofhanzl and V. Kodet, who were responsible for financially covering all the work, and F. Lysák for inspiring us to test similar treatments. Our greatest thanks go out to M. Brom, who conceived and realised the treatments with great accuracy, personal inventiveness and practical commitment.

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# Horse grazing as a way of restoring inland salt marshes

Jiří Kmet, František Foltýn & Helena Prokešová

| | |
|---|---|
| Location | Milovicko-valtická pahorkatina, Slanisko u Nesytu NNR; elevation 176 m |
| Conservation status | PLA, NNR |
| Restored area | 9.06 ha |
| Financial support | ME Landscape Management and Restoration Programmes |

## Abstract

Slanisko u Nesytu is the richest site of halophilous flora and fauna in the Czech Republic. Until 2009 the maintenance of the site was restricted to mechanical mowing and occasional low-intensity grazing. In the past eight years grazing intensity has been increased. In 2015, intensive rotational horse grazing was introduced at the site, which meant a distinct turning-point in the maintenance history of this salt marsh, leading to an increase in halophyte abundance and species diversity.

## Site description

The saline meadows around Nesyt pond used to be grazed in the past (Zimmermann 1916, Fröhlich 1935 in Danihelka 2005). Although the high concentration of dissoluble salts in the soil and waterlogging in spring made it impossible to grow cereals here, attempts to convert drier parts of the salt marsh to arable land emerged in the 1930s (Zapletálek 1939). These attempts were unsuccessful, apparently as a result of frequent inundations and dependence of the groundwater level on the water regime of the Lednické rybníky lakes. Nevertheless, some higher situated, drier parts of the reserve were cultivated in that time. In the eastern part, remains of a lucerne (*Medicago sativa*) culture persisted until the 1990s (Danihelka 2005).

The salt marshes were intensively used as pastures and probably also mown once annually even after World War II. However, while a large flock of domestic geese grazed on the salt marsh in the 1960s, it was not grazed anymore in the 1970s (V. Grulich in verb. in Danihelka 2005). Nature conservation measures in that time consisted in deepening the rills in the western part and clearing out a large square depression in the eastern part. These terrain depressions were to serve as a refuge for the most demanding halophytic species. This did not work, as the depressions were gradually overgrown by reed, a reason why they were later levelled with the soil surface, enabling at least mechanical mowing of the site.

Abandonment of reserve maintenance in the 1970s and 1980s was probably one of the reasons why the most critical obligate halophytes *Salicornia prostrata* and *Suaeda prostrata* disappeared. However, also a drop in groundwater level probably played a role here, as well as gradual desalination of the soil due to a decrease in salt concentrations in the water of Nesyt pond, into which water started flowing through irrigation channels from the Dyje river after completion of the upper reservoir of the Nové Mlýny lake complex (Danihelka & Hanušová 1995).

After 1990, the site was yearly mown manually or mechanically (once or twice) and terrain adjustments (sod-cutting, rill deepening) were carried out here. In 2000, the reserve was grazed by a mixed herd of sheep and several goats for the

**Fig. 1.** Horses are transferred between the enclosures in approximately two-week intervals. During the grazing, permanent enclosures are combined with electric fences. (J. Kmet)

first time in many years. As the grazing took place in summer, the grassland was not disturbed as desired, but at least the degradation of the area by encroaching reed beds was brought to a stop. This rotational management, consisting in a combination of mechanical mowing and sheep and goat grazing, continued until 2008.

## Initial state

The described maintenance unfortunately made the grassland denser and denser, so that the most sensitive halophytes concentrated in artificially deepened rills or sporadically maintained themselves on a field road and in its margins. Larger areas without dense vegetation were totally missing. In a great part of the salt marsh, common reed (*Phragmites australis*) dominated and the shores of Nesyt pond were completely separated from the salt marsh by a dense reed ridge. Permanent surface waters were lacking in the area.

## Restoration objectives

Supporting rare halophilous plant species associated with strongly disturbed places and exposed bottoms. Securing better conditions for hitherto surviving halophilous plants and creating a suitable environment for possible return of locally extinct halophytes.

Considerably expanding the area with halophytic vegetation, especially in the direction of Nesyt pond.

**Fig. 2.** *Crypsis schoenoides* is a species typical of exposed salinised soil bottoms. It occurs sporadically on the bottom of Nesyt pond, when the water level falls in the summer time. In 2015 it was found in the salt marsh for the first time in more than 10 years. (J. Kmet)

## Measures applied

| Time | Measures |
|---|---|
| 2008–2012 | Opening up reed beds on the shore by cutting 10–20 m wide strips in the direction of Nesyt pond (1.5 ha in 2008, 1.5 ha in 2009, 0.75 ha in 2012) and removing the biomass out of the reserve |
| 2009 | Building stable wooden fences in the western part of the site (2.68 ha), initiation of more permanent grazing |
| 2009–2012 | Eastern part: mowing strips, leaving ¼ of the area unmown for the entire season |
| 2009–2014 | Western part: grazing by a mixed herd of sheep, goats (total 60 animals at a ratio of 4:1) and Holstein cattle (4 animals); yearly demarcating unmown plots measuring 15–20% of the fenced part; mowing ungrazed patches with biomass removal at the end of the season; preferring start of grazing as early as possible (May to June) |
| 2012 | Building stable wooden fences in the eastern part of the site (2.2 ha), dividing the area into two parts of the same size, initiating rotational grazing by 10 heifers |
| 2013 | Expanding the area by elimination of invasive trees and reed beds on an area of 1.0 ha; sod cutting to a depth of 30 cm in plots of 4 × 4 m in three places |
| 2014 | Expanding the mixed herd with two horses; separating the horses from the rest of the herd (to compare the impact of horse and mixed herd grazing on the vegetation) |
| 2015 | Rotational grazing by 8 Kladruber mares and 5 sheep (5.69 ha; April to Oct.); partial elimination of poplar population at the western boundary of the reserve (0.97 ha; Oct. to Nov.) |
| 2015/2016 | Cutting reed strips in the eastern part of the site, connecting salt marsh and Nesyt pond (1.2 ha; Nov. to March) |
| 2016 | Rotational grazing by 8 Kladruber mares (9.06 ha; April to Oct.); deepening 5 shallow pools |

## Monitoring methods

Since grazing was introduced in 2009, the flora at the site has been monitored in roughly monthly intervals. Particularly new occurrences of halophytes are recorded at different microsites as well as stepwise increases in number. Already in 1993, permanent monitoring plots (5 × 5 m in size) were established in the salt marsh to monitor the vegetation. In these, relevés are almost yearly recorded and archived in a database. Of the six monitored plots, three are outside the current enclosures and three inside the grazed enclosures. Assessment of the relevé data has made it possible to compare the development of the vegetation in plots where grazing had been introduced and plots which have so far only been mown. When making the relevés, we also recorded cover and height of the herb layer. These were used in the analysis as indicators of grazing impact on the vegetation structure.



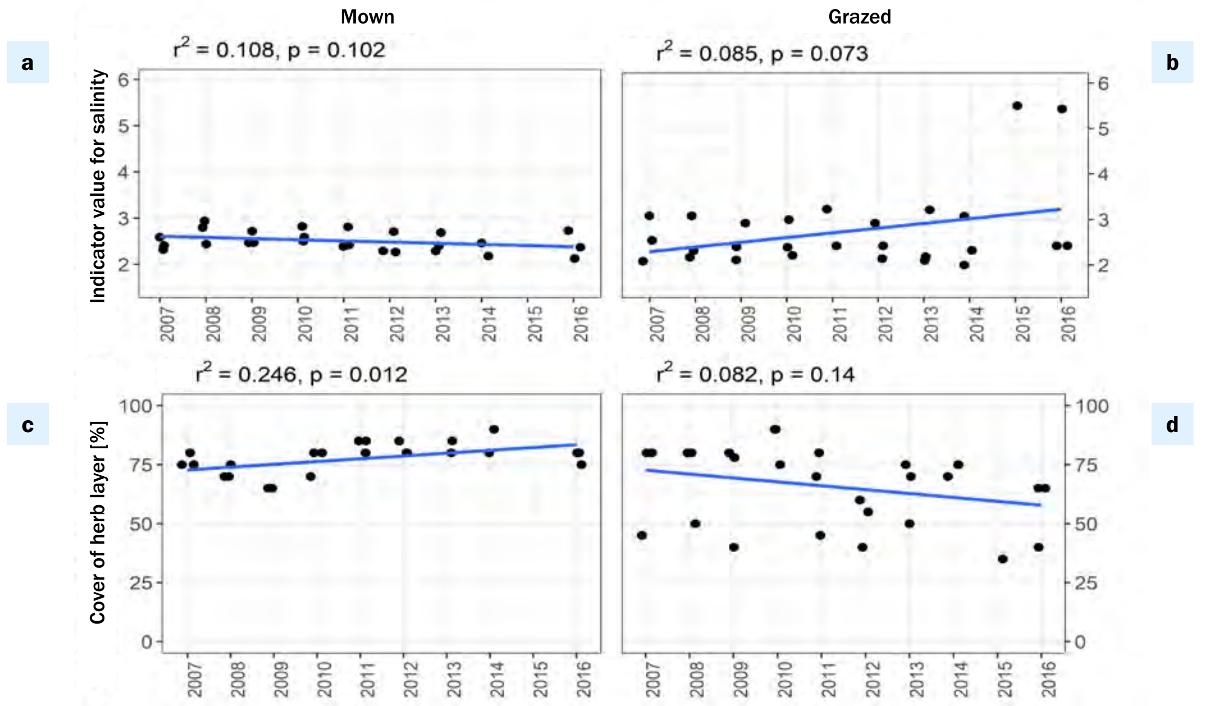


**Fig. 3.** While the salinity in mown plots stagnated or declined with time (a) and the cover of the herb layer increased (c), salinity values in grazed plots went up (b) and the cover of the herb layer decreased (d).

Average Borhidi indicator values for salinity (Borhidi 1995), calculated for each relevé using values assigned to the different species, were used as a tentative indicator of the salinity of the environment.

## Results

By introducing intensive rotational grazing by horses (Fig. 1) the structure of the halophytic communities has started to change distinctly. In the most strongly disturbed plots, where – thanks to the exposed soil – evaporation was more intensive, bringing salts closer to the soil surface, the number of obligate halophytes increased notably. The trend graphs (Fig. 3) clearly show that salinity increased in the grazed plots (Fig. 3b) and the total cover of the herb layer decreased (Fig. 3d), while the development in the mown plots stagnated or slightly impaired (Figs. 3a, 3c). At the same time, a decrease in average height of the herb layer was observed in the grazed plots.

The halophytes *Spergularia media*, *Bupleurum tenuissimum*, *Plantago maritima* and *Tripolium pannonicum*, which occurred rather as an admixture in dense salt marsh grasslands until the introduction of intensive rotational grazing, became dominant species in the most strongly disturbed plots (Fig. 5). This fact confirms their strong dependence on open vegetation. Their rapid entry, almost immediately after the plots had been grazed, can probably be explained by the hitherto sufficient seed supply of these plants in the soil.

Besides an overall reinforcement of populations of mostly obligate halophytes, also three plant species which had been missing for a long time appeared after just two years of intensive rotational horse grazing of the salt marsh. In 2015, two critically threatened grasses, *Crypsis schoenoides* (see Fig. 2) and *Crypsis aculeata* (see Fig. 4), were found in the western part in a rill by a concrete path for the first time in more than ten years. These are annual, competitively weak species of exposed saline bottoms, occurring very rarely in the Czech Republic. Both grasses grew here also in 2016, in a larger number and in more places than in the previous year. Their expansion can be ascribed to the intensive movement of the horses, which spread plant seeds on their hooves, and also to intensive grazing of *Agrostis stolonifera*, which strongly competes with the two mentioned grasses in the waterlogged depressions of the salt marsh. In 2016, several flowering plants of *Samolus valerandi*, last found here in the 1990s, were discovered in the eastern part of the salt marsh (J. Danihelka in verb). We therefore assume that there is a hitherto viable seed bank in the soil, which will manifest itself also in the following years if the current grazing pressure is maintained.

**Fig. 4.** *Crypsis aculeata* was found in the western part of the salt marsh in 2015. In 2016 it also grew in other places. Slanisko u Nesytu is presently the only recent locality of this species in the Czech Republic. (Dedek 2015)

**Fig. 5.** Slanisko u Nesytu, September 2016. Area in the eastern part of the reserve with halophytic species, incl. dominating *Tripolium pannonicum* in flower. (J. Kmet)

## New insights and recommendations

During the past twenty years, a whole range of management regimes have been applied at Slanisko u Nesytu. According to general recommendations, grazing by different farm animals has strongly been preferred since 2009. The results of sheep and goat grazing were the least distinct. Beef cattle grazing brought a certain improvement, but due to their lower mobility these animals did not disturb the soil cover as intensively as horses. Indeed, intensive rotational horse grazing with frequent transfer of the animals between enclosures gave the hitherto best results. The reserve has six separate enclosure segments, which can be divided into smaller units according to need, creating non-intervention zones for undisturbed development of organisms associated with halophilous plant species. Particularly a fine mosaic of grazed patches and different grazing terms at the microsites demonstrated to be an appropriate management strategy, especially for species which are able to survive in the seed bank for a long time. It is however still necessary to approach some sensitive species, e.g. *Taraxacum bessarabicum* and *Scorzonera parviflora*, very prudently. The spots where these species grow must be sufficiently protected from grazing, so that they can produce seed.

The positive impact of horse grazing on the salt marsh can be increased if no antiparasitics are given to the animals (if their state of health allows that). In 2015 the horses received antiparasitics. The decomposition of their dung that year was very slow and the number of coprophagous insects very low. In 2016 the owner did not medicate the animals anymore, which was well visible on the dung, which decomposed quickly and hosted various insect species.

Since Slanisko u Nesytu has gone through radical changes in the past four years, it is necessary to continue monitoring of the reactions of halophilous species on the measures in the entire area and the extent to which new open plots (former poplar stand, strips in reed beds, bottoms of new pools) are occupied. A condition for a rise in their abundance, or even an increase in the number of species, is keeping the grazing pressure at a level which permanently guarantees the presence of a sufficient area of exposed soil.

Despite the positive results of horse grazing, it should always be kept in mind that an extremely important role in the salt marsh is played by the water regime, which is closely linked to the management regime of Nesyt pond. According to the authors' experience, the dynamics connected with a fluctuating groundwater level is a positive phenomenon in the salt marsh. This can be achieved for example by management consisting in a two-year fishing cycle.

## Acknowledgements

Thanks go particularly out to Jiří Danihelka for his long-time systematic research into the flora and vegetation of the site. Kryštof Chytrý is thanked for creating the trend graphs. We would also like to thank Vlastimil Weiser for his practical contribution to the management of the site, his patient collaboration and great willingness to meet our requirements.

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# Revitalisation of a formerly canalised river

Zdenka Herová & Karel Prach

| | |
|---|---|
| Location | 2.65 km section of the Stropnice river near the town of Nové Hrady, southern Bohemia, 48.82° N, 14.80° E; elevation ca 470 m |
| Conservation status | SAC, Landscape Heritage Zone |
| Restored area | Approx. 20 ha (area directly affected) |
| Financial support | Operational Programme Environment; Povodí Vltavy, s.p. |

## Abstract

In the beginning of the year 2014, revitalisation of a section of the Stropnice river, canalised in the 1980s, was completed. The development of the vegetation was monitored over three vegetation seasons. Vegetation dominated by grassland and wetland species spontaneously regenerated. Synanthropic species mostly occurred in the first year only. Non-indigenous species were not significantly represented in the vegetation.

## Site description

A section of the Stropnice river below Nové Hrady was rigorously canalised in the 1980s as part of so-called substitute reclamation for the construction of the Temelín nuclear power station. The riverbed was fixed with turf-stone blocks and lined with species-poor vegetation dominated by *Phalaris arundinacea* and *Urtica dioica*.

In the surrounding floodplain, regularly managed *Alopecurus pratensis* and *Deschampsia cespitosa* meadows prevail, interspersed with smaller wetland sections, mostly dominated by short as well as tall sedges, e.g. *Carex nigra* and *C. acuta*. The outer boundary of the floodplain is mostly lined with tree vegetation including *Alnus glutinosa*, *Salix* spp. and *Prunus padus*; see Figs. 1 and 2.

## Restoration objectives

Returning the artificially straightened and reinforced stream to a natural state, at the same time slowing down the water flow rate and reducing anticipated flood waves.

## Restoration measures

In the winter of 2013–2014, Povodí Vltavy, s.p. revitalised a 2.65 km long section of the river. Later other sections of the

**Fig. 1.** Illustration of the revitalised section, summer 2014. (Z. Herová)

**Fig. 2.** Approximately the same section, 2016. (K. Prach)

stream should have been revitalised (Hladík 2009). The revitalisation work consisted in clearing the riverbed, removing the concrete reinforcements from the riverbed, shaping the riverbed into meanders and removing topsoil from both banks up to a distance of approx. 20 m from the stream. In order to limit inundation of the surrounding land by a flood wave to a level of five-year floods, roughly the upper 30 cm of soil was removed in this zone on both sides of the stream (Havlová & Filip 2011). By doing this, nutrients were also removed and the substrate, predominantly a mixture of clay and sand, was mostly exposed. The revitalisation included planting of native tree species such as *Quercus robur*, *Alnus glutinosa*, *Salix euxina* and *Prunus padus* saplings in a scattered way on the restored part of the banks.

## Monitoring objectives

Finding out (a) how fast grassland and wetland vegetation regenerates after the performed revitalisation, and (b) if ruderalisation occurs; (c) proposing optimal and well-timed management in the restored section.

## Monitoring methods

At the top of the first vegetation season in August 2014, succession monitoring was started by setting up five linear transects located at regular distances of 500 m from each other, perpendicular to the stream and with a revitalised strip on both riverbanks including undisturbed adjacent grassland vegetation. Along these transects, a row of 1 × 1 m plots was established, in which relevés were recorded using the regular methods. The results were mainly processed using multivariate analysis.

## Results

In 2014, four groups of plants with comparable cover grew on the banks of the revitalised river section:

**Fig. 3.** One of the artificially created pools in the revitalised floodplain of the Stropnice river, 2017. (K. Prach)

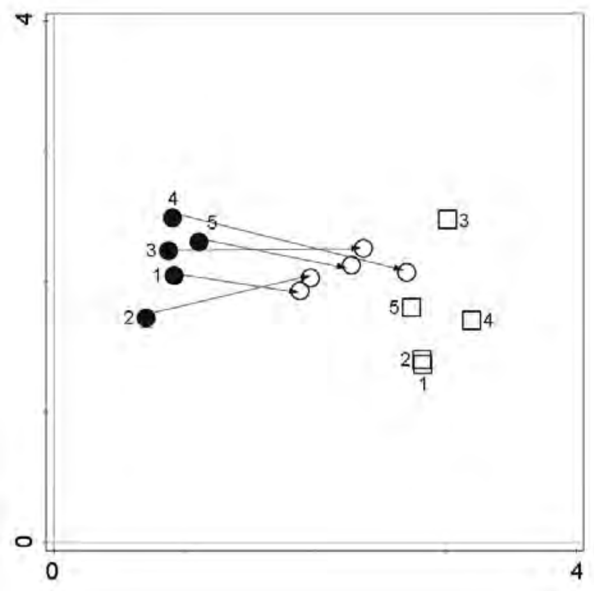


**Fig. 4.** Indirect gradient analysis (DCA, Canoco programme – ter Braak & Šmilauer 2012) shows that the vegetation composition of the restored section comes close to that of the surrounding alluvial meadows already within the first two vegetation seasons. Full circles – Transects 1 to 5 in the year 2014; open circles – ibid. in 2015; squares – permanent meadows adjacent to Transects 1 to 5 in the year 2015 (centroids were used for the graphic representation).

**a) Synanthropic species**, most often *Chenopodium polyspermum*, *Echinochloa crus-galli*, *Rumex obtusifolius* and *Trifolium hybridum*;

**b) Species of exposed bottoms**, mainly *Alopecurus aequalis*, *Bidens radiata*, *Carex bohemica*, *Cyperus fuscus*, *Eleocharis ovata*, *Gnaphalium uliginosum*, *Hypericum humifusum*, *Juncus bufonius*, *Peplis portula*, *Persicaria hydropiper*, *Persicaria minor* and *Potentilla supina*;

**c) Wetland species**, mainly *Carex nigra*, *Glyceria fluitans*, *Poa palustris* and *Ranunculus flammula*;

**d) Grassland species** (examples below).

In 2015, wetland and grassland species distinctly dominated: *Agrostis capillaris*, *A. stolonifera*, *Alopecurus pratensis*, *Carex acuta*, *C. leporina*, *C. nigra*, *Cirsium palustre*, *Holcus lanatus*, *Juncus effusus*, *Phleum pratense*, *Poa palustris*, the latter dominating in a considerable area, further *P. pratensis*, *P. trivialis* and *Ranunculus repens*. Annual synanthropic species but also species of exposed bottoms declined.

In 2016, the actual species composition had not changed much, but the cover of grassland and wetland species had further increased. Synanthropic species occurred relatively rarely and species of exposed bottoms only sporadically. *Poa palustris* maintained its dominance in wetter places close to the stream, where it often grew together with *Juncus effusus*, *Deschampsia cespitosa*, and close to the stream also with *Phalaris arundinacea*. In drier places on sandy substrate, *Agrostis capillaris* dominated distinctly over a large area.

In many places in the zone where the topsoil had been removed, relatively dense stands of invasive willows, mainly *Salix cinerea* and *S. auxina*, established already from the



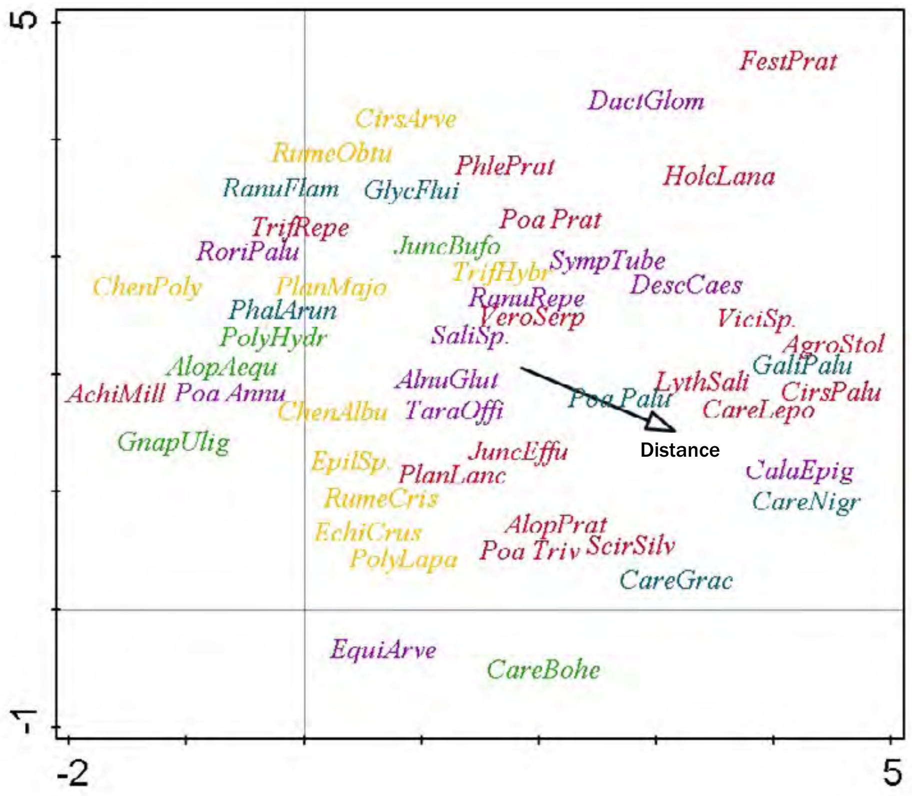


**Fig. 5.** Indirect DCA gradient analysis of species (the first 50 best fitting the model). Species are indicated by the first four letters of their genus and species names. The species are classified into groups after Ellenberg et al. (1991): red – grassland species, yellow – synanthropic species, green – species of exposed bottoms, blue – wetland species, purple – other species. The Distance arrow indicates increasing distance from the stream and was passively projected.

first year onward. They were particularly dense in wet places close to the stream and gradually developed further.

The changes in vegetation in the first two years, immediately after the revitalisation, compared with the existing floodplain meadows, is shown in Fig. 3. It is clear that the succession runs rather rapidly to a restoration of alluvial grasslands. The occurrence of the main species, divided into coenotic groups depending on distance to the stream, is shown in Fig. 4. The total number of species declined with growing distance from the stream, which is probably caused by the fact that species of exposed bottoms can grow better close to the stream.

## New insights and recommendations

In the revitalised section of the Stropnice river, vegetation dominated by grassland and wetland species is spontaneously regenerating at a surprising speed. Synanthropic species (mainly annuals) were more abundant in the first year only. Non-indigenous species are not a significant part of the vegetation and no invasive behaviour was observed. It is evident that if we do not intervene, dense willow stands, locally with admixtures of other trees (*Alnus*, *Betula*), may develop in a broad zone along the stream within a few years. In order to preserve and restore wetland and grassland vegetation it would be good to manually mow the banks regularly once a year, starting not later than four years after revitalisation. The restored, regularly managed grasslands would then gradually become similar to the existing meadows and increase the possible agricultural utilisation of the floodplain. Willows can be allowed to develop in selected sections close to the stream.

The results have confirmed the effectivity of spontaneous succession in the restoration of floodplain ecosystems, but some management is desirable.

## Acknowledgements

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# Near-natural flood control measures on a river in an urban environment

Tomáš Just & Miroslav Barankiewicz

| | |
|---|---|
| Location | Town of Vlašim, Central Bohemia; elevation ca 340–345 m |
| Conservation status | SAC, Regional Biocentre and Biocorridor |
| Restored area | 1,550 m of river corridor of various widths in built-up area |
| Financial support | Operational Programme Environment; Povodí Vltavy, s.p.; Municipality of Vlašim; €3.25 mil. |

## Abstract

In the years 2012 to 2014, an earlier canalised section of the Blanice river was restored on the territory of the town of Vlašim, representing the first large (so far the largest) urban revitalisation in the country. Its aim was to reinforce flood prevention of the town to the Q100 level, to improve the ecological state of the river, and to access the river area for recreation. A partial ecological goal of the measure, monitored in detail, was to improve the conditions for fish and other aquatic animals in SAC Vlašimská Blanice, including the restoration of migration corridors restricted by historical weirs.

## Site description

In the past the Blanice river in Vlašim had been technically adjusted by straightening the streambed, giving it a geometrically simplified shape, and reinforcing it. Two weirs are from an earlier date. The upper one, situated at the lower boundary of the chateau park, regulates the water level in the lower part of the park. The lower weir used to serve a mill, but today it provides water to an industrial laundry built in its place.

The function of these weirs had to be maintained, so they were not removed in the revitalisation, but reconstructed and supplemented with fish passages. The revitalisation work could not include restoration of the natural shapes of the Blanice river, i.e. the morphological pattern of a meandering watercourse. The space in the floodplain in which natural meanders had been created is built up today, so that the restoration of the Blanice river had to be based on the existing river zone and on the land provided for realisation of the plan by the Municipality of Vlašim.

## Initial state

The Blanice river channel in Vlašim had canalised shapes: it was markedly straightened and had a predominantly geometrical, regularly trapeziform cross-section. It did not provide the urban area with sufficient flow rates during floods, it was filled up with nutrient-rich sediments supporting ruderal vegetation on the banks, and the tree stands consisted mostly of planted poplar cultivars. Moreover, significant

**Fig. 1.** Blanice river at the lower outskirts of Vlašim before revitalisation. The riverbed had geometrised technical adjustments and the banks were covered by nutrient-rich soils with ruderal vegetation. (T. Just)

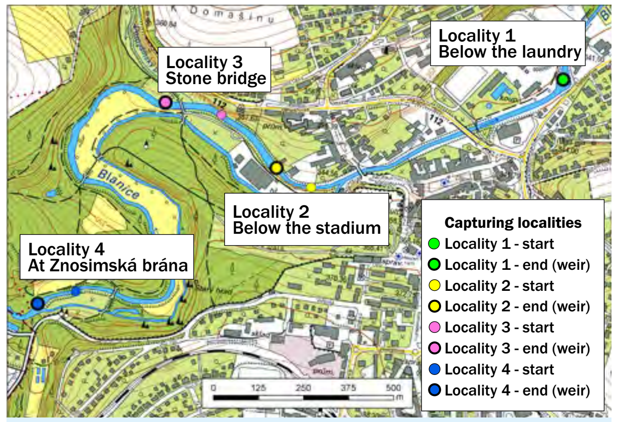


**Fig. 2.** Vlašim, locations of fish passages monitored as part of ichtyological research.



parts of the fore-bank were ruderalised. The river corridor was lengthwise insufficiently permeable and did not provide residents with space for quality recreation.

Before the reconstruction, the river bottom was mostly covered by muddy sediments. The Blanice river is a Special Area of Conservation from Vlašim upstream to Mladá Vožice, protecting among others the mussel *Unio crassus* and the lamprey *Lampetra planeri*. The ecological conditions of the river have been problematic for a long time, especially with regard to the combined action of seasonally small flow rates and a strong pollution of the river with nutrients and contaminants from the towns and villages, but mostly from the intensively farmed river basin.

## Measures applied

Technically seen, the construction included continuous adjustments of the Blanice riverbed in Vlašim to reach a safe proposed flow rate of Q100 = 101 $m^3/s$ from Km 17.000 to 18.550, i.e. over a length of 1,550 m. The construction was designed to improve the river's permeability in the town during floods, its morphological-ecological state and recreation opportunities for residents in the river area (Just et al. 2005, Just 2010). This set of effects was to be achieved by the following measures.

- Opening up the riverbed by removing significant volumes of soil from the banks. This was expected to expand the cross-section as well as to have a favourable ecological impact by eliminating strongly nutrient-rich earth with ruderal vegetation.
- Building protective side walls (especially in the exposed built-up area nearby the town centre) and protective dikes (particularly in the lower part of the town).
- Variable riverbed shaping by deepening a chain of pools and creating a system of riprap structures in the form of lateral bank spurs; locally broadening of the riverbed.
- Reconstructing the two fixed weirs.
- Building fish passages.

**Fig. 3.** Blanice at lower outskirts of Vlašim during revitalisation. After removing nutrient-rich soil from the banks and opening up the riverbed, a relatively near-natural riverbed was shaped and then stabilised and diversified with bottom stone strips, spurs and stone riprap structures. (T. Just)

**Fig. 4.** Near-natural flood protection of the Blanice river in the historical centre of Vlašim. Protection walls demarcate the river corridor with a near-natural riverbed, diversified and stabilised with stone structures. New infrastructural elements – a parallel working path and bridge – are well visible. (T. Just)

- Building a work path along the entire river section to be used as a footpath and cycle trail, connecting to the bridges.
- Removing a large part of the former riparian stands with surviving poplar cultivars, which are inappropriate as for species and habitat. Replacing these stands with new plantings of more suitable composition and structure.
- Eliminating several constructions in the floodplain.

The Blanice reconstruction in Vlašim was carried out by investor Povodí Vltavy, s.p. The project was completed by Hydroprojekt – Sweco Praha, based on a territorial study elaborated by CUNC LC Vlašim and realised by Hochtief. The activity received the Water Management Structure of the Year 2014 award from the Water Management Association in the category 'Structures of over €2 million'.

Separately, fish passages were built near two other weirs in the chateau park, and surface waters were restored in the floodplain.

## 1. Hydraulic functionality of fish passages

### Monitoring methods

After completing the fish passages, the NCA assessed their functionality concerning water flow velocity in the gaps between the boulders of the baffles. Primarily, too high flow velocities in the gaps were regarded to be a risk. From there, interest shifted to the question of uneven distribution of fish passage gradients between the boulder baffles, which supports the creation of places with too high flow velocities. The monitoring was started by measuring water flow velocities in the gaps between boulders of transverse steps and in bottlenecks of the upper entrances, particularly during standard flow rates, eventually getting to a simple levelling of partial water levels in the passages.

**Fig. 5.** There were not many opportunities to open up the Blanice riverbed in Vlašim. One of them occurred at the lower outskirts of the town. In a widened place, an untraditional islet with a pool was created. (T. Just)

## Results

The fish passages were designed to have a 1:20 lengthwise slope, in the preparation stage assumed to be adequate. This slope was calculated to correspond to a fall of 13 cm per transverse boulder step. Corresponding to hydraulic calculations and as confirmed by measurements, a flow velocity of around 0.8 m/s would be reached at such a fall in the gaps between the boulders. This should be surmountable by most fish in the Blanice river. However in reality, the fall of near-natural boulder baffles could not be divided evenly. Some of them, with a fall of several centimetres, remained unused, while the fall of others ran up to 25 cm, with flow velocities in the gaps of up to 2.2 m/s. Such 'fast gaps' can be hard to overcome for common fish in the Blanice river. For *Cottus gobio* and *Lampetra planeri* they are clearly impassable. Based on this knowledge, the contractor attempted to carry out some improvements before the final approval, but the possibilities of additional adjustments of gaps between the natural boulders were shown to be strongly limited. The problem of uneven fall distribution between boulder steps is yet enlarged by uneven filling of the gaps with all kinds of material.

The measurements provided information on the limited effectivity of fish passages as a result of too high flow velocities in the gaps between the boulders. The main solution to this problem for the chosen construction type only seems to be the building of passages with a considerably gentler slope. Also the monitoring results in Vlašim show that a 1:40 slope for fish passages with transverse boulder steps, usually recommended in Germany today, is justified. Such a slope would, in comparison with the realised 1:20 slope, divide the channel of the passage into a double number of boulder steps, and the fall per step would be reduced to half. This would also reduce the height of the critical and largest falls. Improvement could also be reached by using prefabricated 'boulders', which would – besides easier and safer manipulation during construction – mean more regularly shaped gaps, however at the expense of natural authenticity.

## 2. Monitoring of migration passability of four selected fish passages

### Monitoring methods

In 2015, a detailed assessment of the migration passability of four weirs was carried out by the T.G. Masaryk Water Research Institute, Prague. The position of the monitored localities is illustrated in Fig. 2. The presence of fish species and fish size classes below the weirs at the localities and in fish passages was recorded by means of electrofishing. Fish migration was further monitored by recapturing marked fish, with a VAKI bioscanner and using biotelemetry. The fish were divided (categorised) according to size at 50 mm intervals. Loss rates for VI elastomers, the VI Alpha and PIT tags were obtained from scientific publications. To assess the functionality of the fish passages, we used the fish marked below the weirs of each site, subsequently recorded in the part of the course above the migration barrier.

### Results

In total 7,434 specimens of 24 fish species were caught by means of electrofishing at the four sites, of which 2,762 specimens were detected in the four fish passages. Of these, 16 fish species belonged to the Cyprynidae, two to the Percidae and Salmonidae, and one species to the freshwater eels (Angullidae), the pike family (Esocidae), the Nemacheilidae and the sculpins (Cottidae), respectively. Altogether 20 fish species were marked, of which 2,485 specimens with a VIE tag, 708 specimens with an Alpha tag and 713 specimens with a PIT tag. The results of recapturing marked fish is illustrated in Tab. 1.

Species composition of the fish below the weirs and in the fish passages was recorded by means of electrofishing, see Tab. 1. The presence of fish was established with the same fishing effort. At particular localities, some species were recorded only in the fish passage, not below the weir, which may indicate that some species prefer the passage as a habitat and stay there for a longer time. The results show that at the same fishing effort the number of recorded species in the passage was always – except for Locality 2 – lower than below the weir. Despite, most fish species enter the fish passages and those missing there are, as a rule, the ones that were caught in small numbers below the weir. As to the number of recorded fish species, the passages can be considered little selective, however knowing that just the presence of a species in a passage does not have to mean that its migration through the passage is successful.

Electrofishing data was also tested with regard to the size spectrum of fish caught below the weirs and in the respective fish passages. At Localities 1, 3 and 4, slightly more frequently fish of size class 101–150 mm were found in the passage, while larger and smaller fish were found here less frequently than below the respective weir. This pattern is however weak. Data from Locality 2 shows that small and large fish were recorded even more frequently in the fish passage than below the weir. At Localities 2 and 3, also larger specimens were now and then recorded in the fish passage. The results indicate that the investigated passages are not very selective as for fish size.

In the monitoring period, successful migration across fish passages was documented (fish detected in the section above vs below a barrier) based on a total of 103 recaptured specimens (13 migrating through the fish passage downstream, 90 upstream). They most often belonged to the species *Squalius cephalus*, *Leuciscus leuciscus*, *Rutilus rutilus*, *Gobio gobio*, *Alburnus alburnus* and *Salmo trutta*. Fish measuring 110 mm to 262 mm were found to migrate.

The VAKI bioscanner was in operation from 26 April to 30 June 2015. A total of 422 records were obtained, 226 of upstream migration and 196 of downstream migration. The largest numbers of migrating fish were detected in late May, the second week of June and late June. This pattern was similar for upstream and downstream migration. The smallest recorded specimen measured 240 mm, the largest 810 mm. Migration was found to take place mostly in the morning (6–8 am) and evening (8–10 pm) hours.

Biotelemetry (RFID) managed to record 48 out of 143 specimens belonging to nine fish species migrating through the PIT frame of the fish passage below the weir at Locality 4.

**Tab. 1.** Presence of fish species below weirs and in fish passages at different localities; data based on electrofishing results. Highlighted fields indicate absence of a species in a fish passage despite its presence below a particular weir.

| Species | Locality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | |
| | Below weir | Fish passage | Below weir | Fish passage | Below weir | Fish passage | Below weir | Fish passage |
| *Aspius aspius* | - | - | - | - | - | - | + | - |
| *Abramis brama* | - | - | - | - | + | - | - | - |
| *Blicca bjoerkna* | - | - | - | - | + | - | + | - |
| *Gobio gobio* | + | + | + | + | + | + | + | + |
| *Leuciscus idus* | + | + | + | + | + | + | + | - |
| *Leuciscus leuciscus* | + | + | + | + | + | + | + | + |
| *Squalius cephalus* | + | + | + | + | + | + | + | + |
| *Gymnocephalus cernuus* | - | - | - | - | + | - | - | - |
| *Cyprinus carpio* | - | - | - | - | - | - | + | + |
| *Tinca tinca* | - | - | + | - | - | - | - | - |
| *Barbatula barbatula* | + | + | + | + | + | + | + | + |
| *Perca fluviatilis* | + | + | + | + | + | + | + | + |
| *Chondrostoma nasus* | - | - | - | - | + | - | - | - |
| *Alburnus alburnus* | + | + | + | + | + | + | + | + |
| *Barbus barbus* | + | - | - | + | + | + | + | - |
| *Scardinius erythrophthalmus* | - | + | - | + | - | + | + | - |
| *Rutilus rutilus* | + | + | + | + | + | + | + | + |
| *Vimba vimba* | - | - | + | - | - | - | + | - |
| *Oncorhynchus mykiss* | - | + | + | + | - | - | + | - |
| *Salmo trutta* | + | - | + | + | + | + | + | + |
| *Pseudorasbora parva* | + | - | - | - | - | - | - | - |
| *Esox lucius* | + | - | - | - | - | - | - | - |
| *Anguilla anguilla* | + | + | + | + | + | + | + | + |
| *Cottus gobio* | + | - | - | - | - | - | - | - |

**Fig. 6.** Weir at Kyselý Laundry after reconstruction. Here, the lower facial side of the weir was filled up to create a stone platform, and a fish passage was built. The passage is made up of a concrete channel with lateral boulder steps. (T. Just)

**Fig. 7.** Fish passage at the weir (upper part of the adjustment) at the old ice stadium in the chateau park, conceived as a concrete channel with lateral boulder steps. NCA workers are levelling the pools in the passage in order to judge the evenness of the fall between the lateral boulder steps. (T. Just)

Six species migrated successfully, five of them belonging to the Cyprinidae and one to the Salmonidae. After deduction of tag loss, the total migration success works out to around 40% on average. A total of 85 marked specimens passed all localities. The smallest fish detected was trout (*Salmo trutta*) with a total body length of 113 mm, the largest one European chub (*Squalius cephalus*) with a length of 355 mm.

The temporal development of upstream migration was monitored for indicator species European chub. According to the results, the top of migration was in mid-April, but the species migrates through the fish passage regularly also in the rest of the period. An advantage of this method is that individuals are identified, enabling exact determination of specimens which really migrated through a passage. In the mentioned period, 38% of all marked European chubs migrated through the passage.

Analysis of the size classes recorded in biotelemetric monitoring at Locality 4 and of migrants detected with a scanning frame after swimming through the fish passage confirms that

**Fig. 8.** Members of the Ichtyological Group of the T.G. Masaryk Water Research Institute during fish capturing inspection in the Blanice section above the revitalisation structure in the chateau park of Vlašim. (M. Barankiewicz)

size selectivity of the fish passages is negligible and that different size classes migrate through the passages with similar success. By means of telemetry, three species (*Gobio gobio*, *Leuciscus leuciscus*, *Squalius cephalus*) were also found to be able to overcome the entire array of four fish passages.

## New insights and recommendations

The urban revitalisation of the Blanice river in Vlašim has demonstrated that a morphologically diverse near-natural river channel can be restored even in the constrained space of a built-up urban area, and combined with flood protection measures and improvements of the recreational functions of the revitalised area. Essential for the success of the whole project was the clear vision of the river channel (inspired by an urban river revitalisation in Bavaria) by the Municipality of Vlašim, availability of land in the surrounding of the river, support by the local people and excellent collaboration with Povodí Vltavy, s.p., which eventually took over the role of investor.

Lack of experience with planning similar structures in the Czech Republic led to e.g. overdimensioned stone ripraps for bank reinforcement and insufficiently designed elements increasing riverbed diversity. Most of these problems were overcome thanks to increased assistance of NCA workers in the realisation and completion of the project.

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# Elimination of knotweeds in a river basin


Renata Vojkovská & Martin Krupa


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|---|---|
| Location | Moravian-Silesian Region, watercourse of the Morávka river over a total length of 29.4 km; elevation 800–290 m |
| Conservation status | NNM, NM, SAC |
| Restored area | 360 ha |
| Financial support | Programme LIFE, Hyundai Endowment Fund |


## Abstract

The Morávka river is unique not only from the geomorphological perpective. In the surrounding of the river, rare plant species grow and at the same time alien plant species with invasive potential occur here in large numbers. The Morávka river basin can be considered a model area, since invasive plant species, in particular knotweeds (*Reynoutria* spp.), have been monitored here for a long time and were also eliminated in the years 2007 to 2010. The persistent knotweed has been suppressed to less than 10% of its original occurrence thanks to a project titled Preservation of Floodplain Habitats in the Morávka River Basin. It is however necessary to keep monitoring the entire area and direct our attention also to other invasive plant species.


## Site description

The Morávka river in the Beskid Mts is, mostly in the section of Skalická Morávka NNM, a near-natural watercourse which has hardly been technically adjusted. Its conservation is aimed at the natural course lined with gravel banks hosting characteristic communities and accompanying natural forest stands, in which populations of rare and threatened plant and animal species are found (Šindlar et al. 2009). The geomorphologically unique riverbed branching with frequently added layers of gravel and ever displacing branches is one of the last remnants of so-called wild rivers in the Czech Republic.

**Fig. 1.** Flowering knotweeds (*Reynoutria* spp.) on the Morávka river, autumn 2015. (R. Vojkovská)

Through water management measures since the first half of the 19th century, approx. 1200 ha of gravel banks in the Morávka basin have disappeared. The width of the active riverbed often used to exceed 100 m, but today it is narrowed to less than half, which has been documented for a 19 km long monitored section of the Morávka river (Hradecký 2014). The current extensive woodland areas are temporarily inactive riverbeds where many stands have been planted on gravel fields to adjust the direction of the water flow. Locally nearly pure populations of *Alnus incana* have developed from spontaneous seeding on gravel banks after the floods of the late 1970s. The gravel banks of the Morávka river are the habitat of the critically endangered *Myricaria germanica*. These initial succession stages are followed by willow scrub of river gravel banks and in the wider surrounding of the river by alluvial ash-alder forests, which have a rich spring aspect.

## Initial state

On the Moráva river, in the current longer period of disturbed spring flood dynamics, bare gravel banks occur only to a small extent and get gradually overgrown with vegetation. The restriction of natural processes by water management measures, shaping the river channel, considerably threaten the reason for protection, which is the geomorphological channel, where branches create a broad riverbed in which new gravel layers are frequently added. The originally exposed gravel banks with specific, often extreme conditions for rare plant and animal species vanish and become gradually overgrown by succession of competitively stronger vegetation (with either alien plant species or the rare *Salix elaeagnos*).

**Fig. 2.** Invasive plants on the Morávka river: knotweeds (*Reynoutria* spp.), *Oenothera biennis*, *Impatiens glandulifera*, *Cytisus scoparius*. (R. Vojkovská)

The main nature conservation objective for the last sections of the wild Morávka river – i.e. the conservation of a natural water regime – is however so far just theory. Momentarily, measures here and in the area of Skalická Morávka NNM are directly concentrated on the welfare of rare plant species. Suitable management measures for the maintenance of the earlier repatriated *Myricaria germanica* and isolated populations of *Calamagrostis pseudophragmites* consist in suppressing alien plant species and vegetation directly in the close surrounding of these rare species.

The main threat to biodiversity is formed by knotweeds (*Reynoutria* spp.). *R. japonica* is most frequent in the Morávka river basin, while *R. sachalinensis* and their hybrid (*R. ×bohemica*) are encountered less often. During the years 1930–1996 a slow spread of knotweeds was recorded in the surrounding of the river. The 100-year flood of 1997 accelerated its spread. The area affected by knotweeds in 2006 was quantified to be 360 ha in total, which is considerably more than in the case of two other Beskid streams, the Ostravice and the Olše (Tab. 1).

**Tab. 1.** Comparison of areas (ha) affected by two strong invasive plants in the river basins of important Beskid rivers.

| River basin | Morávka 2006 | | Ostravice 2012 | | Olše 2014 | |
|---|---|---|---|---|---|---|
| Main course (km) | 28 | | 29 | | 23 | |
| Species | Area (ha; km) | | | | | |
| *Reynoutria* spp. | **360** | 12.9 | 142 | 4.9 | 38 | 1.7 |
| *Impatiens glandulifera* | 2 | 0.1 | 20 | 0.7 | 23 | 1.0 |
| River basin total | 362 | 12.9 | 162 | 5.6 | 61 | 2.7 |

More than thirty plant species with an invasive potential have been found in the Morávka river basin, the most frequent of them being *Impatiens glandulifera*, *Solidago* spp., *Lupinus polyphyllus*, *Telekia speciosa*, *Rudbeckia* spp., *Heracleum mantegazzianum*, *Symphoricarpos albus* and *Helianthus tuberosus*. Occurrence and spread of invasive plant species is facilitated by the fact that the plants get here as waste from the surrounding gardens and weekend house areas, from where they successfully spread further also thanks to the river.

In the years 2007–2010 a LIFE project titled Preservation of Alluvial Forest Habitats in the Morávka River Basin was realised.

## Restoration objectives

Revitalising habitats and suppressing invasive knotweeds in SAC Niva Morávky and part of SAC Beskydy, including the elaboration of a method for these measures with regard to their long-term impact.

## Measures applied

**The elimination of knotweeds was carried out using the following two basic methods.**

- Most places occupied by knotweeds was treated by spraying the Roundup Biactive herbicide in combination with mechanical elimination of the plants. The treatment was performed with a 10% solution of the herbicide by means of motor sprayers. The herbicide was applied in each project year from July to September, in total five times per spot on average. After the first and second spraying, in autumn, dead knotweed plants were mown and burnt. Knotweeds cannot be destroyed by spraying the herbicide just once. Spraying needs to be repeated, ideally for several years – see optimised procedure below.
- In places with a risk of damaging surrounding vegetation (e.g. *Myricaria germanica*) or endangering drink water sources, the herbicide was injected in a 15% solution. It was applied on the stem low above the ground (under the 2nd or 3rd node) or at a height of 1.3 m above the ground on most stems in a polycormon. These elimination operations were planned depending on the weather, in order not to endanger biota, water or soil as a result of rain or strong wind. Dead knotweed stems were cut after three to four weeks with a brushcutter and burnt in stacks.

**Subsequent regeneration of the herb layer at selected sites and planting of indigenous shrub species.**

Timely regeneration of the herb and shrub layers after knotweed elimination is necessary to suppress a spread of other invasive species (e.g. *Impatiens*, *Solidago* spp.), which encroach places where knotweeds have been eliminated. For these reasons willows, in particular *Salix caprea*, *S. euxina*, *S. purpurea*, *S. triandra* and *S. viminalis*, were planted at selected sites, mainly adjacent to the watercourse along ripraps. The planting stock came from the Morávka river basin so as to preserve genetic indigeneity. Also *Cornus sanguinea*, *Euonymus europaea* and *Ligustrum vulgare* were planted and further a seed mixture of 16 grass and herb species was sown (seed source: OSEVA PRO s.r.o., Zubří), mainly on larger plots where knotweeds had been eliminated and which were situated at a greater distance from the Morávka riverbed (e.g. under high-voltage power lines in the cadastral municipality of Raškovice). The most valuable places where the rare shrub *Myricaria germanica* grew were left without any treatment.

**Fig. 3.** *Impatiens glandulifera* and *Calamagrostis pseudophragmites*. (R. Vojkovská)

## Monitoring methods

From 2011 to 2015, monitoring of knotweeds took place yearly in the surrounding of the Morávka river, concentrated on hotbeds of knotweed spread. The spread of other alien species with an invasive potential was also monitored – predominantly *Impatiens glandulifera*, *Solidago* spp., *Robinia pseudoacacia* and *Oenothera biennis*. For larger areas of invasive plant occurrence, their acreage was recorded.

## Results

It was documented that knotweeds can be suppressed to cover less than 10% of the initial area several years after the end of the project (2010). A year after the project had ended, the area of knotweeds amounted to only 1% of the initial area (Tab. 2). This result was however influenced by a flood in May 2010, when just a few small plots of knotweeds were surveyed, because a large part of the vegetation along the river had been washed away by flood water. We therefore regard the total area of knotweed sites recorded in 2014 (Tab. 2), i.e. 6% of the initially established area, a realistic result of the LIFE project. In the years 2006–2008, a similar project aimed at elimination of knotweeds was realised in the Nisa river basin, where a knotweed area of 34 ha was reduced to 13% of its initial size (Modrý et al. 2008).

At the end of the project in 2010, we observed in 18 monitoring plots that the elimination of knotweeds and opening of the vegetation had caused an increase in the number of herb species from 23 to 44 species (Lacina et al. 2010). However, this was by virtue of the knotweed reduction and again the May 2010 flood. This event (with the character of a 100-year flood) helped the spread of diaspores of a range of short-lived and ruderal species, which occurred at the monitored sites for only a short time (Lacina et al. 2010).

The places cleared after knotweed elimination were rapidly occupied by other invasive plant species, most of all by *Impatiens glandulifera*. After the first herbicide application (in 2007) a massive increase of this species was recorded (Tab. 2). It was additionally eliminated by mowing the populations and eradicating the plants. Its incidence fluctuated considerably in the years of monitoring (Tab. 2). In 2015, this annual plant occurred scattered along the entire Morávka watercourse.

**Tab. 2.** Most important invasive plant species in the Morávka river basin from 2007 to 2014.

| | 2007 | 2009 | 2011 | 2014 |
|---|---|---|---|---|
| Species | Acreage (ha) | | | |
| *Reynoutria* spp. | **360** | **120** | **4** | **20** |
| *Impatiens glandulifera* | 2 | 70 | 1 | 3 |
| *Cytisus scoparius* and *Solidago* sp. | <1 | | | |
| *Cytisus scoparius* | | | 1 | 1 |
| *Solidago* sp. | | | 3 | 4 |

*Solidago* species have a strong spreading ability thanks to the high production of seeds which disperse very well by wind. Already Konupková-Kalousová (2011) predicted their strong expansion. Drier sites in the surrounding of the watercourse or zones along stone ripraps are successfully colonised by *Cytisus scoparius*. *Oenothera biennis* is encountered in large numbers, although in a lower cover.

## New insights and recommendations

Projects aimed at suppressing invasive knotweeds can be regarded to be successful in the seasons following the end of the project. Despite their suppression in the Morávka river basin (from the initial 360 ha to 20 ha, see Tab. 2), this plant is reappearing in the basin. Its populations thrive best in a medium-wet type of floodplain forest, in places with open vegetation and in forest fringes (Lacina et al. 2010). At present, knotweeds grow in the proximity of small streams and permanently wet places in forests around the Morávka river and also along the watercourse. Every plant weakened after spraying, even scattered vital knotweed specimens, must be considered to be a potential source or hotbed of further spread.

Long-term monitoring of knotweeds is necessary and the same counts for other invasive plant species, which get free space after plant elimination and suitable conditions for spreading. Possible hotbeds of other invasive species, especially *Impatiens glandulifera*, need to be eliminated before the seeds ripen.

Based on experience obtained from the project, a general optimal procedure of eliminating knotweeds has been formulated. Herbicide should be applied 1× yearly (August to September)

**Fig. 4.** *Solidago canadensis*. (R. Vojkovská)

**Fig. 5.** *Oenothera biennis* and *Impatiens glandulifera*. (R. Vojkovská)

over a period of 8 years: 1st year: spraying, 2nd year: spraying, 3rd year: spraying, 4th year: no spraying, 5th year: spraying, 6th year: no spraying, 7th year: no spraying, 8th year: spraying.


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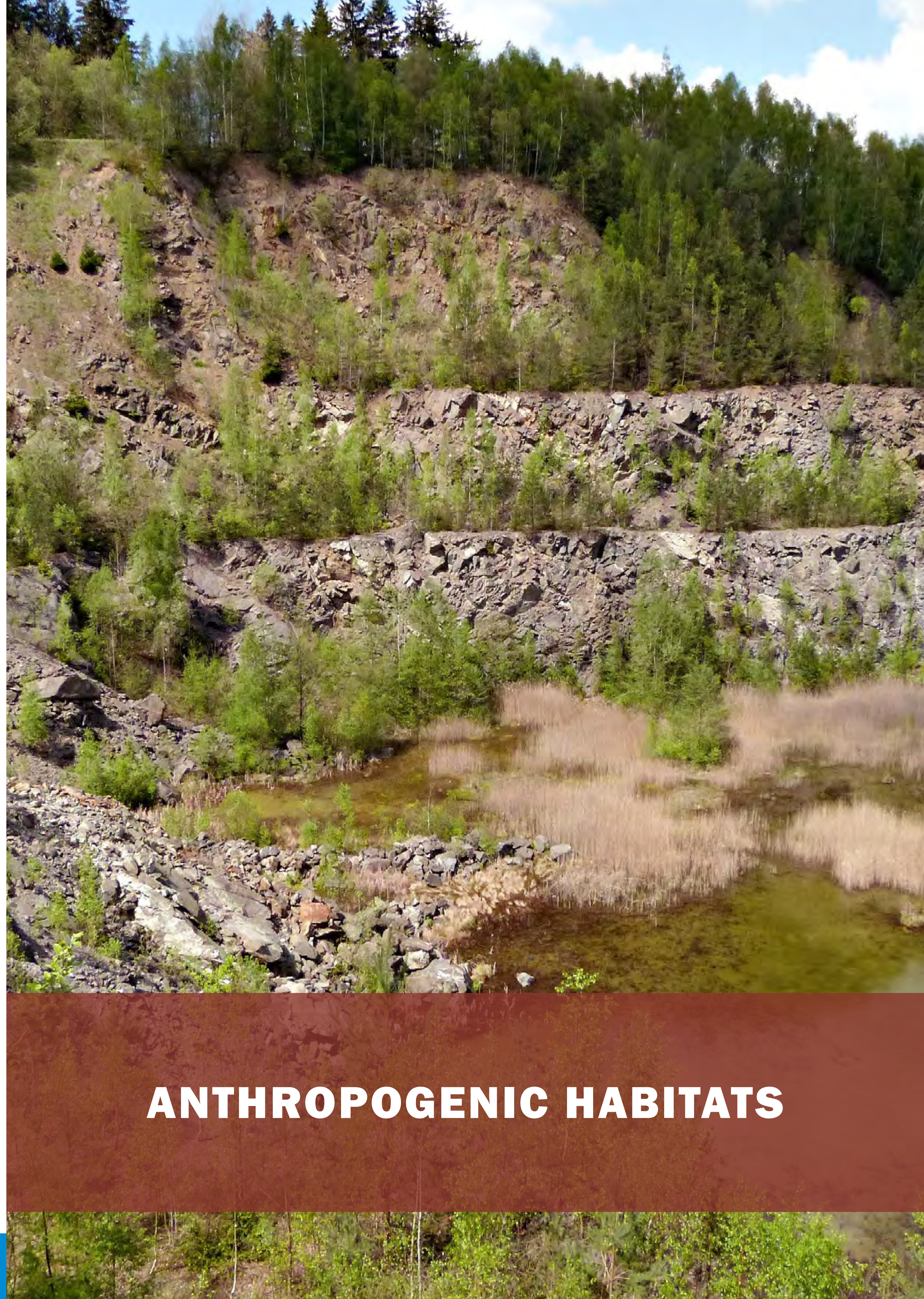
**Fig. 6.** Exposed gravel bank after floods in 2010. (M. Krupa)





# ANTHROPOGENIC HABITATS

# Introduction

Karel Prach

Anthropogenic habitats include here all areas created or strongly influenced by human activity, such as sites disturbed by various kinds of exploitation, ruderal sites, road and railway verges, and also arable land. In a broader sense, meadows, pastures and fishponds belong here as well, but these are not dealt with in this section. This part of the publication will mainly deal with the restoration of ecosystems at industrial sites and on abandoned farmland. A study of the restoration of the landscape structure on agricultural land in a strongly man-altered landscape is also included. Other habitats are only mentioned in brief notes or in some partial studies in other chapters of this volume, since not all items can be strictly categorised.

Restoration ecology has its main roots in the research into sites disturbed by mining (Bradshaw & Chadwick 1980) and this is also valid for the Czech Republic (Prach 1987). Knowledge of the process of spontaneous succession can directly be applied in the ecological restoration of anthropogenic habitats. Spontaneous succession can moreover be accelerated and directed in various ways, e.g. by sowing or planting desirable species, or conversely by suppressing unwanted, often alien invasive species, and adjusting environmental factors, e.g. by raising water levels. Spontaneous succession sometimes needs to be blocked or even reversed, because initial and young successional stages often host rare and threatened species, the populations of which need conservation or reinforcement (Řehounková et al. 2016). In all these cases we can speak of controlled or assisted succession. Examples are the transfer of raked biomass from psammophytic communities to an exploited sand pit (see Fig. 1) and the gradual mulching of quarry étages in Hády limestone quarry in the years 1999–2014, in some years accompanied by sowing typical steppe species under the mulch (Tichý 2012).

## Restoration of sites disturbed by mining and other industrial activities

With regard to near-natural restoration (i.e. using spontaneous processes) of mining sites and similar industrial sites in the Czech Republic, all essential information can be found in published overviews: Prach et al. (2013), Řehounek et al. (2015), Tropek & Řehounek (2012). This introductory chapter will therefore be restricted to an overview of basic principles, which is an abbreviated and adjusted version of the conclusions of a study by Řehounek et al. (2015). Some of the conclusions below are valid in general, i.e. they do not only apply to mining and similar activities at disturbed sites. They also refer to the general chapter in the previous volume, Ecological Restoration in the Czech Republic (Tropek & Prach 2012).

**Basic principles of near-natural restoration of sites disturbed by mining or other industrial activities**

**1)** Already before exploitation, it is necessary to perform a biological survey of not only the actual space, but also its surrounding. This should be done by people familiar with the latest knowledge in the field of restoration ecology.

**Fig. 1.** Sheep grazing – controlled management of experimentally transferred psammophytic vegetation on an island in the Cep II sandpit, Třeboň region. (K. Prach)

Kosov Quarry near Jihlava, where near-natural restoration is considered, supported by the exploiters. (K. Prach)

**Fig. 2.** Fifteen-year old rock steppe at Dálky, a former limestone quarry near Čebín, established by planting several tussocks of *Sesleria caerulea* on the northern wall of the quarry. The plants were transferred here from a limestone hill named Čebínka at a distance of one kilometre, where most of the original vegetation has vanished by advancing mining. (L. Tichý)

**2)** The surrounding should include an area up to a distance of at least 100 m from the mined site, from which the largest number of species spontaneously arrive. These may be desirable (target) species as well as unwanted, invasive and expansive weedy and ruderal species.

**3)** If possible, exploitation should be planned in a way preserving as many natural and near-natural habitats in the close surroundings as possible, so that subsequent colonisation is facilitated.

**4)** During exploitation, the dumping of various waste material should be accompanied by continuous research into the occurrence of legally protected species and other ecologically valuable species and their communities. These may appear at the exploited site and can sometimes be supported or at least preserved with even simple means. Also reclamation plans could be adapted to their benefit.

**5)** A large majority of sites disturbed by mining or other activities in the Czech Republic have the potential to restore through spontaneous succession. This may in some cases be regulated, blocked or reversed. It is a potential that does not have to be utilised everywhere. At least 20% of the area of an exploited site can realistically be left to spontaneous succession, even meeting the demands by reclamation companies, foresters, etc. This should be an acceptable compromise. The utilisation of spontaneous succession is economically very profitable.

**6)** Since young succession stages are often valuable, it would be good to purposefully create or at least maintain these by occasional disturbance. Open vegetation is sometimes more favourable for biodiversity than dense shrub and tree stands, which spontaneously develop in most disturbed areas.

**7)** Diverse terrain should be preserved or possibly created. A high geodiversity is the basis of high biodiversity. No nutrient-rich material should be introduced.

**8)** The costs of ecologically sound management should preferably be paid from the obligatory payments by mining companies, which are determined for the prevailing technical reclamations (forestry reclamation in the form of planting monocultures of sometimes even alien species; agricultural reclamation using commercial, species-poor grass-clover seed mixtures).

**9)** After exploitation has ended, the most valuable mining sites and other post-industrial sites should be designated nature reserves or at least prominent landscape elements.

Generally spoken, if mining and similar activities do not destroy the site valuable from the perspective of nature or e.g. archaeology or disturb the scenery, they can be a benefit. Biologically valuable areas can really be created by mining (for details, see Řehounek et al. 2015). A condition is however that the area is not technically reclaimed. It is important to preserve a diverse relief and low nutrient level. Mining sites and other disturbed sites are often substitute habitats for vanishing plant and animal species. Nutrient-poor habitats are scarce in our eutrophicated landscape, but mining can create them. However, no nutrient-rich, organic material, such as topsoil layers, wood chips, hammer-milled bark, sewage plant tailings, etc. must be brought into the mining sites, as often happens in the case of technical reclamation. An increase in nutrient level supports competitively strong, ubiquitous species which suppress others. This way often monotonous, ecologically inappropriate areas arise. It is good to keep in mind that spontaneous or slightly controlled succession is on average much cheaper than technical reclamation. It runs for free, even if its possible regulation may demand some finances. However, the costs of this kind of reclamation does not reach such staggering sums as e.g. the €120 million invested from the state budget into the reclamation of the Tuchlovice dumps in the Kladno region, or the slightly smaller sum of money for the reclamation of the Radovesice spoil heaps in the Most region (which cost as much as €78 thousand per hectare).

**Fig. 3.** Quarry near Ondřejov, Vysočina region, where vegetation is spontaneously establishing. (K. Prach)

The advantages of spontaneous succession are also documented by the results of case studies (Vojar et al., p. 169; Mudrák & Frouz, p. 174).

Besides sites created by mining, particularly various spoil heaps, stone and sand quarries, and exploited peatbogs, also detailed information on the restoration of ecosystems in sedimentary basins is available in the Czech Republic (Kovář 2004, Tropek a Řehounek 2012). A study dealing with this habitat is included in the previous (Kovář et al. 2012) as well as this volume (Kovář et al.). Ore and slag-ash sedimentary basins have specific problems because of their susceptibility to wind erosion and the fact that they sometimes contain toxic material. They therefore require, more often than mining sites, various technical measures.

## Restoration of ecosystems on arable land

First of all it is good to mention that different types of ecosystems can be restored on arable land and in various ways: forest (by artificial planting or spontaneously), grassland ecosystems (mostly by a combination of spontaneous processes and human interventions), wetlands (sometimes artificially, e.g. by creating a fishpond on a former field, sometimes spontaneously – see below). Also the restoration of ecosystems on arable land has received quite some attention in the Czech Republic. Already in the 1970s and the early 1980s, comprehensive research into spontaneous succession on abandoned fields in the Bohemian Karst was carried out, led by Marcel Rejmánek of the Geobotany Dept. at the Faculty of Science of Charles University, Prague. Its results were published collectively (Osbornová et al. 1990, Prach et al. 2007) and the research has eventually been extended to other abandoned fields in the country (Prach et al. 2014; see also Prach, p. 193).

Succession leads in most cases to shrub and tree stands. This is well visible, among others, in military training areas (Vojta et al., p. 188). Only in the driest places in warm regions of the country a sort of shrubby steppe, sometimes even pure grassland, may spontaneously regenerate. On the

**Fig. 4.** Former field at moderately humid site near Mšeno, abandoned for approx. 20 years and encroached mainly by *Acer pseudoplatanus*. (K. Prach)

**Fig. 5.** Example of spontaneously revegetating road verge near Hrádek nad Nisou. (K. Prach)

**Fig. 6.** Diverse marshes spontaneously formed in abandoned sand quarry near Nová Bystřice. (K. Prach)

**Fig. 7.** Spoil heap after uranium mining at Okrouhlá Radouň – dry southern slope. (K. Prach)

**Fig. 8.** Spoil heap after uranium mining at Okrouhlá Radouň – humid southern slope. (K. Prach)

other hand in the wettest places, wetlands may successfully develop spontaneously, which is presently happening when drainage systems are clogged. In the middle of a field sometimes really small marshes may arise, which help diversifying the landscape and provide a refugium to a range of threatened organisms, plants as well as animals (Vittek 2017). They can also help reducing erosion and improve the water retention of the landscape. Preserving wetlands and protecting them from re-ploughing is mostly very desirable ecologically seen, even if the landowner or tenant may have another opinion, which is fully understandable.

A well-approved method of ecosystem restoration on arable land is the combination of spontaneous succession and regular mowing (or alternatively grazing). In this way, often species-rich meadows are created, which can very well be used in agriculture, and such a site is also kept from succession towards woodland. Examples can be found in the works by Lencová & Prach (2011) and collectively in the previous volume (Jongepierová et al. 2012), in Prach et al. (2014) as well as in the section dealing with grassland restoration in this publication. If a landowner or tenant does not need fodder immediately and mows his land and removes the biomass for several years, he will soon live to see a proper harvest of high nutritional quality. Even in the case of sowing a commercial, species-poor grassland mixture there is a certain chance that a species-rich meadow will arise through spontaneous colonisation processes. This takes however more time and the result strongly depends on the distance of meadow species growing in the surrounding and their abundance. Recreation of species-rich meadows on arable land by means of regional seed mixtures is described in the section on grassland restoration and in more detail also in a number of papers from the Bílé Karpaty Mts, where arable land has been 'regrassed' this way since 1999 (Jongepierová et al. 2015). The section on grassland restoration deals with methods of assisted meadow restoration on arable land in more detail.

**Basic principles of near-natural ecosystem restoration on arable land**

- It is first of all necessary to make clear what the target ecosystem on the abandoned field in question should be, whether a shrub or tree stand, a meadow or a wetland, and then to decide if we will rely on just spontaneous succession, assisted succession, sowing or, alternatively, on planting. (Arable land is sometimes spontaneously abandoned and then these questions are not dealt with.)
- To estimate how the succession – either spontaneous or assisted – will proceed, basic scientific information is needed. First it is necessary to establish (at least generally) what the main environmental factors are, in particular soil moisture, amount of nutrients and occurrence of desirable and unwanted (e.g. alien invasive) species in the surrounding. These factors essentially determine the succession process, which can at least globally be predicted with the obtained knowledge.
- If we do not wish to have a tree stand on the abandoned field (except for the driest and wettest places, woodland regenerates everywhere), the field must be regularly mown from not later than the third year after abandoning it. In many cases a meadow with a favourable species composition develops rapidly. An alternative is grazing, which mostly leads to a grassland with scattered shrubs.
- If we decide for sowing, the use of a regional grassland mixture is an ecologically appropriate way of restoring. In this case, regionality should be observed, i.e. no seed of unclear origin must be used. An alternative is hay transfer from an adjacent preserved meadow.
- If possible, arable land should not be artificially afforested on a large scale, with the exception of regions with a considerable lack of woodland. In any case this should be carried out with species corresponding to the site in question. Large-scale afforestation often leads to a deterioration of the landscape mosaic, a decline in species of open landscapes and an impoverishment of the landscape as a whole. On the other hand, planting linear landscape elements (lines of trees etc.) and solitary trees is an appropriate measure everywhere.
- Grasslands and wetlands in an advanced stage of succession are often re-ploughed. This concerns especially spontaneously restoring minor field wetlands. According to Government Decree No. 307/2014, effective since 1 March 2016, field wetlands can be included in the agricultural land register as ecologically significant landscape elements with the aim of securing their protection.

## Notes on other anthropogenic habitats

Rather detailed information on the process of spontaneous or slightly assisted succession is available. We therefore know of the possibilities of using succession in near-ecological restoration of not only mining sites and abandoned fields, but also of various other anthropogenic habitats, such as road banks, open corridors remaining after the former Iron Curtain, fishpond sediment dumps, etc. (for an overview, see Prach et al. 2008). In these habitats, principles similar to those mentioned above can be applied, with some specific ones depending on the nature of these habitats.

For example in the case of road banks, the risk of water erosion and gravitational movement must be taken into account. It is then necessary to adopt technical measures, such as the use of geotextile, stabilisation of the substrate by bringing on soil, and especially by quick sowing. This is, by the way, also imposed by relevant regulations. When sowing road banks, it would be good to use species-rich mixtures instead of commercial ones containing only a few species. Just as in the case of mining sites, an important requirement here is not to use nutrient-rich substrates and not to fertilise, as often happens. At the moment, the first experiments with using regional seed mixtures are being carried out in the Czech Republic. We consider planting of exotic trees absolutely inappropriate, because indigenous trees mostly establish well on their own (median motorway strips exposed to intensive salting, which are tolerated better by exotics, may be an exception).

Open corridors left after the former Iron Curtain can be entirely left to spontaneous succession, which has already progressed towards woodland after all these years. An exception may be formed by places where rare and threatened light-demanding species occur. It is then good to locally reduce tree stands. This also relates to fishpond sediment dumps, which arose mainly in the 1970s to the 1990s. Other anthropogenic habitats to be mentioned are dumpsites of domestic and other waste (landfills). These places are usually quickly remedied by isolating them and covering them with inert material (which is also necessary with regard to possible seepage and erosion). They are then always covered with organic soil, sown and planted with shrubs and trees. These are however often useless steps. Such a remedied site would better be left to revegetating on its own. A first foray into ecologically appropriate waste dump restoration was the use of regional grassland mixtures for the revegetation of dumpsites near Bojkovice and Strání in the Bílé Karpaty Mts.

## Restoration of disturbed landscapes

A future challenge is the restoration of entire disturbed landscapes, particularly their ecological functions and services, including e.g. reduction of water and wind erosion, improvement of water retention, i.e. of flood protection on the one hand and reduction of the impacts of drought and maintenance of soil fertility on the other, increasing scenic values and therewith also its recreational use, and of course also biodiversity (in the broadest sense) as well as landscape connectivity. One of the ways to support these ecological functions and services on the landscape scale is the above-mentioned ecosystem restoration on arable land. Any permanent vegetation protects the soil better than tillage. Vegetation on former arable land can also create suitable buffer zones along streams, around towns and villages, roads and nature reserves. Particularly the creation of wetlands, which retain water in the landscape, is desirable. Also planting linear green elements in the open landscape (mostly on farmland) is certainly a positive contribution, as is reported in the case study from the Bílé Karpaty Mts included in this publication.

With the growing spatial scale of any ecological restoration we reach the landscape scale. In other words, most restoration activities mentioned in this publication have a potential landscape dimension. An overview of the state of the Czech landscape and partly also possibilities of restoring it are given in the publication by Petřík et al. (2017). Restoration of complete landscape units unfortunately encounters many obstacles in our country. A basic problem is that there is no integrated landscape planning. Properly designed and realised territorial systems of ecological stability (TSES) could offer a chance to increase the ecological value and mainly functionality of the landscape. To the detriment of this,

**Fig. 9.** Abandoned village of Hraničky, Tachov region, 70 years after expulsion of the original inhabitants. (K. Prach)

**Fig. 10.** Former Iron Curtain near Rozvadov, encroached by trees. (K. Prach)

non-ecologists often engage in these systems, turning the realisation of proposed biocorridors and other TSES elements into technical solutions. Moreover, this is just a partial topic of the entire landscape restoration issue. The present state or our landscape is still very unsatisfactory, even though things have changed for the better since 1989. In particular relatively large area of arable land have been revegetated, the quality of air and water has improved, and probably also the general awareness of the importance of an ecologically sound landscape has grown. Further improvement of our landscape, i.e. mainly restoration of its ecological functions and services, depends to a great extent on political will, adjustment of legislation and economic stimuli, including various compensational measures for landowners. Let us hope we will live to see this realised anytime soon.

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# Ecological value and abundance of water habitats on spoil banks

Jiří Vojar, Jana Doležalová & Milič Solský

| | |
|---|---|
| Location  | Northern Bohemian/Most brown coal basin, Districts of Chomutov, Most, Teplice and Ústí nad Labem; 50°23'–50°38' N, 13°17'–13°56' E; elevation ca 250 m |
| Conservation status | NM (part of the area – Kopisty spoil bank), Regional Biocentre, SAC CZ0423216 |
| Restored area | 17 external spoil banks on an area of ca 85 km$^2$ |
| Financial support | No direct financial support |

## Abstract

The ecological value and conservation potential of post-mining areas have been increasingly recognised by scientists and conservationists during recent decades. Especially valuable are sites left to spontaneous succession, which constitute habitats with high species diversity, and habitats serving as refuges for threatened species including amphibians. The first aim of our study was to assess the water environment on reclaimed and unreclaimed post-mining sites from an 'amphibian' perspective. Therefore, we compared the proportion of water habitat area, the number of ponds and their habitat features in 14 technically reclaimed and 6 unreclaimed sections of spoil banks in the North Bohemian brown coal basin in the Czech Republic. We found that primary succession leads to more valuable water habitats for amphibians than technical reclamation does. As the next step, we compared the effects of technical reclamation and spontaneous succession on amphibian presence, species richness, and abundance of a model species, the agile frog (*Rana dalmatina*). Mean species richness per pond, the proportion of ponds occupied by amphibians, and the mean numbers of *R. dalmatina* clutches per pond were significantly higher at unreclaimed sites than at technically reclaimed sites. Despite the undisputed ecological value of unreclaimed post-mining areas, rigorous technical reclamation with negative effects on habitats as well as populations of threatened species however still prevails in the Czech Republic.

## Site description

Spoil banks are usually very extensive formations – often spanning hundreds of hectares – formed by the dumping of overburden from brown coal surface mining. They comprise a considerable part of the foothill basins in the vicinity of the Ore Mountains in the regions of Most and Sokolov. As is true of other, similar anthropogenic environments, such as quarries and sandpits, spoil banks tend to be spontaneously colonised by organisms from the surrounding landscape. In particular, technically untreated sections of spoil banks left to spontaneous development are very important for a number of species because such parts naturally turn into markedly diverse environments with various types of wetland and terrestrial habitats.

The diversity of environmental conditions on brown coal spoil banks is determined by the method of their establishment. In the case of brown coal surface mining, the overburden is dumped by stackers into approximately regular shapes, although these vary considerably in height (Fig. 1). The rugged morphology is a pre-condition of habitat heterogeneity which creates waters of various forms and sizes on the impermeable subsoil of tertiary clays in terrain depressions, while higher-positioned parts possess xerothermic features (Fig. 3). In addition to the aforementioned waterbodies (so-called rain-filled ponds), other waters occur at the bases of spoil banks where water is pushed to the surface by the immense pressure of the dumped material. These water sources are highly important in the colonisation of the

**Fig. 1.** The rugged morphology of brown coal spoil banks is caused by the method of their establishment and conditions the diversity of habitats created there. Internal spoil bank of the Šverma quarry in an early succession stage. (M. Hendrychová).

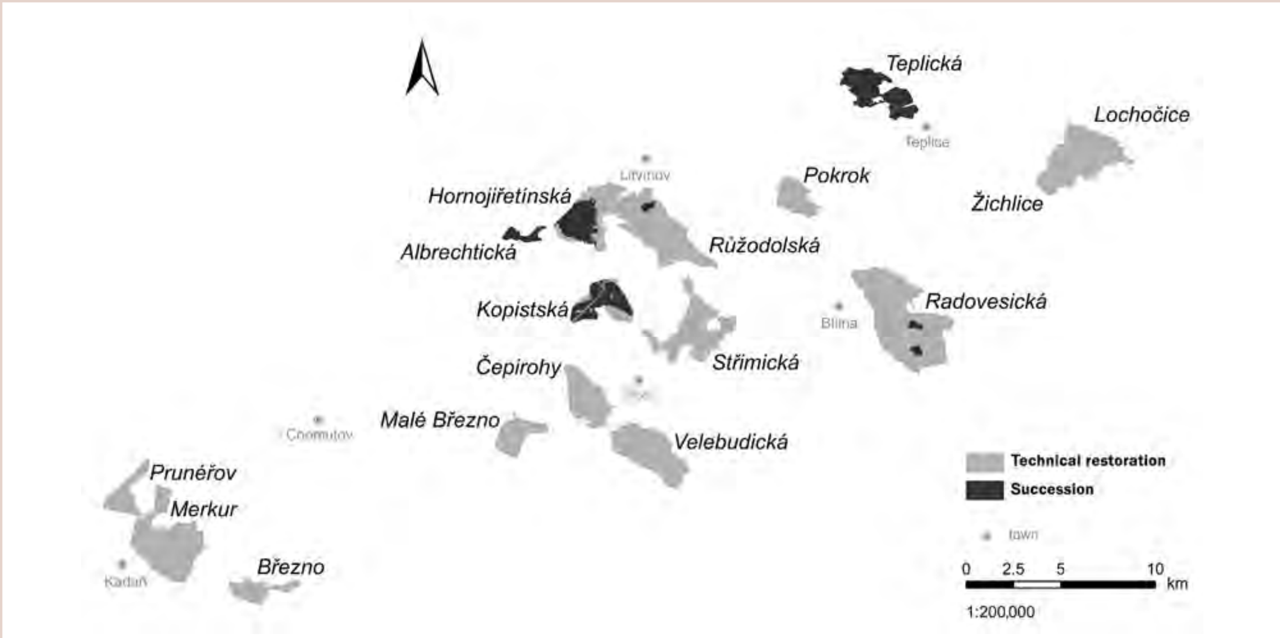


**Fig. 2.** Surveyed spoil banks in the North Bohemian brown coal basin. (After Doležalová et al. 2012a).

banks because they serve as a sort of 'stepping stones'. The heterogeneity of the water environment is increased by water-filled troughs, drainage ditches, and numerous small water surfaces created by the movement of heavy machinery. The biological value of these areas is markedly reduced, however, by inappropriate technical reclamation. Instead of a wide range of water habitats, only a few large water reservoirs are retained or established on the spoil banks in this case. The surfaces of the spoil banks are then drained and subsequently reclaimed, usually employing agricultural or forest land reclamation (Fig. 6).

## Restoration objectives

Increasing species diversity and occurrence of threatened species of initial successional stages by supporting habitat diversity on spoil banks. Using a combination of spontaneous succession and suitable ways of ecological restoration to establish a varied environment consisting of diverse habitats in different successional stages.

## Monitoring objectives

We aimed to compare technically reclaimed spoil bank areas with those left to spontaneous succession for various reasons. Specifically, the following factors were evaluated: (i) waterbody parameters like area, depth, and frequency of vegetation as well as number and connection of (distance between) water habitats; (ii) species diversity of amphibians, including a comparison of the abundance of agile frog (*Rana dalmatina*) as a model species.

## Monitoring methods

### Comparison of water habitat parameters

The study was carried out on 17 large spoil banks in the North Bohemian brown coal basin in the Czech Republic. Several spoil banks contained both spontaneously developing and technically reclaimed areas. We distinguished 14 technically reclaimed sections and 6 sections without technical reclamation with a total area of 84.3 km$^2$. In total, we found 924 waterbodies, 694 on spontaneously developing and 230 on technically reclaimed spoil banks. Each pond was located with GPS navigation and described according to different categories of characteristics important for amphibians: (i) pond features – acreage, maximum depth, shore slope, insolation of water surface, aquatic vegetation cover; (ii) prevalent type of surrounding terrestrial environment and reclamation status; (iii) number of ponds within 300 m, as a rate of connectivity with other ponds in the surrounding area. To compare the numbers of ponds belonging to a particular value of a categorical variable and method of reclamation, we used log-linear models with Poisson distribution of the response variable, i.e. pond numbers.

**Fig. 3.** A large number of various waterbodies occur on spoil banks left to spontaneous development. Technically untreated part of the Radovesice spoil bank. (M. Hendrychová).

### Comparison of species diversity and abundance

The study was conducted at 13 out of 17 large spoil banks in the North Bohemian brown coal basin, where we distinguished 13 technically reclaimed and 6 unreclaimed sites, where 890 waterbodies occurred. For a comparison of amphibian presence, species richness and *R. dalmatina* abundance between reclaimed and unreclaimed sites, a total of 176 ponds were selected, of which 98 were situated at 7 technically reclaimed sites and 78 at 6 spontaneously developing sites. For each waterbody, two surveys for the detection of amphibian occurrence (all monitored amphibian species) and abundance (only in case of *R. dalmatina*) were conducted by skilled researchers using standard surveying techniques under standard weather conditions. The abundances of *R. dalmatina* were assessed by counting clutches of this species. Waterbodies were characterised according to the features mentioned above. Generalised linear models were employed to compare amphibian species richness (number of species per pond) and *R. dalmatina* abundance between technically reclaimed and unreclaimed sites. To analyse the effects of environmental characteristics on amphibian presence, a direct canonical correspondence analysis (CCA) was run in Canoco for Windows 4.5.

**Fig. 4.** Agile frog (*Rana dalmatina*) is one of the most frequent amphibians on the Most spoil banks. (J. Doležalová)

**Tab. 1.** Water environment properties and agile frog abundance on technically reclaimed (TR) and non-reclaimed (N) spoil banks (SB) in the North Bohemian brown coal basin.

**Legend:** Recl. – type of reclamation: T = technical, F = afforestation, $A_{AR}$ = agricultural – arable land, $A_{GS}$ = agricultural – permanent grassland, H = hydrological, S = natural succession; WH – water habitat; WH/SB [%] – ratio of the total area of all WH to SB area; n – number. (After Vojar et al. 2012).

| Name of spoil bank | Recl. | SB area [ha] | WH area[ha] | WH / SB [%] | Average WH area [ha] | n WH | n WH / ha SB | n clutches | n clutches / ha SB |
|---|---|---|---|---|---|---|---|---|---|
| **Technically reclaimed spoil bank sites** | | | | | | | | | |
| Březno | T, F, $A_{AR}$ | 231.36 | 1.61 | 0.70 | 0.40 | 4 | 0.02 | 0 | 0 |
| Čepirohy | T, $A_{AR,}$ F | 496.77 | 9.66 | 1.94 | 0.25 | 39 | 0.08 | 15 | 0.03 |
| Hornojiřetínská – TR | T, F, H | 351.28 | 16.37 | 4.66 | 2.05 | 8 | 0.02 | 24 | 0.07 |
| Kopistská – TR | T, $A_{AR}$, $A_{GS}$ | 119.94 | 4.74 | 3.95 | 2.37 | 2 | 0.02 | 0 | 0 |
| Lochočice | T, $A_{AR}$, F | 847.81 | 2.13 | 0.25 | 0.30 | 7 | 0.01 | 8 | 0.01 |
| Malé Březno | T, F, $A_{AR}$ | 306.62 | 1.35 | 0.44 | 0.23 | 6 | 0.02 | 0 | 0 |
| Merkur | T, F, $A_{AR}$ | 100.45 | 3.97 | 3.95 | 0.23 | 17 | 0.17 | 0 | 0 |
| Pokrok | T, F, $A_{AR}$, $A_{GS}$ | 289.39 | 5.28 | 1.83 | 0.53 | 10 | 0.03 | 75 | 0.26 |
| Prunéřov | T, F, $A_{AR}$ | 261.31 | 4.67 | 1.79 | 0.67 | 7 | 0.03 | 5 | 0.02 |
| Radovesická – TR | T, $A_{AR}$, F | 1,483.00 | 14.34 | 0.97 | 0.42 | 34 | 0.02 | 136 | 0.09 |
| Růžodolská – TR | T, F, $A_{GS}$ | 952.99 | 33.52 | 3.52 | 0.44 | 76 | 0.08 | 298 | 0.31 |
| Střimická | T, F, $A_{AR}$ | 743.55 | 16.98 | 2.28 | 1.41 | 12 | 0.02 | 0 | 0 |
| Velebudická | T, F, $A_{AR}$ | 729.32 | 1.32 | 0.18 | 0.16 | 8 | 0.01 | 0 | 0 |
| Žichlice | T, F | 103.35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Reclamation – average** | | **501.22** | **8.28** | **1.89** | **0.68** | **16.43** | **0.04** | **40.07** | **0.06** |
| **Non-reclaimed spoil bank sites** | | | | | | | | | |
| Albrechtická | F, S | 89.85 | 0.24 | 0.26 | 0.01 | 26 | 0.29 | 54 | 0.60 |
| Hornojiřetínská – N | F, S | 352.71 | 33.40 | 9.47 | 0.14 | 242 | 0.69 | 1.488 | 4.22 |
| Kopistská – N | F | 359.06 | 14.64 | 4.08 | 0.04 | 334 | 0.93 | 1.294 | 3.60 |
| Radovesická – N | S | 57.34 | 5.42 | 9.45 | 0.09 | 61 | 1.06 | 63 | 1.10 |
| Růžodolská – N | F, S | 31.28 | 1.76 | 5.61 | 0.15 | 12 | 0.38 | 41 | 1.31 |
| Teplická | F | 519.31 | 23.58 | 4.54 | 1.24 | 19 | 0.04 | 399 | 0.77 |
| **Succession – average** | | **234.93** | **13.17** | **5.57** | **0.28** | **115.67** | **0.57** | **556.50** | **1.93** |

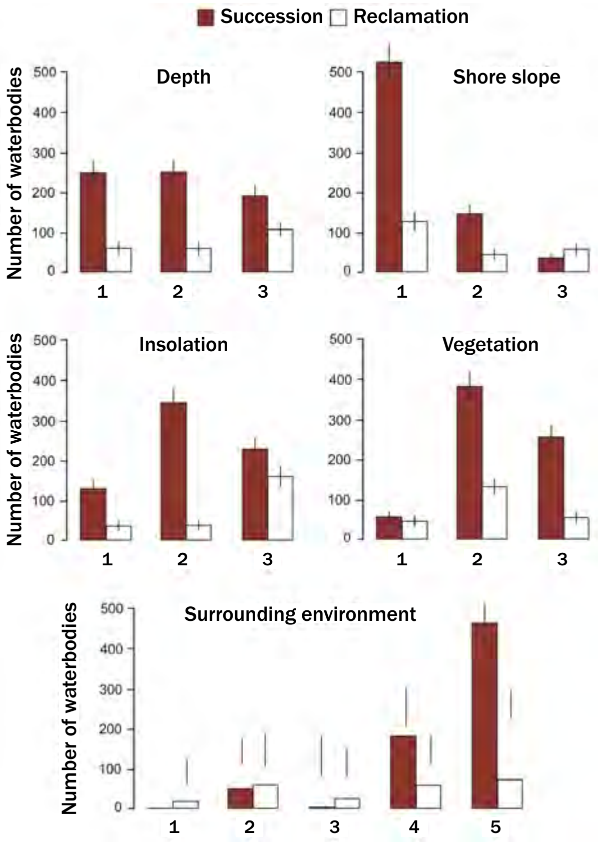


**Fig. 5.** Number of ponds according to habitat parameter and reclamation status of spoil bank sites (Succession vs Reclamation). Depth: 1 = <0.5 m; 2 = 0.5–1.5 m; 3 = >1.5 m; Shore slope: 1 = <30°, 2 = 30–55°, 3 = >55°; Insolation (in % of water surface): 1 = <5%, 2 = 5–75%, 3 = >75%; Vegetation (cover in % of water surface): 1 = <5%, 2 = 5–75%, 3 = >75%; Surrounding environment: 1 = initial successional stages, 2 = arable land, 3 = grassland, 4 = forest steppe, 5 = forest. (After Doležalová et al. 2012a).

## Results

### Comparison of water habitat parameters

The overall proportions of waterbody and number of ponds are many times higher in spoil banks left to spontaneous development. Due to the considerable number of waterbodies on non-reclaimed spoil banks, ponds are located close to one another and are therefore accessible to amphibians. These conditions support the development of extensive and viable (meta)population structures not seen in open landscapes. On the Horní Jiřetín spoil bank, for example, there are on average 18 other waterbodies within 300 m of each pond, most of which are colonised by amphibians. Furthermore, waterbodies on spontaneously developing spoil banks were found to have properties more suitable for amphibians than waterbodies created as part of technical reclamations have. The former predominantly included small ponds with gently sloping embankments, partially filled with water vegetation. In contrast, the latter have typically larger areas and depths as well as steeper banks, thus limiting the development of littoral vegetation (Fig. 5, Table 1).

### Comparison of species diversity and abundance

In total, 9 of the 21 Czech species of amphibians were detected on spoil banks of the Most region. Although the majority of detected species were found on both types of spoil banks, the proportions of water surfaces colonised by these species was generally higher on spoil banks left to natural succession. For example, agile frog was recorded in 60% of waterbodies on unreclaimed spoil banks, while it was present in only 21% of these habitats on reclaimed spoil banks. Similar findings were recorded for smooth newt (*Lissotriton vulgaris*, 31% vs 20%), fire-bellied toad (*Bombina bombina*, 21% vs 12%), and marsh frog (*Pelophylax ridibundus*, 62% vs 49%). The only species recorded more frequently on reclaimed spoil banks was common toad (*Bufo bufo*, 5% vs 10% of colonised waterbodies). This species is however known as a species without pronounced environmental requirements, having the ability to reproduce in various types of waters.

The diversity of amphibians was higher in spontaneously developing than in reclaimed spoil bank sections (on average 1.95 vs 1.2 species per waterbody). Demonstrably more waterbodies were colonised by amphibians on non-reclaimed spoil banks (88.5%) than on technically reclaimed spoil banks (69.4%). The more suitable parameters of waterbodies on spontaneously developing spoil banks were found to be even more prominent in relation to agile frog abundance. The average number of its clutches per waterbody was approximately six times higher on unreclaimed spoil banks as compared to reclaimed spoil banks (9.05 vs 1.65 clutches), when comparing the number of clutches per hectare of water, the difference was 32 times higher (1.93 vs 0.06 clutches, Table 1).

## Conclusions

The rugged terrain found on spoil banks without technical reclamation creates a more diverse environment and more numerous ponds with conditions suitable to amphibians, thus resulting in greater diversity and abundance. Other studies on particular taxonomical groups in various types of post-mining areas have reached similar conclusions (e.g. Harabiš et al. 2013, Hendrychová et al. 2008, Hodačová & Prach 2003, Holec & Frouz 2005, Prach & Hobbs 2008, Šálek 2012, Tropek et al. 2010). Our results thus confirm the high conservation potential of areas affected by mining, although that potential is still insufficiently exploited in the Czech Republic (Řehounek et al. 2010, Tropek & Řehounek 2010, Zavadil et al. 2011).

## Acknowledgements

The presented text is based on original articles published by Doležalová et al. (2012a) and Vojar et al. (2016a), also presented to the expert public in the journals Ochrana přírody (Vojar et al. 2012, Doležalová et al. 2012b) and Fórum ochrany přírody (Vojar et al. 2016b), where more information on this topic can be found.

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**Fig. 6.** In technical reclamations, the terrain is levelled, drained and prepared for cultivation by bringing on suitable topsoil. The upper part of this image of the Radovesice spoil bank shows an environment created by spontaneous succession, while the lower part shows the results of technical reclamation. (M. Hendrychová).

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# Ecosystem restoration of spoil heaps using spontaneous succession

Ondřej Mudrák & Jan Frouz

| | |
|---|---|
| Location | Surrounding of the town of Sokolov; 50°9'–50°16' N, 12°30'–12°46' E; elevation 500–650 m |
| Conservation status | Part of Regional Biocentre |
| Restored area | 300 ha |
| Financial support | €19–56 thousand per hectare of reclaimed area, €370 per hectare of area overgrown by succession. Although the total cost of spontaneous succession is significantly lower than classical reclamation measures, savings are achieved mainly in the implementation stage. Preparation of the restoration, preceding survey and subsequent monitoring may be more expensive for spontaneous succession than for conventional reclamation. |


## Abstract
Surface mining of lignite substantially impacts the landscape, destroying the original ecosystems on a large spatial scale. This chapter summarises the results of a long-term research of assisted reclamation and spontaneous recovery of these ecosystems in a post-mining landscape.


## Initial state
Since the 1950s, lignite has been mined in surface mines in the Sokolov region (Frouz et al. 2007). The lignite layer is located there at a depth of more than 100 m. For its excavation, a large amount of the overburden material has therefore to be removed and deposited on a heap. The original ecosystems are either removed or overlaid by spoil. The restoration starts here on bare substrate of Tertiary origin, which is mostly Miocene clay of the Cypris formation (Rojík 2004).

**Fig. 1.** Spontaneously vegetated spoil heap with levelled surface, 11 years after substrate deposition. (O. Mudrák)

For successful restoration of these post-mining sites the soil formation is essential. It is a spontaneous process (without direct human assistance) taking place on both reclaimed and unreclaimed (spontaneously developing) sites (Frouz et al. 2008, 2009). Soil formation is affected by many factors, but the interaction of plants and soil macrofauna, mainly earthworms, is probably the most important. Unreclaimed, spontaneously developing sites have an important educative and scientific value, as they allow for the study of succession on the landscape level.

## Restoration objectives
Supporting successional processes which improve most of the non-productive landscape functions, such as soil restoration, protection against erosion, improvement of the water regime and, connected to these, supporting rare species of plants, animals and fungi.

## Monitoring methods
Ecosystem development was monitored in a comprehensive way and included most of the important organisms – microbial communities, soil fauna, algae, higher plants and invertebrates living above the ground. Soil development was also monitored. For the study of individual groups of organisms as well as that of individual soil parameters, always a standard methodology for each particular group was used.

## Measures applied
The total area affected by mining in the Sokolov region which is or will be reclaimed is approximately 9,200 ha. In this area mainly forest reclamation (approximately 5,600 ha) is applied. Different tree species are planted directly into the spoil substrate, which is not fertilised or otherwise improved. On an area of approximately 1,900 ha, hydrological reclamation is used. Small waterbodies (especially lakes smaller than 1 hectare) are often created on the heaps. These are designed to retain water and improve water chemistry before it leaves the post-mining area (because of the high $CaCO_3$ content in the substrate, water in the post-mining area usually has a higher pH than in the surrounding streams, Frouz et al. 2007). In most of the hydrological reclamation area, however, flooding of the remaining surface mine pits (hundreds of hectares, currently mainly the Medard mine) is applied. About 1,500 ha is intended for agricultural reclamation (mainly pastures created by sowing grass-clover seed mixtures). An area of approx. 200 ha falls in the category of 'other reclamations' (Stýs et al. 2014).

**Fig. 2.** Spontaneously revegetating spoil heap without levelled surface, 11 years after substrate deposition. (O. Mudrák)

A considerable part of the post-mining site area (dozens of hectares) is left to spontaneous succession. Since this is not an officially recognised reclamation method, its area is not exactly quantified. It is mainly included in forest reclamation or in the 'other reclamations' category. A part of spontaneously developing areas is included in hydrological reclamation. Depressions, especially at the margin of the spoil heaps, often create wetlands or water bodies. Succession on Sokolov spoil heaps has a strong ecosystem restoration potential, which is evident from the unreclaimed areas.

## Results
### Soil development
The substrate is deposited on heaps in the form of mud stones compacted by calcium carbonate ($CaCO_3$). During weathering, mud stones are continuously decomposed into smaller and smaller lamellar fragments, until they finally (usually 20–30 years after depositing) turn into amorphous clay (Frouz et al. 2008). Very shortly after substrate deposition, heaps are spontaneously (without intentional human intervention) colonised by plants. Earthworms (*Aporrectodea caliginosa*, *A. rosea*, *Dendrobaena octaedra*, *Dendrodrilus rubidus*, *Lumbricus rubellus* and *Octolasion lacteum*) colonise the heaps spontaneously, approximately 15 years after substrate deposition. They are probably mainly brought in with soil on the planted tree saplings (Pižl 2001). The accumulation of plant litter as food for earthworms and the breakdown of lamellar structures in the substrate allow their communities to develop. The earthworms mix the plant litter lying on the surface with the mineral substrate and enrich it with organic matter. The consumption of a considerable amount of soil also creates stable soil structures, which significantly influence plant nutrition and the water regime of the substrate (Frouz et al. 2008). This is because amorphous clay binds a large amount of water by adhesion and water therefore becomes less accessible to plants. The gradual breakdown of lamellar structures thus leads to a decrease in the availability of water for plants. Creation of soil structures (especially stable aggregates) by earthworms improves water availability (Cejpek et al. 2013).

Incorporation of organic matter into the substrate fundamentally alter substrate properties. Shortly after deposition, the pH ($H_2O$) of this substrate is between 8 and 9, but due to organic matter accumulation decreases to 5–6 during the succession (Frouz et al. 2008). The substrate is relatively well supplied with phosphorus (about 1200 $mg.kg^{-1}$). Due to the high pH, however, its availability to plants is relatively low, but increases during the succession. The total nitrogen stock is low in the freshly deposited substrate and, depending on the ambient conditions, later increases to 1000–2500 $mg.kg^{-1}$ (Frouz et al. 2008, Šourková et al. 2005). The formation of an organo-mineral soil horizon by earthworms is important not only for plants but also for microbial and fauna communities, especially for Oribatida, Collembola, Protura, Diptera and Nematoda (Frouz et al. 2008).

**Fig. 3.** Unreclaimed spoil heap 29 years after substrate deposition, spontaneously encroached by *Salix caprea*, with suppressed understorey. (O. Mudrák)

However, the earthworm communities vary considerably between different dominant plant species (Frouz et al. 2009), which is probably due to the quality of their litter. It is because litter is an important source of food for earthworms and litter chemical composition, structure, and consequent digestibility depend on the dominant species (Frouz 2013). Under some trees, such as *Alnus glutinosa* and *A. incana*, a 93 mm thick layer of mull humus (A horizon) is formed in the soil profile within 28 years. At unreclaimed sites encroached by spontaneously establishing shrubs and trees, the soil-forming process is slower: within 28 years, the A horizon layer is on average 27 mm thick (Frouz et al. 2013, Mudrak et al. 2010). However, with increasing age of the sites, this difference decreases, and after 40 years it is already very small.

**Vegetation development**

Shortly after the substrate deposition, ruderal plant species such as *Poa compressa*, *Tanacetum vulgare*, *Tussilago farfara* and *Calamagrostis epigejos* prevail. However, tree seedlings, mainly willow (*Salix caprea*), birch (*Betula pendula*) and aspen (*Populus tremula*), establish rather fast as well and become dominant in unreclaimed areas with ongoing succession.

**Fig. 4.** Spoil heap spontaneously encroached by trees and shrubs, 46 years after substrate deposition. (O. Mudrák)

The topography of a heap is essential to the early stages of succession. When the substrate is deposited, waves are generated due to the used technology (Fig. 2), but in current technological procedures waves are usually levelled shortly after deposition (Fig. 1). The wavy terrain supports establishment of trees, while the levelled topography supports the dominance of the competitively strong grass *Calamagrostis epigejos* (Frouz et al. 2018). The establishment of trees in early stages of succession accelerates further development of the plant communities. If trees do not establish in the first years after substrate deposition, the development towards woodland is considerably longer. Surveying the vegetation of freshly created heaps can thus significantly help to identify sites with the greatest potential for spontaneous succession (Frouz et al. 2015a, Mudrak et al. 2016a).

After 20 years, trees form stands with a closed, compact canopy. They are usually dominated by *Salix caprea*, which largely suppresses herbaceous species in the understory (Fig. 3). As our manipulative experiment showed, *S. caprea* does this mainly by belowground competition for nutrients and water or by other belowground interactions. Aboveground competition for light is less important (Mudrák et al. 2016b). Later

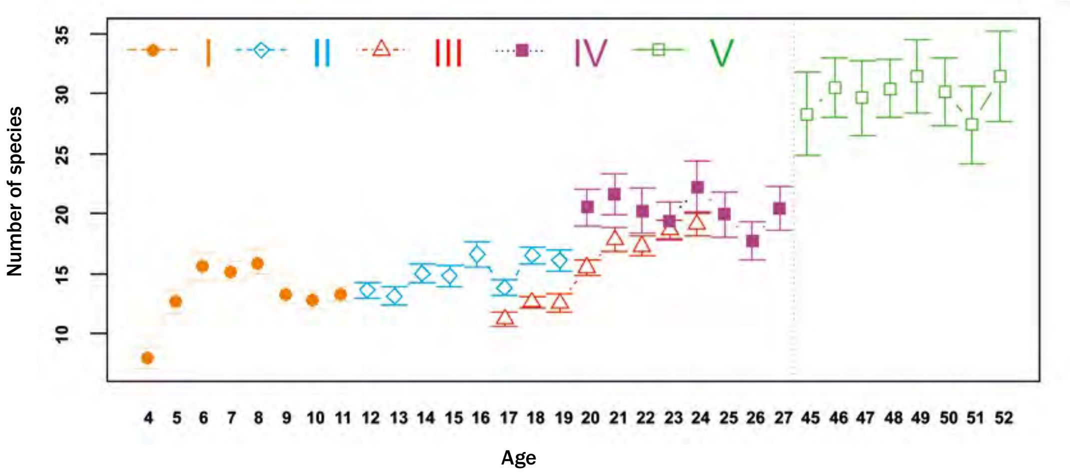


**Fig. 5.** Development of plant species richness at five unreclaimed sites of different age. At each site, 10 permanent plots of 25 m$^2$ were fixed and observed annually in the years 2007–2014. Site I was created in the year 2003, site II in 1995, site III in 1990, site IV in 1987, and site V in 1965. Error bars indicate standard errors of the mean, see Mudrák et al. (2016).

(between the 20$^{th}$ and 30$^{th}$ year of the succession) *S. caprea* stands are replaced by birch and aspen with a richer understorey. At this time, also the activity of soil macrofauna creates more favourable soil conditions. The suppression of early succession species together with soil improvement promotes the establishment of more sensitive, late-successional forest and meadow species (Fig. 4). After more than 40 years, the succession leads to a sparse forest dominated by birch and aspen with a relatively species-rich understorey (up to 51 species per 25 m$^2$). In this stage, meadow species such as *Arrhenatherum elatius*, *Festuca rubra*, *Plantago lanceolata*, and *Lotus corniculatus* are common, but the competitive *Calamagrostis epigejos* also increases in abundance, suppressing other species (Frouz et al. 2008). The development of species richness during the succession is shown in Fig. 5 (Mudrák et al. 2016a). At the same time, seedlings of late-successional tree species, especially oak (*Quercus robur*) and beech (*Fagus sylvatica*), appear in the understorey. Establishment of these trees is more successful at unreclaimed sites than in reclaimed alder plantations (Frouz et al. 2015a). Another interesting finding is that 25 years after succession, unreclaimed sites have a comparable or higher wood biomass production than alder plantations at reclaimed sites of the same age (Frouz et al. 2015b).

At sites reclaimed by means of afforestation, where adverse abiotic conditions of early successional stages have been overcome, the soil conditions are related to undergrowth productivity rather than to its species diversity. Areas with the best developed soil profile have the highest vegetation cover and biomass production, but this is largely due to a single species, the grass *Calamagrostis epigejos*, whose cover negatively correlates with the number of species in the understorey.

When comparing six types of reclaimed sites (20–33 years old) where each type was afforested with one or two tree species of the same genus. i.e. alder (*Alnus glutinosa*, *A. incana*), larch (*Larix decidua*), spruce (*Picea omorika*, *P. pungens*), pine (*Pinus contorta*, *P. nigra*), oak (*Quercus robur*) and lime (*Tilia cordata*), with unreclaimed spontaneously overgrown sites of the similar age mainly covered by willow (*Salix caprea*), birch (*Betula pendula*) and aspen (*Populus tremula*), the highest number of vascular plants was found in the understorey of oak (on average 19 species per 25 m$^2$). Reclaimed sites planted with oak did not differ statistically from areas with spontaneously established trees (on average 17 species per 25 m$^2$). The lowest number of species was found in alder plantations (on average 10 per 25 m$^2$, Mudrák et al. 2010).

**Rare and endangered species**

Spoil heaps, in particular unreclaimed sites left to successional development, host many rare and endangered species. For example, the toad *Bufo calamita* has the largest stable population of the Czech Republic here. Of other amphibians, these sites are inhabited by the toad *Bufo viridis*, the frog *Pelobates fuscus*, the newts *Triturus cristatus*, *T. vulgaris* and *T. alpestris*, the frogs *Rana lessonae*, *R. ridibunda* and *Hyla arborea*. Rare and endangered birds observed here include water rail (*Rallus aquaticus*), bluethroat (*Luscinia svecica*), wheatear (*Oenanthe oenanthe*) and penduline tit (*Remiz pendulinus*) (Frouz et al. 2007). Rare and endangered plants occurring here include mostly orchids such as *Epipactis palustris* and *Listera ovata*.

**Fig. 6.** Afforestation of Sokolov post-mining sites – in the foreground a one-year old plantation of larch (*Larix decidua*), in the background a 35-year old larch planting established in the same way. (O. Mudrák)

## New insights and recommendations

Incorporating spontaneously revegetated areas into a new post-mining landscape leads to an increase in biodiversity at the levels of species and communities and to an improvement of the scenery. It also has important educative and scientific functions. For the practical implementation of spontaneous succession in restoration planning it is important to make a survey of natural conditions (especially spontaneous tree establishment) in early successional stages. In addition, spontaneous processes can relatively quickly restore the soil functions of the spoil, especially when trees (such as alder) produce litter suitable for macrofauna. The relatively expensive overlay of the spoil with an organic substrate layer (as is often the case in other mining areas) was not necessary here. However, sites with developed soil profiles are favourable for competitive plant species, such as the grass *Calamagrostis epigejos*. Support of soil-forming processes can thus lead to further expansion of this grass and similar species, which will lead to suppression of species of the plant communities. In this view, it is more appropriate to support tree species producing litter less favourable for soil macrofauna (e.g. oak).

## Acknowledgements

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**Fig. 7.** Approx. 55-year old spontaneously vegetated spoil heap in the Sokolov region. (K. Prach)



# Plant-ant interactions in habitat restoration on abandoned tailings

Pavel Kovář, Ota Rauch, Pavel Pech, Romana Prausová, Markéta Dvořáčková, Michal Štefánek & Pavel Vojtíšek

| | |
|---|---|
| Location | Elbe floodplain near Chvaletice, eastern Bohemia, 50°02' N, 15°26' E; elevation 200 m |
| Conservation status | No particular protection |
| Restored area | 40 ha |
| Financial support | No direct financial support |

## Abstract

This study deals with the interaction of plants and ants, an ecologically important phenomenon in the spontaneous ecosystem restoration of an unreclaimed ore tailing containments near the town of Chvaletice. Mechanisms accelerating vegetation succession include in particular the distribution of seeds by ants and facilitation of vegetation development by superficial bioturbation (building of ant nests). The resulting effect is an increase in plant diversity in plots occupied by ants.

## Initial state

The complex of post-industrial deposits at Chvaletice consists (except for the slag-ash waste sedimentation pond constructed later at the power station of the 1970s) of three ore tailings as the remains of former pyrite exploitation in a surface mine at the northern boundary of the Železné hory Mts (Iron Mountains) opened in 1952. Sulfidic shale and carbonate Fe-Mn ore waste were the main side-products of sulphuric acid production. The substrate was transported hydraulically to the sedimentation basins as a water suspension (Kovář 2004). The Chvaletice surface mine was closed in the mid-1970s, after which two of the three waste ponds were reclaimed in a conventional way (partly agriculturally, partly by planting trees and shrubs, Kovář 1979). The third and smallest sedimentation basin never reached its maximum deposition capacity. Its drained surface remained untouched until the early 1980s, when it became an object for the monitoring of further development and testing of spontaneous colonisation by organisms (Kovář et al. 2011). The most essential change in the process of primary succession was that ca 5 m tall, dense tree stands (Prausová et al. 2017), as a rule dominated by *Betula pendula*, locally with admixed *Betula pubescens*, and *Populus tremula*, became the oldest succession stage in the vegetation mosaic of the waste pond.

The ecotoxicological aspect of the dumpsite plays an important role in its restoration (Kovář 1990). High concentrations of heavy metals, extreme pH values and high contents of sulphur and phenolic substances complicate spontaneous processes leading to a natural restoration of ecosystems (Vos & Opdam 1993, Prach et al. 2016). The surface of the substrate is periodically and mosaically covered with efflorescences (released from gypsum and jarosite). Secondary salt accumulation is determined by the duration of periods of drought in the vegetation season. In deeper layers of the

**Fig. 1.** Surface crust created by retrogradation of reopened places of the abandoned sedimentation basin with visible route of *Lasius* ants. (P. Kovář)

substrate, a strongly consolidated horizon with brown-red iron oxides and gypsum developed (Rauch 2004). The unreclaimed deposit, whose development was not influenced by any management measures therefore remained treeless for a long time. In such a toxic environment, vascular plant diversity is usually low. The substrate surface at the described sites is often covered by biological soil crusts which arise spontaneously and represent an analogy to crusts found in semiarid and desert environments (Evans & Johansen 1999, Hroudová & Zákravský 2004). In both types of environment, the crusts are typically formed by mushroom mycelium, cyanobacteria, algae, lichens, mosses and liverworts (Neustupa et al. 2009). The initial state of the surface in this stage disables vascular plant colonisation (Palice & Soldán 2004, Pohlová 2004) because its rugosity is insufficient (having an extremely low ability to intercept and retain plant seeds transported by wind) and a humus layer is completely absent (no biotic nitrogen, no carbon fixation). The surface crust dynamics support the transport and building activity of ants (Jarešová 2001), which become one of the most important factors contributing to an acceleration of vegetation succession and in the particular case of waste ponds logically also to disintegration of the crust and structuring of the substrate profile (Dostál et al. 2005, Vlasáková et al. 2009, Kovář et al. 2013).

## Restoration objectives

Restoring vegetation stabilising an industrial spoil-tip of toxic substrate using natural processes of vegetation succession as much as possible.

## Monitoring objectives

Assessing the effect of changes in ant species composition on vegetation succession and changes in their bioturbation activity at the substrate surface on plant diversity and vegetation development.

## Monitoring methods

The site with two reclaimed and one abandoned (unreclaimed) ore waste pond at Chvaletice has been studied since the 1970s (Kovář 1979, 2004, etc.). Searches for ant species in the waste pond in the course of the vegetation season were repeatedly carried out in the years 1998–2000 (surface cover of the plateau covered by a mosaic of lichens,

**Fig. 2.** Seed supply facility for the removal of seeds exploited by *Formica* ants. (P. Kovář)

**Tab. 1.** Two sets of supplied seeds, the first one harvested mid-June and early July, the second at the turn of July and August (2011).

| Set One | Set Two |
|---|---|
| *Potentilla argentea* | *Holcus lanatus* |
| *Rumex acetosella* | *Hieracium laevigatum* |
| *Holcus lanatus* | *Plantago lanceolata* |
| *Calamagrostis epigejos* | *Trifolium arvense* |
| *Trifolium dubium* | *Calamagrostis epigejos* |
| *Poa pratensis* | *Melilotus officinalis* |
| *Trifolium repens* | *Senecio jacobaea* |
| *Vicia hirsuta* | *Lotus corniculatus* |
| *Agrostis capillaris* | *Picris hieracioides* |
| *Plantago lanceolata* | *Trifolium repens* |
| *Lychnis flos-cuculi* | *Vicia cracca* |
| | *Lathyrus tuberosus* |
| | *Cirsium arvense* |
| | *Centaurium erythraea* |

mosses, herbs and shrubs; Jarešová 2001, Jarešová & Kovář 2004) and 2011–2012 (more differentiated vegetation mosaic including young tree stages; Vojtíšek 2012, Matejicek & Kovar 2015). The ant species composition was monitored in fixed quadrats of 10 × 10 m in each succession stage of the vegetation. For the three most frequent ant size classes in the quadrats, the incidence of nests was recorded. In the years 1998–2001 this concerned *Tetramorium caespitum*, *Lasius niger* and *Formica rufibarbis*, in 2011–2012 the last one was replaced by *F. pratensis*. The latter species, building hill-shaped nests, was only discovered in the most advanced succession stages, i.e. in the second period. Several times per vegetation season (June to September) an assortment of ripening seeds from the surrounding of the waste pond were periodically offered close to the nests (Tab. 1).

For the seed-supply experiments, we used a series of dishes with the base rim situated on the level of the soil surface and having a lid for protection. After a defined exposure time (8 hours, i.e. from 10 am to 6 pm) during the highest day activity of ant workers, the removal of seeds of each plant species was quantified.

We also compared the increase in plant species when enlarging the sampling in a part of the waste pond densely covered with ant nests with a part not occupied by ants (except for a few sporadic nests, usually not lasting long after young queens had established them). In order to exclude any other factors having effects on plants, in particular differences in substrate conditions, both plots with small squares measuring 15 × 15 cm in a random design were experimentally sown with several plant species (*Holcus lanatus*, *Vicia hirsuta*, *Plantago lanceolata*, *Agrostis capillaris*, *Trifolium repens* and *Rumex acetosella*) from the surrounding of the sedimentation pond.

Plant lists for both areas were made in a series of quadrats of which the side was doubled each time, starting with a size of 1 × 1 m (four for each quadrat size). A study of possible changes in chemical parameters of the substrate in ant nests is currently conducted by Jílková et al. (2017, see also Frouz & Jílková 2008).

## Results

Myrmecochory, i.e. the distribution of seeds by ants, tested here by means of supply dishes, was based on seed attractiveness, not on the distance ants needed to transport the seeds (the dishes were always located in the close vicinity of a nest to avoid removal by competing ants). Most of the supply in 2011 was taken away by *Formica pratensis*, i.e. a species associated with the so far oldest vegetation succession stages with a tree layer. *Lasius niger* and *Tetramorium caespitum* did not differ much in the total amount of seed they removed (Fig. 3). This outcome differs significantly from the results of a study by Jarešová (2001) using the same method at the same site. Here, most seeds of all supplied plant species were taken away (in 1998–2000) by the medium-sized *Lasius niger*. It is however a fact that of the large-sized ants (genus *Formica*), the 'consumers' were each time other species than in an analogical experiment in 1999 (the dietary needs may be species-specific, just as the size of nests, i.e. the number of individuals in them).

Over 10 years, the succession of ants saw a multiple increase in their diversity. Their latest known state (2015) included 24 species (see Tab. 2 for a list).

*Formica sanguinea*, *F. pratensis* and *Lasius umbratus* represent a group of temporarily parasitic species exploiting nests of already settled pioneer species, such as *Formica cunicularia*, *F. fusca* and *F. rufibarbis*, *Lasius niger*, *L. platythorax* and related species, to take control of the space.

**Tab. 2.** List of ant species at the waste pond of Chvaletice (2015). Highlighted names indicate species not recorded in the years 1998–2001.

| |
|---|
| *Camponotus ligniperda* |
| *Dolichoreus quadripunctatus* |
| *Formica cunicularia* |
| *F. fusca* |
| *F. rufibarbis* |
| *F. cinerea* |
| *F. sanguinea* |
| *F. pratensis* |
| *Lasius niger* |
| *L. flavus* |
| *L. platythorax* |
| *L. umbratus* |
| *Leptothorax acervorum* |
| *L. gredleri* |
| *L. muscorum* |
| *Myrmica rubra* |
| *M. ruginodis* |
| *M. rugulosa* |
| *M. sabuleti* |
| *M. scabrinodis* |
| *M. schencki* |
| *Solenopsis fugax* |
| *Temnothorax crassispinus* |
| *Tetramorium caespitum* |

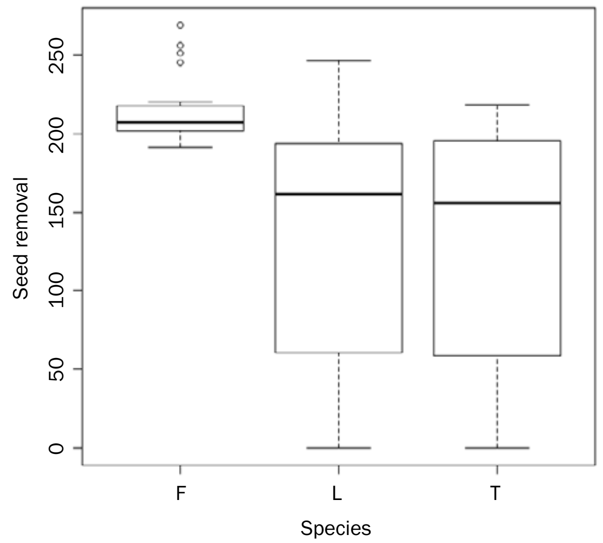


**Fig. 3.** Comparison of average seed 'consumption' per supply (2011–2012) for three dominant ant species in descending order of size class (F – *Formica pratensis*, L – *Lasius niger*, T – *Tetramorium caespitum*). (After P. Vojtíšek)

The curves showing dependence of number of plant species on increasing area were obtained from the surface of the deposited substrate, where it is easy to detect one large area with a high incidence of ant nests of a large number of species and another large area where – although visited by ant workers – nests are absent or only scarce and usually remain for a short time (Fig. 4).

The curve is considerably steeper in the plot densely occupied by ant nests as compared to the plot without or with just a sporadic occurrence of nests (the highest number of nests in a group of four 10 × 10 m quadrats was 30 per plot).

Effects of other factors than the presence of ant colonies which could be a reason for differences between the monitored plots, were excluded experimentally: seedlings of 6 selected plant species from the surrounding of the waste pond, sown in a random arrangement of small squares in the compared plots, did not show any statistically significant differences (see Monitoring methods).

## Conclusions

After approx. 10 years of monitoring the vegetation development (2011–2012) on an unreclaimed ore waste pond (in comparison to the years 1998–2001), the following conclusions can be drawn:

- Experiments with supplying seeds of plants from the surrounding showed that ants take a relatively large amount of the seed offered to their nests: first most seeds were removed by *Lasius niger*, but 10 years later most seeds were removed by *Formica pratensis*, which only appeared after more advanced succession stages had developed, i.e. with the presence of full-grown trees and shrubs. *Lasius niger* and *Tetramorium caespitum* removed about the same amount of seed. Part of the transported seeds germinated in the proximity of their nests, and part of the seedlings survived. Some species are able to create a viable population completing the succession stage of the

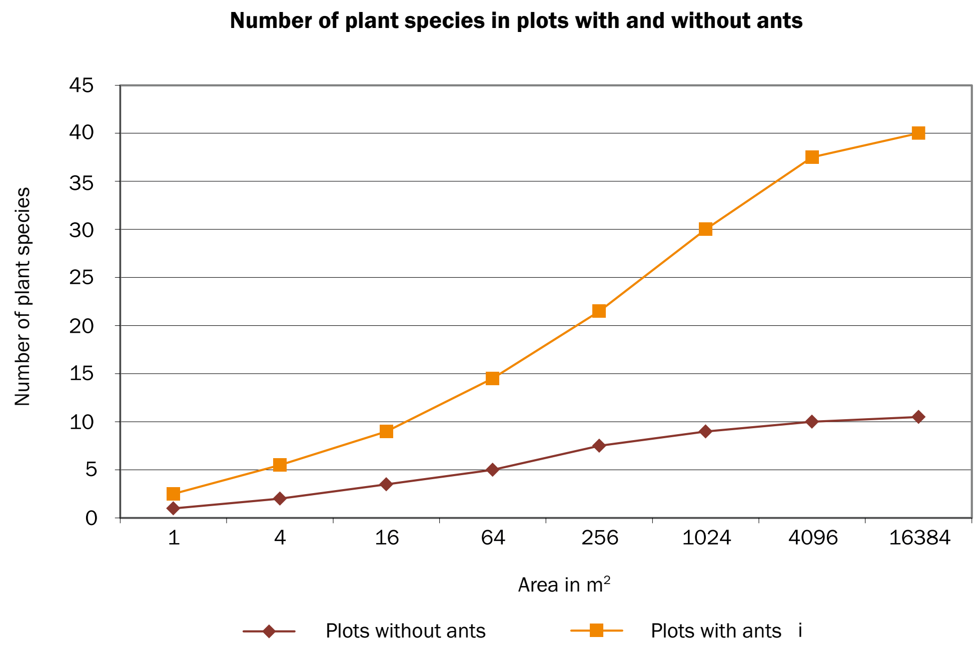


**Fig. 4.** Dependence of number of plant species on increasing area of abandoned waste pond plateau, in an area with scarce ant nests and in an area with a high density of ant nests. Data from 2011. (After P. Vojtíšek)

established vegetation, e.g. small-seeded *Vicia* species and some grasses.

- A nearly double increase in the number of ant species was recorded. Species of more advanced succession stages, *Formica sanguinea*, *F. pratensis* and *Lasius umbratus* (usually having a temporarily parasitic way of life associated with their colonisation of the new space) appeared. Pioneer species abundant at the start were suppressed considerably (*Formica cunicularia* and *F. rufibarbis*; *F. cinerea* disappeared completely). Also the total plant diversity increased by an order of magnitude.
- During the ten years, the surface of the waste pond also diversified habitat-wise (the surface still has bare spots which are unsuitable for the growth of vegetation due to their properties). At the start, the waste pond plateau lacked shrub and tree stands, while today these reach a height of around 5 m in a considerable area and have become part of the vegetation mosaic.

**Fig. 5.** *Myrmica schencki* at nest entrance. The chimney made from grass is very typical of the nest of this species. (P. Pech)

- Plots not colonised by ants (with ephemerous or scarce nests) differed considerably in number of plant species from plots with an order of magnitude higher incidence of ant nests, on which more plant species grew. The main cause of the increase in plant species richness is myrmecochory. The total number of plant species on the waste pond plateau in 1998 was not more than 10, whereas plant species numbers were approximately 4× higher in 2012.
- The surface crust is significantly disturbed, i.e. heterogeneity is raised, by ants (*Formica*, *Lasius*, *Tetramorium*) building nests on the surface. Moreover, especially in nests of ants of the genus *Formica*, the substrate is considerably enriched with nitrogen (Jílková et al. 2017).

## New insights and recommendations

Natural habitat restoration on the abandoned waste ponds with a substrate of ore origin at Chvaletice demonstrates the importance of a growing group of organisms which compose a developing ecosystem, whose function in certain stages of succession grows in importance. In middle vegetation succession stages, ants – i.e. myrmecochory mechanisms – play an essential role in the increase of plant diversity and in the transformation of substrate properties. In a timespan of approximately a decade, when part of the vegetation mosaic on the waste pond shifted from a herb/shrub formation to a dense tree stand, the number of plant species increased manifold (apparently through ants contributing substantially to seed distribution).



**Fig. 6.** Young nest mound of *Formica pratensis*. (P. Kovář)

**Fig. 7.** Space of former nest of *Lasius niger* with a mixture of seeds of small-seeded vetches, *Vicia hirsuta* and *V. tetrasperma*. (P. Kovář)

Parallel to the changes in vegetation and therewith also in micro-site conditions, the composition of the ant fauna successionally changes, and with the alternating ant species with different dietary preferences also the assortment and numbers of transported plant seeds change. It can be assumed that in the future, with maturing vegetation succession, the importance of types of zoochory other than myrmecochory will grow (the impact of wild boars and birds as consumers and distributors of fruits of climax trees is already rising).

The methods of monitoring, conservation and assistance should correspond to this and counted with in the management of the area. This means that massive disturbance of the stabilised waste pond surface should be prevented, as it would cause the material deposited in the deepest layers to weather again, thus reversing the succession (accompanied by toxicity). Similarly, in support of the vegetation-facilitating mechanisms by ants, organic litter (tree leaves, dead herbal biomass) should neither be removed nor added by means of mulching. The formation of a gypsum crust under the surface in the deeper layers of the waste pond, especially in exposed marginal parts, remains a problem. Here, the development of a root system of particularly trees and shrubs is blocked and subsequently plant cover is retrograded.

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**Fig. 8.** Vegetation mosaic of advanced successional stages with pioneer trees and open places on the original substrate with visible insolation in time of summer drought (survived by a very small number of the many germinated birch seedlings). Chvaletice ore tailing, summer 2017. (P. Kovář)



# Restoration of habitats of a critically endangered *Minuartia* species

Hana Pánková, Zuzana Münzbergová & Karel Kříž

| | |
|---|---|
| Location | Hadce u Želivky NNM, 49°41′01″ N, 15°07′55″ E; elevation 410 m |
| Conservation status | NNM, SAC |
| Restored area | 850 m$^2$ |
| Financial support | LIFE Programme, CUNC and LČR Biodiversity Conservation programme, ME Landscape Management and Restoration Programmes, Central Bohemian Region |

## Abstract

One of the populations of the Czech endemic sandwort *Minuartia smejkalii* is located in a rather small quarry with an illegal dumpsite and a large number of anthropogenic species. Its revitalisation included a combination of thinning of the vegetation and removal of the humus layer. The first stage was performed on a small scale and did not influence the species composition. In the second stage, soil was extracted down to the serpentine layer over the entire site, which opened up the vegetation considerably, in its turn leading to restoration of the habitat and improvement of the conditions for *Minuartia* populations as well as other target species.

## Site description

Hadce u Želivky NNM consists of two different vegetation types: crevice vegetation of serpentine rocks and rubble, and peri-Alpidic serpentine pine forests of the *Asplenion serpentini* alliance growing on steep rocky slopes above the water level of the Švihov reservoir (Želivka). On the upper plateau, the vegetation passes into a man-made pine forest (classified as altered boreo-continental) of the *Dicrano-Pinion* alliance, in the herb layer of which serpentine species grow, particularly *Thlaspi montanum*, *Potentilla crantzii* subsp. *serpentini*, and *Knautia serpentinicola*.

One of the most significant species is the Czech endemic *Minuartia smejkalii*, which occurs at only two sites (Hadce u Želivky NNM and Hadce u Hrnčíř NM). This species is protected and included in the category of Strongly Threatened Species according to Appendix II of Regulation No. 395/1992 of the Ministry of the Environment, relating to Act No. 114/1992. At the EU level it is a priority species according to Council Directive 92/43/EEC, demanding special territorial protection (Appendix II) as well as strict protection on the entire territory of the member state (Appendix IV). It is further included in the category of Critically Endangered Species (C1) of the Black and Red List of Vascular Plants of the Czech Republic (Procházka 2001) as well as the updated Red List (Grulich & Chobot 2017) and also in the international IUCN Red List (Walter & Gillett 1997). On international level it is further mentioned in the Convention on the Conservation of European Wildlife and Natural Habitats (Berne Convention, Appendix I).

In the Middle Ages, the described area was deforested and used for pasturing. Later, open pine forests, which were also grazed, occurred here. In the first half of the 19th century it was afforested, but grazing was still practised on steep slopes before the reservoir was filled with water. In the 1970s, the serpentine area was divided up and part of it irreversibly destroyed by two structures, the Švihov (Želivka) water reservoir and the D1 motorway. Their realisation led to abandonment of the original farming of the rocks and

**Fig. 1.** Initial state of the site in 2006: illegal waste dump. (H. Pánková)

**Fig. 2.** Serpentine rocks used to be overgrown with mosses and species of anthropogenic habitats. *Minuartia smejkalii* was only found on exposed rocks at the edge of the quarry. (H. Pánková)

**Fig. 3.** Exposing the serpentine bedrock and opening up the vegetation at the site led to a reduction in total vegetation cover, to an increase in the percentage of target species and to improvement of the state of the *Minuartia smejkalii* population. (H. Pánková)

management of the adjacent forests. Due to this, *Minuartia smejkalii* was divided into 7 isolated micropopulations, five natural ones on rock slopes, at one of which it has gone extinct, and two at secondarily created sites: the body of the original Protectorate motorway and a small rural serpentine quarry. The quarry arose at the turn of the 19th century and was abandoned before World War II. Here, characteristic serpentine vegetation with *Minuartia smejkalii* has developed. As a result of increased shading by full-grown pines, the serpentine bedrock has gradually been covered through accumulation of litter and a humus layer. This has led to the development of tall graminoids and to an easier establishment of shrubs and trees. It remains a question if the change in microclimate after the water reservoir was filled and the increase in $NO_x$ deposition from the nearby D1 motorway have a negative impact.

## Initial state

Before the revitalisation, the site was considerably shaded. In its lower part and on the periphery of the quarry, dense spruce and pine stands with admixed *Quercus robur* and *Frangula alnus* were present. A larger part of the site was taken in by an illegal domestic waste dump (see Fig. 1), which had caused enrichment of the soil with nutrients and led to ruderalisation of the site. The lower part of the site was strongly waterlogged. The high humidity manifested itself in a high cover of mosses which had locally overgrown protruding serpentine rocks completely. Graminoid and ruderal plant species (e.g. *Urtica dioica*, *Rubus idaeus* and *Galium aparine*) dominated the vegetation here, see Fig. 2. The serpentine bedrock was covered with a deep humus layer. *Minuartia smejkalii* only grew on serpentine rocks protruding at the periphery of the quarry (except for the area of the illegal waste dump, where it did not grow at all).

## Restoration objectives

Restoring site conditions suitable for the growth of *Minuartia smejkalii* and for the development of serpentine vegetation by means of exposing the serpentine bedrock and clearing the site.

## Measures applied

The revitalisation took place in two separate stages. Both were realised by CUNC LC Vlašim. The first measure was carried out in 2007, when the illegal dumpsite was removed from part of the quarry and spontaneously establishing spruce was eliminated in the southern part. This operation appeared to be insufficient and, moreover, dumping was resumed during later years.

In the years 2016–2017, under a LIFE project aimed at rescuing *Minuartia smejkalii*, the deep humus layer, ruderal vegetation and mosses were therefore completely removed from the lower part of the quarry as well as from the serpentine rocks (Fig. 3). An excavator was used for the work in the lower part of the quarry. Soil, vegetation and the moss layer from the rocks were removed manually. In order not to damage sandwort tussocks, the operation was not carried out in places where it was growing. Further, spruce trees and expansive shrubs and trees were cut in the southern part as well as on the periphery of the quarry.

## Monitoring methods

In 2006, permanent monitoring plots measuring 1 × 1 m were fixed in places with *Minuartia smejkalii*, and each plant in the plots was marked with a tag. Every year in the flowering time of the sandwort (second half of June) all the plants were counted and their fitness (tussock size, numbers of flowering and non-flowering stems) was measured. Based on this data the ratio between flowering and non-flowering stems was calculated, which is a parameter best characterising the condition of a population (Pánková & Münzbergová 2011). Assessment of the state of *Minuartia smejkalii* populations was based on a monitoring methodology for the species (Pánková 2011).

Assessment of the state of the habitat was performed by annually recording the total cover of the herb vegetation, the cover of the different plant, moss and lichen species and the amount of litter in the permanent plots. The species were divided into species of anthropogenic habitats (characteristic of X habitats or included in the Catalogue of Alien Plants, Pyšek 2012) and species of near-natural habitats (further referred to as target species) typical of preserved parts of Hadce u Želivky NNM and regarded to be indicators of the quality of the habitat. Each species was assigned an Ellenberg indicator value for light, temperature, nutrients and soil reaction (Ellenberg et al. 1992). Species bound to the created waterbody (Ellenberg value for humidity above 6) were exempted from the analyses. Abiotic conditions at the site were assessed by determining tree layer shading, total irradiation, chemical soil composition and depth of the soil horizon.

To determine the success of the measure, assessments of the state of the sandwort population and that of the habitat were combined in the years 2007–2011 and 2014–2017. Since the measures affect the entire site, the classical approach with parallel non-intervention control plots could not be used to assess the impact of the measures. Changes were therefore assessed in correlation with time.

## Results

### Shaded sites

After the first measure in 2007, the vegetation opened up as a whole (Fig. 4). During the following years the site became more and more shaded again by the growth of juvenile spruce and pine trees all around the quarry. Also shrubs and trees spontaneously establishing right in the quarry as well as along the asphalt forest trail caused considerable shading. These trees were removed during the operations in the years 2016–2017, thanks to which the shading rate dropped from over 75% to nearly 65%. Despite these operations the shading of the site is much higher than at sites with the highest fitness of *Minuartia smejkalii*, where shading reaches a rate of 40% (Pánková, unpubl.).

### Vegetation

The total cover of herb vegetation fluctuated between 35 and 45% in the years 2007–2009, but as of the year 2010 it rose to nearly 85%. The first measure in 2007 thus did not have an impact on the herb layer cover. By contrast, extensive thinning of the vegetation and removal of the humus layer at the site in the years 2016–2017 has led to a quick reduction of the total cover of the herb layer to the initial value of 40%.


**Fig. 4.** Shading by the tree layer in the years 2007, 2008, 2016 and 2017.

**Fig. 5.** *Minuartia smejkalii*. (H. Pánková)

The percentage of species of anthropogenic habitats and target species (Fig. 6) as well as their cover remained very stable over time, with around 20% anthropogenic species. The only exception was the year 2011, when – probably as a result of low precipitation – the cover of target species increased and the cover of species of anthropogenic habitats decreased. The year after, this ratio returned to the original state. Only the second measure, the effect of which was not apparent until the second year after its realisation, had a significant impact ($p < 0.001$) on the increase in the percentage of target species. The time lag was caused by the fact that species of anthropogenic habitats, e.g. *Rubus idaeus* and *Agrostis stolonifera*, colonise rather fast and thus occupied exposed spaces already in the first year after intervention. These species reached however a low cover. In the following vegetation season, many target species characteristic of preserved sites, e.g. *Potentilla crantzii* subsp. *serpentini*, *Knautia serpentinicola*, *Thymus praecox*, *Festuca ovina*, *Pimpinella saxifraxa*, including *Minuartia smejkalii*, appeared in these places, whereas ruderal vegetation did not develop further. The new species *Dianthus carthusianorum* subsp. *capillifrons* spread to the serpentine quarry from the surrounding woodland. The shift in species composition from species of anthropogenic habitats to target species was confirmed by

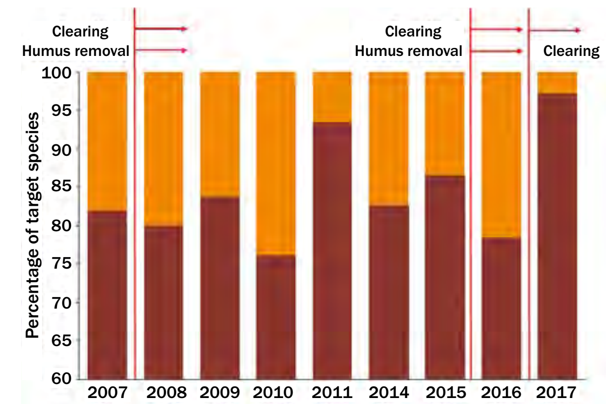


**Fig. 6.** Percentage of species of anthropogenic habitats, i.e. species characteristic of X habitats or included in the Catalogue of Alien Plants (Pyšek 2012) (orange), and target species characteristic of the preserved part of Hadce u Želivky NNM and regarded to be indicators of the quality of the habitat (brown).

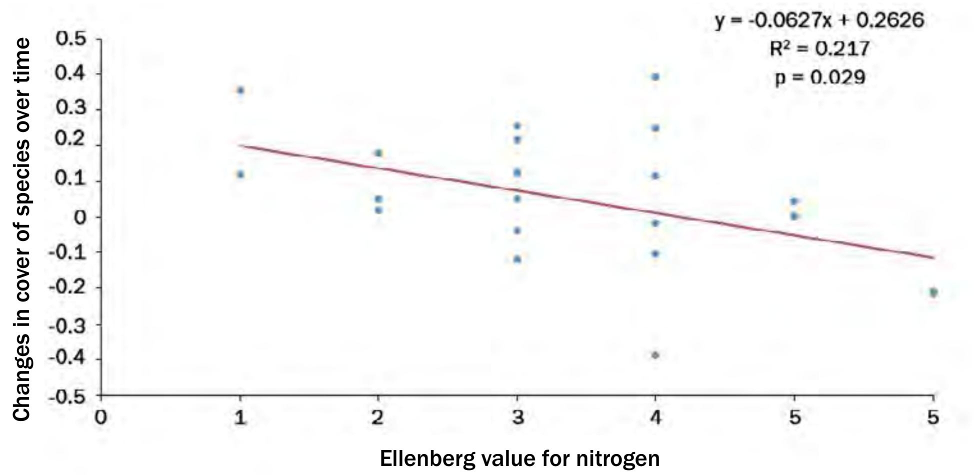


**Fig. 7.** Correlation between changes in cover of different plant species over time (2007–2011 and 2014–2017) and Ellenberg values for nitrogen. On the Y-axis, scores of species obtained from the RDA analysis are given. A positive value on this axis means that the species increased in cover during the years.

means of RDA analysis and a negative correlation between species cover over time and the Ellenberg value for nitrogen (Fig. 7). The target species have a low value for nitrogen because they occur in nutrient-poor habitats, whereas species of anthropogenic habitats prefer nutrient-richer soils.

**Sandwort population**

The *Minuartia smejkalii* population at the site long remained stable, but the ratio of flowering to non-flowering stems was found to be low (only 20–30%) as compared to the other sites. The largest number of tussocks was recorded in 2011. After that the number of sandwort plants drastically declined and their occurrence became limited to a small part of the original population (Tab. 1). The measures in the years 2016–2017 led again to an expansion of *Minuartia smejkalii* to the original and newly created places on the slopes and the bottom of the quarry. At the same time, the ratio of flowering to non-flowering stems increased significantly ($p < 0.001$) to a value of 40%. In 2017 the sandwort also started to spread to the woodland surrounding the quarry, but here it flowered less abundantly.

## New insights and recommendations

Comparison of both measures has shown that it is sometimes necessary for species bound to specific substrates to carry out very rigorous operations leading to exposure of the original bedrock. In this way the creation of suitable 'starting' conditions can be achieved, subsequently leading to rehabilitation of the original communities and the interactions and processes taking place in them. The rigorous measure had a positive impact on the species composition, shifting towards natural serpentine vegetation, as well directly on expansion of *Minuartia smejkalii* in the revitalised part, but also to the surrounding woodland. To assess the stability of the restored community in the long term it is however necessary to continue monitoring the vegetation and population of *Minuartia smejkalii* in the years to come.

**Tab. 1.** Numbers of *Minuartia smejkalii* tussocks at the site in the years 2006–2011 and 2014–2017.

| Year | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of tussocks | 117 | 98 | 106 | 86 | 93 | 203 | 54 | 40 | 42 | 90 |

## Acknowledgements

Our thanks go out to the Municipality of Bernartice, owner of the parcel, which enabled realisation of the measures, and finance providers, particularly project LIFE15 NAT/CZ/000818 and the Ministry of the Environment, Lesy České republiky, s.p. and the Central Bohemian Region. We also thank members of CUNC LC Vlašim for their voluntary management work.

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# Succession of woody plants in a military training area

Jaroslav Vojta, Josef Brůna, Eva Horčičková & Lucie Kačmarová

| | |
|---|---|
| Location | Marginal parts of Hradiště Military Training Area, Tocov (abandoned village), 50°18' N, 13°05' E; elevation ca 400–700 m |
| Conservation status | SPA, SAC |
| Restored area | Approx. 15 thousand ha |
| Financial support | No direct financial support |

## Abstract

The extensification of agriculture results in abandonment of relatively large areas on which shrubby succession stages develop and succession runs towards woodland. This study demonstrates, on the example of a marginal part of Hradiště Military Training Area, that extensive grazing as well as a complete non-intervention regime may be the appropriate management of such places.

## Site description

Hradiště Military Training Area in the Doupovské hory hills was established in 1953, causing the town of Doupov and more than 60 other human settlements to perish. Today only part of the territory is exploited as a military training area. The marginal parts were left to fate and successional changes have changed the former agricultural landscape consisting of a mosaic of fields, meadows, pastures and woodlands into a landscape of scrubland and thickets. At a model site around the abandoned village of Tocov, the most pronounced change took place in the course of the 1970s (Fig. 1), when woody plants became the dominant component of the landscape. Since that time, the initially interconnected non-forest land has been turning into a complex of isolated patches among continuous tree stands.

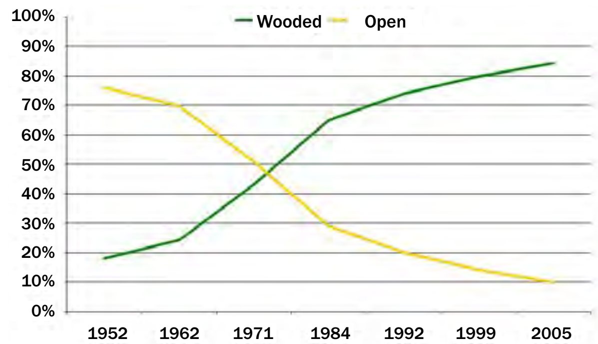


**Fig. 1.** Development of open and wooded vegetation percentages around the abandoned village of Tocov. (Brůna 2009)

## Restoration objectives

Restoring valuable ecosystems by facilitating, regulating or blocking spontaneous succession of shrubs and trees.

## Monitoring objectives

Assessing to what extent spontaneous succession of shrubs and trees can be regarded beneficial for the restoration of valuable ecosystems and how it must be possibly regulated, blocked or reversed.

1. Is succession in an abandoned landscape a positive phenomenon with regard to nature conservation?

2. Which measures can be proposed to preserve and restore the natural values of an abandoned landscape?

**Fig. 2.** Woodland rich in structure on former farmland. Uprooting and crown breaking are caused by heavy wet snow. (J. Vojta)

**Fig. 3.** Forests in the place of abandoned villages resemble scree forests in species composition as well as physiognomy. (J. Vojta)

## Measures applied

Spontaneous succession.

## Monitoring methods

In order to compare abandoned and cultural landscapes, a grid-based plant survey was carried out in 60 quadrants measuring 25 ha (surroundings of the abandoned villages Tocov, Tunkov and Lipoltov, and the inhabited villages Stráň, Krásný les, Lučiny, Svatobor, Jakubov and Osvinov (Vojta et al. 2012).

To assess the species diversity and vegetation heterogeneity on a small spatial scale, 133 groups of relevés of 1 m² plots were made, arranged at the tops of equilateral triangles with a side length of 4.33 m (Kubát 2010). This was carried out south of the abandoned village of Tocov.

**Fig. 4.** Open scrubland is the most valuable habitat regarding plant biodiversity. (J. Vojta)

Monitoring of the spread of woodland herbs was performed by detailed surveying in a quadrant of 25 ha in size north of Tocov and by extensive phytosociological surveying of dense tree stands in the surrounding of Tocov (relevés of 100 m², Drhovská 2007, Vojta & Drhovská 2012).

The impact of grazing by wild herbivores like red deer (*Cervus elaphus*), sika deer (*C. nippon*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) on the vegetation was determined by means of 24 enclosures (to exclude grazing) and grazed control plots. In each enclosure, the vegetation in 4 m² large plots and the volume of trees were monitored (Horčičková, unpublished data).

## Results

Already a 40% shading of the undergrowth by shrubs was found to cause a reduction in the number of species of open habitats by half (Fig. 5, Kubát 2010). However, the scrubs form patchworks where very variable light conditions can be found, resulting in a fine vegetation mosaic and a high β-diversity on a scale of a few square metres. In places without scrubs, heliophilous species like *Koeleria pyramidata*, *Festuca rupicola*, *Securigera varia* and *Thymus pulegioides* grow. In shaded places just a few metres away, we find more mesophilous and wood fringe species, e.g. *Dactylis glomerata*, *Brachypodium pinnatum* and *Trifolium medium*, while completely shaded places are most often inhabited by *Geranium robertianum*, *Geum urbanum* and *Aegopodium podagraria* (Kubát 2010). The scrub environment also benefits some rare species, which may occur massively here. These are e.g. *Orchis mascula*, *Gentianopsis ciliata* and *Ophioglossum vulgatum*. Surprisingly, grassland species were found to maintain better than in the surrounding farmed landscape. A more detailed analysis has shown that species of

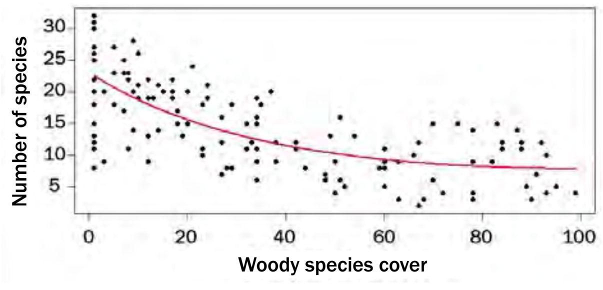


**Fig. 5.** Correlation between woody species cover and number of vascular plant species in plots of 1 m².

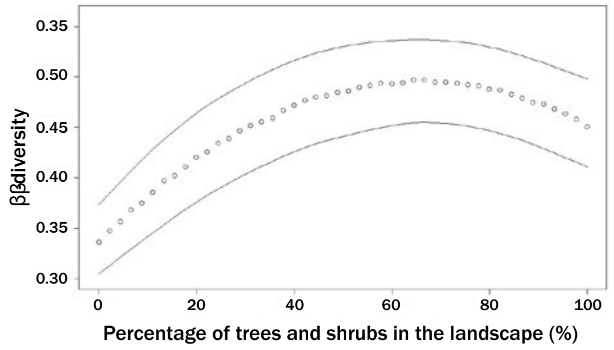


**Fig. 6.** β-diversity in a hypothetic landscape created by a random combination of relevés from scrubs (at least 10% shading, one third of all relevés have a shading of more than 40%) with relevés of open vegetation. The lines represent the 2.5% confidence interval.

nutrient-poor habitats (characteristic of the *Koelerio-Phleion phleoidis* and *Hyperico perforati-Scleranthion perennis* alliances) are typical of abandoned landscapes. This feature can most probably be attributed to the fact that landscapes abandoned in the post-war years did not experience the later intensification of agriculture with all its negative consequences (soil eutrophication, expansion of competitively strong species, elimination of some habitats) (Vojta et al. 2012).

With the current species composition, the site would have the highest vegetation diversity if the scrub occupied approx. 60% of the area (Fig. 6). An important condition is however that these scrubs should have an open character, since further densening of it leads to a rapid decline in heterogeneity and the total number of species. Grazing by wild ungulates slows down encroachment of minor open patches with shrubs. In the experimental enclosures preventing grazing and browsing, the shrub encroachment speed was three times higher in comparison to the unfenced control. Another biotic factor increasing plant diversity in open areas considerably is disturbance by wild boar (Horčičková 2010).

**Fig. 7.** Clearances in scrubs on shallow soil are particularly species-rich. (J. Vojta)

Open scrubs differ in physiognomy as well as species composition from dense scrubs dominated by hawthorn (*Crataegus* spp.) and pioneer woodland with *Fraxinus excelsior*, *Acer pseudoplatanus*, *Populus tremula*, *Betula pendula*, and in wet places also *Alnus glutinosa*. The species diversity of the tree and shrub layers is high, since many pioneer species mix with gradually establishing species of middle and climax succession stages (Vojta & Kopecký 2006). Combinations of shrubs or low trees and tall trees are very frequent. These stands are therefore very rich and dynamic in structure. Some pioneer species live to old age and are then uprooted or break under the weight of snow. Fallen trees are usually not removed. The dynamics of these pioneer stands thus resemble virgin forests. Forest species reach woodland on former farmland in the Doupovské hory hills exceptionally rapidly. The habitat is well colonised by species like *Galium odoratum*, *Hordelymus europaeus* and *Mercurialis perennis*. Surrounding forests or former hedgerows and scrub in fields are often source populations of these colonists (Drhovská 2007, Vojta & Drhovská 2012).

## Conclusions

The abandoned landscape of the Doupovské hory hills is unique in Central Europe by its large extent of natural habitats and its successional changes on a landscape scale. Without human intervention these changes lead inevitably to natural woodlands rich in structure. The succession process is however connected with a gradual disappearance of light-demanding species. Landscape restoration and conservation measures should lead to the preservation of a mosaic of habitats and various succession stages, and support natural succession at least in part of the area. These measures must at the same time be economically sustainable with regards to the enormous range of valuable habitats.

## New insights and recommendations

Three approaches (which may partly overlap) need to be combined to preserve the local landscape and its biodiversity.

1. Intensive management at sites of very rare and valuable species, leading to the preservation and restoration of habitats suitable for particular target species (only relating to a limited area; there is a large amount of literature available to realise this management).

2. Non-intensive measures leading to maintenance or locally to restoration of species-rich succession stages of dispersed scrubs.

With regard to the large area of open scrubs this can be realised only in case of economic interest complementary to the target of the approach. Non-intensive grazing by cattle in scrubs and open woodlands, connected with a moderate clearing of shrubs to secure permeability of the landscape,

**Fig. 8.** Woodland rich in structure on former farmland. (J. Vojta)

appears to be very effective. Such grazing is taking place in marginal parts of the military training area and has long-term positive effects. Today the vegetation structure resembles that of wood pastures. In areas where no domestic animals graze, we can count on support by hunting activities. Also creating corridors through the scrubs to facilitate hunting, on condition that the operation is repeated, has appeared to be positive so far. When clearing trees and shrubs, it is however necessary to preserve the mosaic character of the vegetation and to preserve the vegetation in places of former hedgerows, which are the refugia of many woodland species and also the site where old trees often grow. It would be very inappropriate to remove shrubs over a large area without further management of the open vegetation.

3. A strategy of non-intervention preserving the succession at its unique landscape scale. It is good to realise this approach on a relatively large area (up to half of the former treeless area). The formation of biologically valuable woodland here presupposes absence of forestry measures, particularly planting and large-scale felling.

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**Fig. 9.** Thickets with hawthorn and ash on former crop field. (J. Vojta)



# Restoration of ecosystems on arable land by spontaneous succession

Karel Prach

| | |
|---|---|
| Location | 173 old fields in all parts of the Czech Republic; elevation 170–756 m |
| Conservation status | Some sites situated in PLAs |
| Restored area | Approx. 150 ha |
| Financial support | No direct financial support |


## Abstract

Spontaneous succession on abandoned arable fields in the Czech Republic was studied. In some areas, also the development of vegetation on old fields left untilled but regularly mown soon after abandonment was monitored. An overview of late successional stages which spontaneously develop on old fields depending on their moisture, soil nutrient content and presence or absence of management is presented. It is demonstrated that spontaneous succession leads to ecologically favourable vegetation in most cases.


## Initial state

Spontaneous succession on former arable land can be divided into two basic categories: (a) succession without any intentional measures after abandonment of the field, and (b) succession influenced by subsequent management, mainly mowing or sometimes grazing. In the first half of the 20th century, arable land was abandoned only exceptionally. From the 1950s to the 1980s, various small and isolated fields and some badly manageable parts of fields were abandoned, most of them without subsequent management. Many fields were abandoned in the 1990s after cooperative and state farms had disintegrated. As a result of subsidies issued after the country had joined the European Union in 2004, these old fields were partly ploughed up again or regular mowing or grazing was introduced here.

## Monitoring objectives

Determining the variability in the process of spontaneous succession on former arable land on the scale of the Czech Republic, and assessing this variability with regards to the restoration of valuable ecosystems.

## Monitoring methods

Phytosociological relevés were recorded in sample plots 5 × 5 m in size on old fields of at least approximately known age. Other, published or unpublished relevés were excerpted. (A total of 282 relevés from old fields left unmanaged, i.e. without subsequent management, and some other records from old fields subsequently managed by mowing were available; relevés of some plots were repeated). Related information on environment factors were supplemented. Data were processed using ordination methods and generalised linear models with mixed effects. The methods and other details

**Fig. 1.** Old fields at dry sites are not always encroached by woody vegetation. (K. Prach)

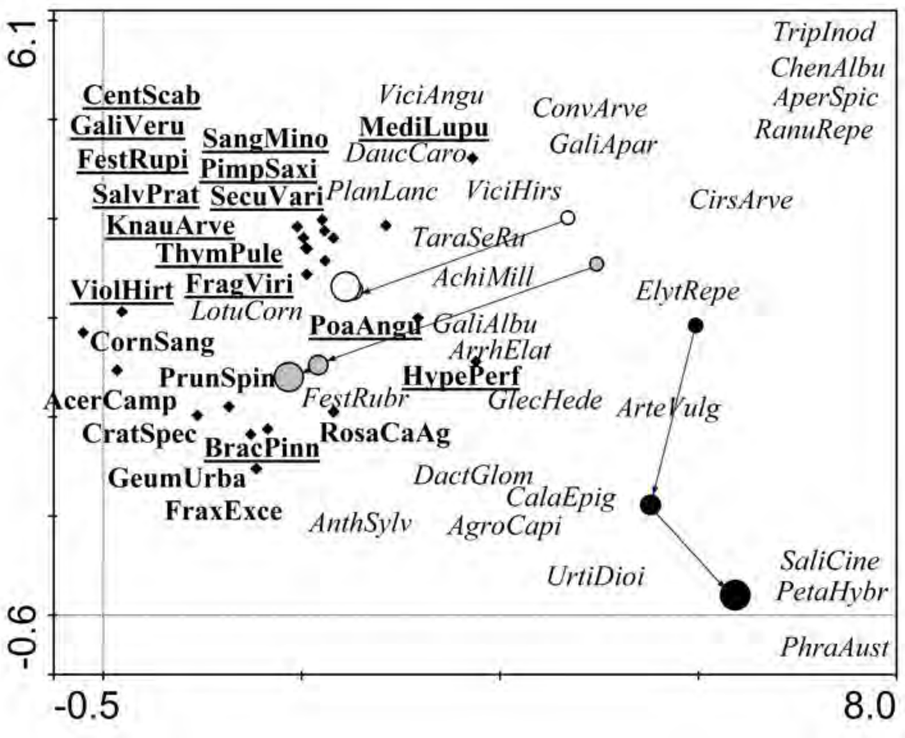


**Fig. 2.** Ordination (DCA) of species based on 282 relevés recorded on Czech old fields left without management and display of centroids representing 1–10-year (smallest symbols), 11–20-year and more than 20-year old (largest symbols) successional stages. Black symbols represent wet succession series, grey symbols the mesic, and empty circles the dry series. The first 50 species best matching the model are illustrated. Species abbreviations were made from the first four letters of the genus and the species names. Target species characterising xerothermic grasslands (*Festuco-Brometea*) are in bold and underlined, woodland species are in bold, and the other species are in italics. Spontaneous succession proceeds from weedy species towards xerothermic grasslands, scrub and woodland or wetlands depending on the moisture of the site. After Prach et al. (2014).

**Tab. 1.** Most frequent dominants of older successional stages (>20 years) on old fields left to spontaneous succession without subsequent management. Potentially dangerous and locally dominant species are given in brackets. Partly after Prach et al. (2007).

| Abandoned fields | Dry | Mesic | Wet |
|---|---|---|---|
| Nutrient-poor | *Pinus sylvestris*, (*Robinia pseudoacacia*) | *Betula pendula*, *Pinus sylvestris* | Data missing |
| Moderately rich | *Festuca rupicola*, *Bromus erectus*, *Brachypodium pinnatum*, (*Calamagrostis epigejos*) | *Betula pendula*, *Populus tremula*, *Crataegus* spp. | *Salix cinerea*, *Alnus glutinosa* |
| Nutrient-rich | *Bromus erectus*, *Calamagrostis epigejos* | *Fraxinus excelsior*, *Crataegus* spp., *Betula pendula*, *Calamagrostis epigejos*, (*Solidago canadensis*) | *Phragmites australis*, *Salix cinerea*, *Alnus glutinosa*, (*Aster lanceolatus*) |

of old fields left unmanaged are given in Prach et al. (2014), those of old fields with subsequent management (regular mowing) in Lencová & Prach (2011).

## Results

In general, three partial series of spontaneous succession on old fields can be distinguished: dry, mesic and wet (Fig. 2). Another important site factor is nutrient concentrations. Former arable fields can be generally poor, moderately rich or very rich in nutrients (Osbornová et al. 1990, Prach et al. 2007, 2014, Jírová et al. 2012). Under the Czech climatic conditions, combinations of these factors mostly lead to the vegetation types (in the case of spontaneous succession without subsequent management) given in Tab. 1. On a great majority of the old fields a formation of woody plants is created sooner or later (mostly in the second decade after abandonment). These are first often shrubs, usually *Prunus spinosa*, *Rosa* spp. and *Crataegus* spp. at dry and mesic sites, while *Salix cinerea* commonly appears at more humid sites. Gradually, also trees encroach the sites (see Tab. 1). At specific, mostly nutrient-poor sites where competition by the herb layer is lower, trees like *Betula pendula*, *Po- pulus tremula* and *Pinus sylvestris* may establish soon after abandonment. In the Czech circumstances, grasslands may restore by just spontaneous succession without subsequent management only at very dry or, conversely, at wet sites. At such sites, establishment of woody plants is disabled either physiologically or through competition by the herb layer. At dry sites in the warmest parts of the country, the species composition of older spontaneously established vegetation may come close to that of very valuable natural steppe vegetation (Jírová et al. 2012). (Of course, arable land was never located at really dry sites). At the opposite end of the moisture gradient, some old fields or their margins can be overgrown by *Phragmites australis*, which may block succession for a long time.

**Fig. 3.** Scrubby dry grasslands can be restored by means of spontaneous succession only at dry sites in the warmest regions of the country. Approximately 90-year old field in the Bohemian Karst (Český kras). (K. Prach)

**Fig. 4.** Restoration of species-rich grasslands on old field by means of spontaneous succession and regular mowing. Example from the White Carpathians (Bílé Karpaty), 25 years after abandonment. (K. Prach)

From the perspective of ecological restoration, all vegetation dominated by alien species and the expansive indigenous species *Calamagrostis epigejos* is undesirable, because its species diversity is very low. Also some spontaneously created dense scrub of e.g. *Crataegus* spp. may be species-poor. But even this may have a positive ecological function in the landscape, for example offering birds nesting opportunities, and can in many places create an appropriate buffer, e.g. around nature reserves or intensively managed crop fields.

On the other hand, older vegetation at dry, moderately nutrient-rich sites (often resembling natural steppe vegetation) is usually the richest in species. At dry sites in the warmest regions of the country, if they are not too eutrophicated, rare and threatened weed species (mostly archaeophytes) are often found in initial stages. Their presence does however not last long, although they may survive in the seed bank.

Direct gradient analysis of the entire set of relevés from the Czech Republic (Prach et al. 2014) showed that humidity of the site, characteristics of the substrate (acidic vs basic) and elevation had at least some statistically significant impact on the succession process. Generalised linear models with mixed effects demonstrated that old fields on dry basic substrates in the warmest parts of the country are the richest in species, and that the number of species generally increased during succession. This also counts for threatened species, although their total number decreases (mainly as the result of declining threatened archaeophytes). In general, the percentage of woodland and steppe species increases during succession, while that of archaeophytes, neophytes and synanthropic species decreases (Prach et al. 2014), which is in agreement with the general assumptions.

In case a regular mowing regime is initiated on a field soon after its ploughing has been ceased (ideally once yearly, at relative nutrient-poor sites also once every other year), grasslands (sometimes even species-rich ones) form within a few years. At dry sites in warm regions of the country these are covered with vegetation of the *Bromion* alliance, at mesic sites at low and middle elevations *Arrhenatherion* vegetation and in mountain regions vegetation of the *Polygono-Trisetion* alliance. We do not have sufficient data of good quality for humid sites, but restoration seems to direct towards the *Deschampsion cespitosae* alliance here. On the example of a large number of mown old fields in the preserved landscape of the Pošumaví region around the town of Vimperk it was shown that old fields did not significantly differ in species composition from permanent meadows in their vicinity after approx. 20 years (Lencová & Prach 2011). This was true even for fields which had been sown with a species-poor commercial grass mixture. Spontaneous colonisation by meadow species proceeded relatively fast and successfully here. In an analysis of 82 old fields in the Bílé Karpaty PLA, restored by means of commercial seed mixtures, regional mixtures (Jongepierová 2008) or natural succession, a number of 44 out of 108 target species spontaneously established within the first two decades (Prach et al. 2015). Target species were defined here as those typical of permanent species-rich White Carpathian meadows (for details, see Jongepierová et al., p. 76).

When grazing is introduced on an old field soon after its abandonment, mostly vegetation with dispersed woody plants, predominantly spiny shrubs (*Crataegus* spp., *Prunus spinosa* and *Rosa* spp.), is formed. Its density depends on grazing intensity and on the time when grazing is started. However, we still lack detailed quantitative data for better assessment.

## New insights and recommendations

Spontaneous succession on old fields, with or without subsequent management, mostly leads to ecologically valuable vegetation. An exception is formed by sites where alien or competitively strong indigenous species (usually *Calamagrostis epigejos*) occur. If a farmer does not need an immediate forage crop, we can almost always rely on spontaneous succession, ideally accompanied by regular mowing starting not more than three years after the field is abandoned. Especially in landscapes where permanent meadows or pastures have been preserved so far, grasslands with an ecologically favourable species composition is restored within about ten years. Such grasslands are often better in terms of diversity and scenery than thickets spontaneously established on old fields without subsequent management, although also these are ecologically more appropriate than crop fields.

All the above-mentioned vegetation types possess important soil-protection, anti-erosion and filtration functions and improve the hydrological balance of the landscape in contrast to arable land. They can in many places be used as buffer zones, e.g. around nature reserves. With regard to the ever high farmland tillage rate, restoring grassland, scrub and woodland vegetation remains desirable. Restoration of grasslands is recommended, since these can be easily ploughed again when needed and do not change the landscape scenery much. However, woodland may the objective of restoration in landscapes with a low rate of forest land.


## Acknowledgements

I would like to thank my colleagues who participated in the cited publications on which this contribution was based, particularly Alena Jírová and Kamila Vítovcová. This work was supported by grant GA ČR 17-9979S and resources of the Restoration Ecology Group of the Faculty of Science, University of South Bohemia, České Budějovice.


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**Fig. 5.** On most old fields, thickets are created by spontaneous succession. Old field of approx. 75 years old in the Bohemian Karst (Český kras). (K. Prach)



# Restoration of landscape structure on farmland in the White Carpathian Mts

Hedvika Psotová

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|---|---|
| Location | NE part of Bílé Karpaty (White Carpathians) PLA; municipalities of Brumov-Bylnice, Jestřabí, Návojná; elevation 350–460 m |
| Conservation status | PLA |
| Restored area | 614.7 ha (84 sites) |
| Financial support | Operational Programme Environment |


## Abstract

The company Javorník-CZ s.r.o., Štítná nad Vláří, which farms according to the principles of organic agriculture, has strived for restoring the traditional Wallachian landscape for a long time. Under the Operational Programme Environment, a number of measures have been realised concerning the organisation and utilisation of farmland, integration of disused plots and restoration of the landscape structure. The agricultural company aspires to follow up on traditional forms of agriculture, to support the preservation of the current values and to restore former natural and cultural-historical values of the area, and to facilitate reasonable agricultural production.


## Site description

The area concerned has been an agricultural grassland-woodland landscape since the time of Wallachian colonisation. As a whole, it is not very favourable for classical primary agricultural production. The local soils are not very fertile and the climate is rather harsh and has a submontane character. The development of the landscape has been connected to a considerable extent with the Castle of Brumov. The estate formed the basis of farming, while less valuable tracts were rented to small farmers.

Agricultural land was expanded by burning and clearing forests, and also by the farming of felled forests. A relatively intensive use of grazing was typical of the Brumov dominion: as early as the year 1528, herds of Wallachian sheep and goats, bred using sheepfolds, grazed in the dominion.

Non-intensive farming was preserved until the mid-20$^{th}$ century and has contributed essentially to the creation of the unique picturesque White Carpathian landscape with a strongly diversified field pattern and high biodiversity.

Two types of parcellation (field lay-out) have remained in the described area:

- Pseudo strip parcellation, which is distinguished by a lay-out of parallel, variously oriented strips (its orientation can mostly be read from cadastral maps or maps of the land cadastre);
- Block parcellation, characterised by irregular shapes and lay-out of the parcels (trees and shrubs are usually located at parcel boundaries).

## Initial state

Socialistic mass production meant a very drastic intervention into the landscape context, which consisted of clearing the landscape (eliminating hedgerows and sunken lanes, integrating parcels into large blocks), a massive increase in water erosion and a reduction in the biological potential of the soils. Remote, badly accessible tracts, where large-scale farming had become unprofitable, became gradually encroached by scrub.

Since 1996, when Javorník-CZ was established by transformation of a collective farm, a range of agricultural changes have been realised. In particular, forms of organic farming have been introduced, problematic arable land has been

**Fig. 1.** A country road lined with trees is a significant landscape element and, if well planned, has an anti-erosion function. (H. Psotová)

**Fig. 2.** Division of farmland blocks into smaller units at the site of Březová, Brumov-Bylnice. Linear contour plantings are arranged in a way minimising water erosion, at the same time allowing for continuation of large-scale tillage.

converted to grassland, management measures for grasslands have been taken in collaboration with the Bílé Karpaty PLA Authority, orchards have been planted, etc.

The idea of farming according to traditional principles was fully implemented in a comprehensive landscape restoration project, the first stage of which was realised in the years 2013–2016. It focused on the support of species-rich grasslands, revitalisation of landscape vegetation (orchards, lines of trees, scattered trees) and a general restoration of the scenery. The proposed measures were elaborated in agreement with the Bílé Karpaty PLA management plan.

## Restoration objectives

Including hitherto disused agricultural farmland into the farming system, protecting arable land from erosion, restoring the water regime of the landscape, delimiting specific landscape elements in farmland blocks, and creating a landscape vegetation system.

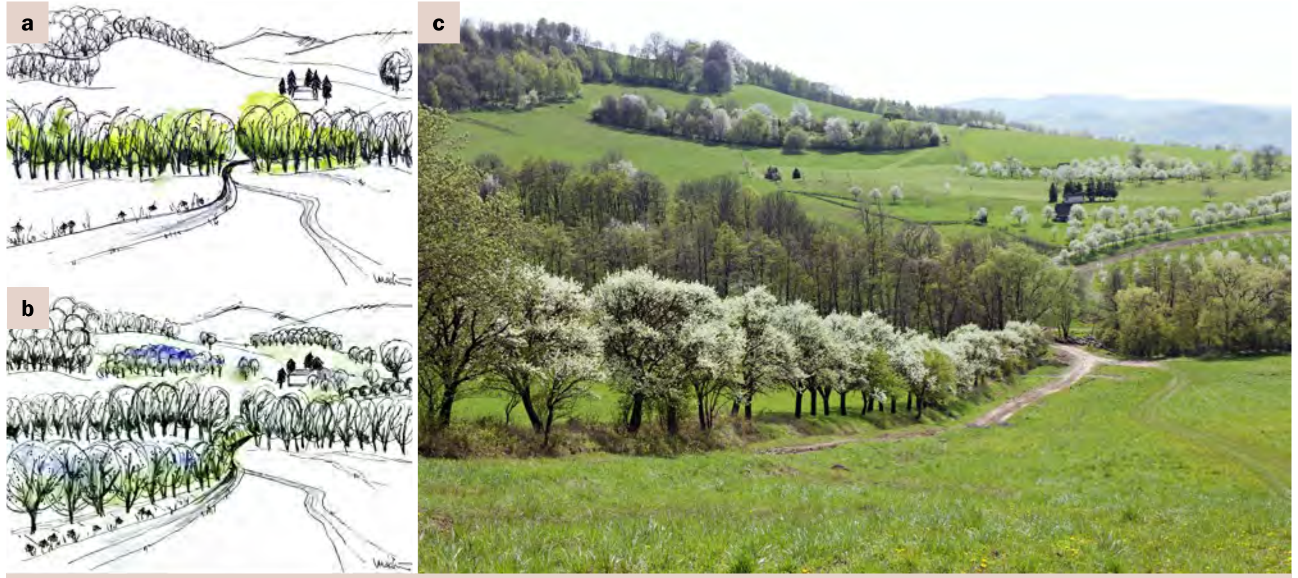


**Fig. 3.** Site named Nad Kanajkou near Brumov, 1990 (a) and 2016 (b, c). Large, empty arable land blocks were divided into smaller units with linear plantings. Orchards were planted and dispersed trees were added to the landscape. (M. Drgáč)

**Fig. 4.** New plantings in the cadastral municipality of Jestřabí harmonise the landscape by adequately supplementing the existing landscape elements, at the same time marking parcel boundaries. (H. Psotová)

## Work procedure

The project was realised in 3 cadastral municipalities, including ca 1700 parcels at 84 localities. Besides parcels owned by the agricultural company, also parcels in private ownership were included in the project, with consent of the landowners to realisation of the project, including a 10-year project sustainability term. Arranging property rights was one of the most difficult and time-consuming parts of the project.

In collaboration with Prof. Tomáš Kvítek, an anti-erosion proposal was worked out, based on the landscape's memory: its traditional parcel arrangement preserved until the 1950s.

## Measures applied

2012–2013 Project preparation, solving property relations

2013/2014 Thinning and clearing of scrub (43 ha), pruning of oversized shrubs and trees (8.8 ha), elimination of ruderal vegetation (7 ha)

2014 Establishment of grassland on arable land (13.7 ha), planting of fruit trees, restoration of orchards (7.2 ha), grassland management (615 ha)

2015 Cutting of undergrowth in plantings, mowing of grasslands, treatment of plantings

2016 Inspection of plantings, formative pruning, replacement of dead shrubs and trees

### Handling wood waste

During pruning, felling and thinning, a large volume of wood waste was produced. Dead wood was used to make loggers and sometimes freely arranged heaps of branches and roots. The rest of the timber was made into woodchips to mulch new plantings. When using a milling cutter, this timber was deposited into the soil.

### Measures to support valuable species

During thinning and clearing, trees of mostly indigenous species (*Quercus*, *Tilia*, *Acer*, etc.) offering good prospects were left at the site. Special attention was paid to *Cornus mas* shrubs, which received space to develop.

Newly established areas sown with the White Carpathian seed mixture were excluded from pastures and mown three times annually. Sites with the critically threatened *Tephroseris longifolia* subsp. *moravica* were fenced off.

To support valuable species, grazing was initiated on restored grasslands according to recommendations by Mládek et al. (2006).

The rich spring aspect of cleared areas, including e.g. *Primula veris*, *Corydalis cava* and *Lathyrus vernus*, turned out to be very attractive (Fig. 7).

### Scenery restoration measures

The planting of landscape vegetation was designed in a way respecting the historical landscape context, at the same time supporting large-scale agriculture.

Part of the plan was also the planting or complementation of non-intensive orchards consisting of regional varieties of traditional fruit trees, and completion of missing sections of the Territorial System of Ecological Stability. Out of a total number of nearly 2000 trees, 59% were natural species, 41% were regional varieties of traditional fruit trees (see Tab. 1).

**Tab. 1.** Overview of numbers of planted trees and shrubs.

| Cadastral municipality | Brumov | Jestřabí nad Vláří | Návojná | Total |
|---|---|---|---|---|
| Fruit trees | 303 | 226 | 269 | 798 |
| Non-fruit trees | 475 | 130 | 118 | 723 |
| Shrubs | 212 | 94 | 102 | 408 |
| Total | 990 | 450 | 489 | 1929 |

## Conclusion

By partitioning land blocks with linear tree plantings, restoring sections of historical parcellation and supplementing dispersed shrubs and trees, a considerable refinement of the

**Fig. 5.** The project included delimitation of cultures, giving priority to soil protection over erosion. At suitable sites (5–20 ha large), arable land allows for producing quality cereals when respecting a safe slope length and also contributes to the desired landscape diversity. (H. Psotová)

**Fig. 6.** Expanding hedgerows were narrowed by pruning branches and eliminating spontaneously establishing young shrubs and trees, 2016. (H. Psotová)

**Fig. 7.** Spring aspect of cleared sites, 2016. (H. Psotová)

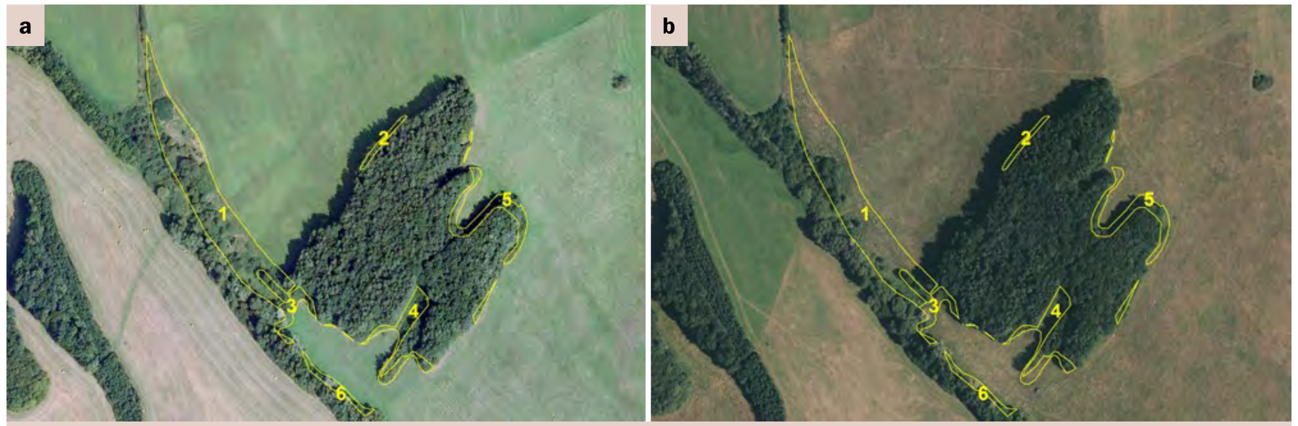


**Fig. 8.** Drawings of proposed measures in the cadastral municipality of Jestřabí. Orthophotograph from (a) 2008, before realisation, and from (b) 2015, after realisation.

Section 1: Clearing of fringes from shrubs and increments, retaining perspective shrubs or trees, additional planting of fruit trees (see Fig. 10). Section 2: Pruning of expanding tree branches. Section 3: Elimination of scrub, creation of sunlit ecotone. Section 4: Restoration of old orchard, treatment of full-grown trees and additional planting of young trees. Section 5: Thinning in ecotone.

**Fig. 9.** Unmanaged site, encroached by shrubs and trees before realisation of the measures in 2013. (H. Psotová)

**Fig. 10.** Restored site near Jestřabí, 2015. (H. Psotová)

landscape mosaic, partial restoration of the historical structure and a general improvement of the scenery have been achieved. The landscape is nevertheless agriculturally managed and provides an economically acceptable production.

## New insights and recommendations

The sustainable farming project in the White Carpathian landscape has confirmed that also large-scale farming in the form of organic agriculture may be beneficial from the perpective of nature and landscape conservation. Eco-friendly agricultural production creates a living and rich landscape which is more than just an open-air museum.

The realised measures required a rather demanding work organisation (securing access to the new plantings and vegetation), intensive watering in the period of extreme drought in 2015, proper treatment of young vegetation, and also a considerate approach to the new elements when working with large-scale equipment. Thanks to public relations, providing regular information on the progress of the work and personal involvement of many workers (including the company management) into landscape restoration, a tolerant approach to the new elements was also acquired from those who were initially rather sceptical to the project.

## Acknowledgements

The very good project results were achieved thanks to excellent collaboration with workers of the Bílé Karpaty PLA Authority, but also with staff of the National Agricultural Intervention Fund Zlín, the municipality authorities concerned and euro-managers of the Renards Group. We are grateful to project contractor Zlínské stavby a.s., and particularly to employees of the Javorník-CZ s.r.o. company, who managed to overcome the barrier of short-time economic profit and to farm in a way enabling them to pass on the farmland and landscape to their children in a much better state than they received them.

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# Conclusions

Comparing the current state of the restoration ecology discipline and practical ecological restoration in the Czech Republic with the situation five years ago, when the preceding volume came out, it can be concluded that the public and enlightened practitioners have become more aware of the discipline. The best example is probably the support of near-natural restoration by the Českomoravský štěrk, a.s. company. Also significant improvement in the application of scientific knowledge in practical nature and landscape conservation measures should be valued.

Still, however, large-scale implementation of near-natural restoration (in the case of strongly disturbed or destroyed ecosystems, mostly represented by spontaneous or assisted succession) is limited by obsolete bureaucratic regulations and legislation. Sometimes it is also hindered by narrow economic interests (the profit of reclamation companies being in the first place, whereas nature and functional ecosystems are unimportant), by lack of information and by reluctance in accepting other solutions. But there is something which has slightly improved. For example since 2016, after amending Act No. 334/1992 on the protection of agricultural land resources, 10% of the area of mining sites can be left to natural development in places which used to be farmland before the exploitation.

Unfortunately, not more than a minimal shift has been made in forests. Practical foresters still cannot be convinced of the necessity to increase the spatial, species and age diversity of forests, even though we are facing a large-scale breakdown of spruce and pine monocultures, dying ash stands and other possible consequences of climate change. The few promising projects aimed at restoring traditional forest management (coppicing) presented in this publication can only serve as model solutions.

The requirements in Agri-environmental programmes have only partially been improved (today part of the land can be left unmown or ungrazed, without loss of subsidy for the tenant). Different restoration management measures from ME Landscape Management and Restoration Programmes, the LIFE+ programme and the Operational Programme Environment largely run successfully. These mostly concern meadows and wetlands. Compared to the previous volume we know more of the dynamics and restoration of mountain ecosystems, which a separate section in this book is dedicated to.

However, the conclusions in the first volume do not have to be essentially changed. Therefore, and for easy access, they are repeated here in slightly adjusted form.

- Our traditional landscape basically consists of a diverse fine mosaic of natural, semi-natural and anthropogenic ecosystems, which should be respected by restoration projects. Sometimes, in order to increase diversity and to preserve declining species, restoration projects should also include less traditional measures, such as controlled burning, local elimination of vegetation with large machines, disturbing the soil with heavy vehicles, etc. Restoration seems to be the most effective if it is heterogeneous in space and time. Uniform large-scale projects, like most of the current Agri-environmental programmes, may be inappropriate for many organisms if these programmes are not properly modified.
- Restoration projects should not concentrate on just one group of organisms or one ecosystem service. If a balance between the requirements of different groups cannot be achieved, mosaic management may be a solution.
- In the field of education, collaboration of scientists and engineers with investors, designers and the public should further be improved.
- Natural processes, usually represented by spontaneous succession, are often an effective and cheap ecological restoration tool. In this way, mostly habitats valuable from the perspective of nature conservation are created. On the other hand, demands for halting or returning succession frequently come up, since early succession stages may be important for biodiversity and for the occurrence of rare and threatened species. Part of the enormous amount of financial means invested in often unnecessary technical reclamation might thus be used for measures leading to the restoration and maintenance of early succession stages.
- We have good scientific and experimental knowledge of how to restore various disturbed ecosystems, mainly with near-natural methods. However, there are still many barriers preventing purposeful realisation of this know-how in practice, often due to a low interest by landowners, agricultural companies, officials, planners, and sometimes also due to inappropriate laws.

For the future we consider it probably the most important to ecologically restore entire degraded landscapes, mainly aimed at increasing their water retention, thus reducing the risk of floods as well as drought. We do not have in mind the construction of new large water reservoirs including ponds here. These will not help the landscape. Our priorities lie in restoring the water retention of the landscape, i.e. primarily in improving farmland quality, restoring wetlands, channels and floodplains, and repartitioning the landscape by means of hedgerows, allees, strips of meadow and pasture, locally also tree stands. It is first of all necessary to limit further degradation of the soil, which is really widespread in our country and still rapidly continues, in the form of erosion as well as massive loss of organic matter from the soil. It would also be good to raise awareness of ecological restoration just as is done in developed countries (particularly in the USA, the Netherlands, Germany, Great Britain, etc.) but also for example in some countries of Latin America. The public awareness of the need to restore disturbed ecosystems or entire landscapes in all these countries is currently higher than in the Czech Republic, although we have enough scientific knowledge of how to achieve it. The only thing to do is to adequately apply this knowledge. Selected examples are given in this publication.

The editors

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## Restoration Ecology Group

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The working group is part of the Department of Botany, Faculty of Science of the University of South Bohemia, České Budějovice (Budweis), Czech Republic. The informal group associates, under the leadership of Karel Prach and Klára Řehounková, 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, and NGOs.

The members are especially interested in using ecological succession in the restoration of various human-disturbed sites (e.g. sites disturbed by mining), restoration of ecosystems on ex-arable land, restoration of various neglected and wrongly managed grasslands, and restoration of natural species composition and functioning of degraded forests. Recently, restoration of former military training areas, and establishment of so-called flower strips have become part of our interest.

The group manages the Czech Database of Spontaneous Succession (DaSS), which is now being expanded to become the European Database of Spontaneous Succession (EDaSS). Global meta-analyses of effectiveness of spontaneous succession in ecological restoration are under progress. Results are published in top ecological journals, books and also in popular publications. Spreading the ideas of restoration ecology to the public is emphasized.

The working group collaborates with many institutions in the country and abroad. It organized the 8th European Conference on Ecological Restoration in 2012.

For details about the group, see:

**http://www.restoration-ecology.eu**
**https://www.facebook.com/ekologieobnovy/**



NATURE
CONSERVATION AGENCY
OF THE CZECH REPUBLIC

Přírodovědecká
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