Ecological restoration in the Czech Republic II

Ivana Jongepierová, Pavel Pešout & Karel Prach (eds)
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Drone view of landscape below Oblík hill, Lounské středohoří Uplands. (J. Bělohoubek)
Contents

Preface
Introduction
Nomenclature, acronyms and glossary

FORESTS
9
Introduction
11
Litter raking as restoration management in an oak forest in Podyjí National Park
17
Results of 20-year conversion of pine-dominated stands in Podyjí National Park
20
Long-term vegetation development of sandstone pinewoods after fire and opportunities of fire management
26
Restoration of coppice biodiversity in southern Moravia
32
Restoration of management and communities of coppices-with-standards in southern Moravia
37
Ecological restoration for the benefit of a critically endangered butterfly
40

MONTANE TREELESS HABITATS
45
Introduction
47
Restoration of alpine vegetation in the Krkonoše Mts
50
Restoration of degraded subalpine grasslands in the Jeseník Mts
55

SECONDARY GRASSLANDS AND HEATHLANDS
61
Introduction
63
Restoration of a floodplain meadow on the Morava river
72
Restoration of species-rich grasslands in the White Carpathian Mts
76
Restoration of diversity in vegetation dominated by Calluna vulgaris
81
Grazing of dry grasslands in the Bohemian Karst
84
Restoration of steppe communities in northern Bohemia
88
Restoration of heath vegetation at a serpentine site
95
Restoration of open sand communities in southern Moravia
99
Restoration management of Molinia meadows in a military training area
102
Heathland restoration by means of controlled burn
107
Restoration of a dry heathland in Prague: comparing the effects of grazing and sod-cutting
111
Restoration of heathlands in Podyjí National Park
115

WATERCOURSES AND WETLANDS
121
Introduction
123
Restoration of a drained mire in Šumava National Park
130
Restoration of an extracted peatbog – reintroduction of two target species
136
Restoration of rich fen bryophyte populations
139
Horse grazing as a way of restoring inland salt marshes
145
Revitalisation of a formerly canalised river
149
Near-natural flood control measures on a river in an urban environment
152
Elimination of knotweeds in a river basin
157
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 Jonge 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.

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.
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 (Korčková 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, Hanáč et al. 2013, Kalma et al. 2014, Vojer et al. 2016) has provided new information. The study of other mining sites such as peatbogs (Korčková & 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 (Koval 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
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 & Filír 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, €777.6 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 m³. In vast urban areas, greenery was restored, which included the planting of 403 km of alleys (Límová 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.

Realisation of Czech ecological restoration projects

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Edward, methodology and popularisation

Besides the traditional tuition of the discipline at the Faculty of Science in Czech Budweis, 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 Suščol, lately also at the Faculty of Science of the University of Hradec Králové. Incidental courses also run at other faculties of various universities. Educational 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 (Českémuvek Příbram), the Chamber of Garden and Landscape Architects, etc. for their conferences or seminars. Popularised articles on ecological restoration have become common in specialised magazines (Plodina, Ochrana přírody, Forum ochrany přírody, Zahrad park Kra- jina, 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 reflect- ed in some professional methodologies. The most significant act in this field was the initiation of creating standards for nature and landscape management in 2012 (Pelout & Štír- ba 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 restora- tion (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/
coal mining dump in relation to their occurrence in the surroundings. – International Journal of Mining, Reclama
tion and Environment at the turn of two programme
Annual evaluation of the National Ecological Network (Future of subvention programmes/
on the effects of disturbed water retention of the landscape, soil degradation, and deterioration of forest structure and func
tioning becoming more and more apparent. The need to re
store 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 landscape subsidy pro
grammes 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 riv
er ecosystems, restoration of degraded secondary grassland ecosystems, restoration of species and spatial forest composit
ion, 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 compil
ing this publication, even though a number of projects are realised every year. Restoration of landscapes is an urgent require
ment 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 habi
tats, decline of threatened species, spread of invasive alien and expansive indigenous species, etc. Realisation of meas
ures on the landscape scale and monitoring of their effectiv
ity are therefore a great challenge for state institutions as well as non-governmental organisations. The appraisal of ecosys
tem services, also developed in this document, along with 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 ecol
omy discipline and its practical applications in ecological res
toration.

References

tion dynamics and ecosystem resilience. – Forest Ecolo


dates – traditional programs. - Ochrana přírody, Ekolo
gické a ptačí informace 141: 113–122.


claimed post-mining sites. – Ecological Engineering 84: 233–239.


Hörská M., Réhounková K. & Prach K. (2016) Are seed and dispersal characteristics of plants capable of pre
dicting colorization of post-mining sites? – Environmen
tal Science and Pollution Research 23: 13617–13625.


Limroth A. (2015): Operační program Zvěstoví prostředí na podkloudu dvou programových období (Operational Pro


Mudrak O., Mladěj K., Blažek P., Lepš J., Doležal J., Nekvapi
sitic Rhinanthus spp. in grassland restoration: lessons learned from sowing experiments. – Applied Vegetation Science 17: 274–287.

position predicts the progress in the spontaneous suc

ment and its implications for species diversity in forest vegetation. – Forest Ecology and Management 345: 88–100.

Pešout P. & Fisel B. (2013): Zeilien podpory pěče o ekolo
gie a včetně včerních zvířat v českého ekologického projektního systému. – Ochrana přírody, Ekolo
gická sít v ČR (special issue): 45–49.

Pešout P. & Štětěl í P. (2013): Standards pěče o přírodní kra
jiny (Standards in nature and landscape management). – Ochrana přírody: 3–8.

Prach K., Lencová K., Réhounková K., Dvořáková H., Jirouš
a, Konvalinková P., Mudrak O., Novák J. & Tmiková R. (2013): Spontaneous vegetation succession at differ


Prach K. & Tolvanen A. (2016): How can we restore biodi


Prach K. & Tolvanen A. (2016): How can we restore biodi


Prach K. & Tolvanen A. (2016): How can we restore biodi

Šalek M. (2012): Spontaneous succession on opencast min

ous revegetation vs. forestry reclamation in post-mining sand pits. – Environmental Science and Pollution Research 23: 13591–13605.

ing species of natural communities by native parasitic plants: the case of hemiparasitic Rhinanthus elector-


tions to grass-dominated multifunctional forests. – Forest 10: 75–82.
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.


Nomenclature, acronyms and glossary

AS – Academy of Sciences
CSF – Czech Science Foundation
CUNC – Czech Union for Nature Conservation
LC – Local Chapter
LCR – 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)
Introduction

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. 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).

Forest restoration may therefore mainly concern revitalisation of stands destroyed by e.g. industrial pollution or insect outbreaks. 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. 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.

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, Polenc 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 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 (Sza-bó & Hédl 2011). Establishing the ‘historical range of variability’ (Sweatman 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...
Although the reality is not that simple, it is well possible to perform management of forest stands. Under the current natural conditions, the aims of practical forest management mainly consist in a substantial thinning of the tree layer. This has recently 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, substantially increasing the diversity of the herb layer by several times. In a plot of 100 m² up to more than 90 species are found here today. (R. Hédl)

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. This implies, among other things, efforts to improve the management of species compositions 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 (Tesal et al. 2004). It is however necessary to point to 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 saprophagic 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 holophilous 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 influences 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. 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, Kotek 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.
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. The connection between the loss of biodiversity and former traditional forest ecosystem management is obvious (e.g. Kvoríčka et al. 2004, Mülterová et al. 2015). Besides coppicing, other widespread forms of traditional forest management were litter raking and wood-pasturing (e.g. Krčmalová 2015). However, wood pastures have probably never been a significant element of the Czech landscape. The restoration of traditional management forms is dependent on local 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. Hrdý 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 (Kadey 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

The knowledge and ideas presented in this contribution would be considerably poorer without the author’s participation in the ERC Longwood project (www.longwood.cz), grant 278085 (FP7/2007–2013). The author thanks K. Prach, T. Vírka, D. Uhlínek and M. Chudomelová for valuable comments on the text.

Footnotes

1. The influence of large herbivores, which were partly exterminated 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.

3. An example of successful restoration of a forest damaged by air pollution was described by Tesář 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).


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 climate and ecological stability it should be noted that today's view of the long-term dynamics of ecosystem, 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 (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. Vírka)

9. The conservative 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. Levi-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 (Szábo et al. 2015).

References


Litter raking as restoration management in an oak forest in Podyji National Park

Ondřej Vild, Radim Hédí & Jesse M. Kalwij

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 ollic (Organo-Gleic 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 Arrhenatherum elatius, Poa nemoralis, Festuca ovina and Melica uniflora dominate the understorey, in more open places, Trifolium alpestre, Galium verum and Lycopus virosus occur. We can rarely also find here some endangered species, e.g. Platanthera bifolia, Fournaea 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 Artenhatherum elatius, have expanded at the study site. Simultaneously, plants of oligotrophic habitats, including many endangered species, have disappeared.


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.

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
The research leading to these results received funding from the European Research Council under the European Union’s Seventh Framework Programme (FP7/2007–2013)/ERC Grant agreement no. 278065. Additional funding was provided by long-term research development project RVO 67985939.

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

Tomáš Vrška, Jaroslav Ponikelský & Petra Pavlicová

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 secondary 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 63 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.

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 thicket 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 story 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-standard 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, Decco 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 decay- ing 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. 1. In 1995, thickets of thin pines from the mid-1980s were disrupted by heavy snow. Microclimatic variation of sunlight and shaded places without routinely straightening of the boundaries was applied to introduce target hardwood species. Situation 15 years after planting. (Photo: Valášek)

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)
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 2 (target) - see Fig. 3.

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

- 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;

- 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;

- appraisal of forest types, aimed at assessing the speed of conversion and effectiveness 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-

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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 34.9 ha (38%) 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 33 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.

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

The authors wish to thank Jiří Zahradniček, independent Czech forester, for his collaboration on the operational survey of the experimental area in the years 2003 and 2013. Our thanks also go out to foresters Petr Růžička, Jiří Novák, Vladimír Auer, Milan Poliška and Petr Vancura of the Podjí National Park Administration for supporting our work in the past more than 20 years.

References


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

Martin Adámek & Věroslava Hadincová

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 monitored 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 dissecting 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 relic) pinewoods (Diozono-Pinetum) or pine-oak forests (Vaccinio vitis-idaea-Quercetum) (Mikuláš et al. 2007). Due to intensive forest management, introduced in these areas approximately 200 years ago, the original forests have been replaced by spruce and pine cultures. According to our 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 relic) pinewoods (Diozono-Pinetum) or pine-oak forests (Vaccinio vitis-idaea-Quercetum) (Mikuláš et al. 2007).

An interesting phenomenon we encounter more often in sandstone areas than elsewhere is fire. Local fires are also frequently mentioned in historical records (Beliová 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), wild fires caused by strokes of lightning are not an exception here. In rugged terrain, most local fires start in the drier 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 understory. 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 (Klaiber 2013). This has led to other tree species entering the stand and the development of semi-natural forest vegetation (Winter et al. 2010).

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. Furthermore 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; 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 dying 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.

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 results

Spontaneous fires and their influence on forest vegetation of sandstone pinewoods showed a considerable degree of resistance and resilience to fires, which monitored supports pine regeneration and species diversity. Fire management thus appears to be a suitable measure of ecological restoration in these forests. The survival rate of these species decreased to ca 40% and 25%, respectively, with increasing fire intensity. Hardly any individuals of Pinus strobus, Picea abies and Quercus petraea 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 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 abies and Quercus petraea showed resistance to fires of high intensity. The ability of Fagus sylvatica to survive fires was unclear due to the small number of observations. In the...
Forests

In the course of a nearly 200-year development of pine-woods 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

<table>
<thead>
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<th>Fire intensity</th>
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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.

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)
than once in 200 years can then maintain pinewoods also
in the conditions we have, for example in those pos-
sibly in the boreal forests of Scandinavia (Kuuluvainen et al. 2002).

New insights and recommendations
Minor forest areas affected by fire do not have to be artifi-
cially afforested if sufficient sources of dispersals are avail-
able in the vicinity. Such areas will develop in a way similar to
to artificially afforested areas, but of course a higher diver-
sity of plants and other groups of organisms will be found in
spontaneously created areas. Controlled fires could thus be
used to maintain a more diverse species composition of
pinewoods also in the conditions we have, for example in those poss-
sessing 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).

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References
fires within a temperate landscape: a dec-
arly and millennial perspective from a sandstone region

of wildfires on temperate Pinus sylvestris forests: Vegeta-
tion dynamics and ecosystem resilience. – Forest Ecology and

Angelstam P. (1998): Maintaining and restoring biodiver-
sity in European boreal forests by developing natural

Belisová N. (2006): Historické záznamy o požárech v Českém Švýcarsku (Historical records of fires in Bo-

Bobek P. (2013): Dlouhodobý vliv požárů na složení lesní
vegetace Long-term impact of fires on forest vegetation
composition. – In: Seiler U., Wild J., Csaplovics E. (eds), Historische Waldentwicklung in Der Sächsisch-Böhmischen
Schweiz / Historicky vývoj lesa v Českosaském Švýcarsku, pp. 225–244, Rhombos-Verlag, Berlin.

Bojustch P., Blazj L., Trizna M. & Henenberg P. (2014): For-
gotten role of fires in Central European forests: critical

Engelmark O. (1987): Fire history correlations to forest type and

Gromtsev A. (2002): Natural disturbance dynamics in the bo-

Benefits for saproxylic beetles (Coleoptera). – Restora-

Kalmar M. (2013): Historické lesní hospodářské plány a
masy dlouhodobého národního parku České Švýcarsko (His-
torial forest management plans and maps of the pres-
et Bohemian Switzerland National Park). – In: Seiler U., Wild J., Csaplovics E. (eds), Historische Wald-entwicklung in Der Sächsisch-Böhmischen Schweiz / Historicky vývoj lesa v Českosaském Švýcarsku, pp. 225–244, Rhom-
mos-Verlag, Berlin.

Kuuluvainen T. (2002): Natural variability of forests as a ref-
ERENCE for restoring and managing biological diversity in
boreal Fennoscandia. – Silva Fennica 36: 97–129.

Marková I., Adaměk M., Antonín V., Bendá P., Žiukov V., Troch-
Jestřebího v národním parku České Švýcarsko: vývoj ploš
fauny na ploše zasažené požárem (The Havraní ská-
lá/Rook Rock near the village in the České Švýcarsko/
Bohemian Switzerland National Park. Flora and Fauna In
an area affected by a fire). – Ochrana přírody 1: 18–23.

Mikušová R., Adamovič J., Hertel H., Bendá P., Trizna M. &
& Williams R. (eds), Sandstone Landscapes, pp. 326–
328, Academia, Prague.

vegetation stability in a lowland pine forest area (Dolcey

Schleger E. (1970): II. etapa historického průzkumu pro lesní
hospodářský celek Růžák (Rook Rock) (Historical research
for the Růžák forest unit – Stage II). – Unpublished, Ustav pro
hospodářskou úpravu lesů, Brandýs nad Labem.

Stándovář T., Đodor P., Aszalós R. & Gálhidy L. (2007): Sens-
sitivity of ground layer vegetation diversity descriptors in
indicating forest naturalness. – Community Ecology 7: 199–209.

Winter S., Fischer H.S. & Fischer A. (2010): Relative quanti-
tative reference approach for naturalness assessments
Restoration of coppice biodiversity in southern Moravia

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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 natural reserve was established here in 1946, large part of the forests kept the structure of aged coppices-with-standards. A 50-year survey 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-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 reserve was founded in 1885 but annulled in 1996. Mainly mouflon and bezoar ibex were kept in the preserve.

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.

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 mesophisation 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 (Chytry & Danišová 1993, Hédl et al. 2010, Müllerová et al. 2014, Müllerová et al. 2015).

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).

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)
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).

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 diasporos (seeds, fruits) from the surrounding agricultural landscape and, if they get the opportunity, germinate immediately. Besides annuals, the endangered Vicia platforms, apparently persisting in the soil seed bank, was repeatedly recorded in the thinned plots.
The most important outcome, however, is the support of biodiversity 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.tnn.pan.gmbh.com/habitat/Gerolfing02.pdf). State ownership, unfortunately, does not appear to be an ideal option in such cases. Although the LDR state enterprise partly developed efforts to modify the forest management at Děvín, its prime objectives are motivated economically.

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**References**


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**Abstract**

Restoration of forest biodiversity at lower and middle altitudes implies the reintroduction of traditional management in the form of coppices and coppice-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 coppice-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...
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 colonize the forest from the surrounding landscape. It is very difficult to predict how long forest species will need to arrive and colonize 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 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, Vítl et al. 2013). All trees were measured with standard methods prior to intervention.

**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 ruder 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 vulgaris, 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.

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**References**


Ecological restoration for the benefit of a critically endangered butterfly

Antonín Krása

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.

Heryonian oak-hornbeam forests are the most widespread community, but also dry and moist acidophilous oak forests, basophilous 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 Droscis 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 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. At 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 polycorons 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.

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

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

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

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
- 0.32 ha / 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 ha / 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 ha / 2011
- Planting of target trees (oak and ash) in place of a felled spruce stand; realised in stands of falling age.

Stand reconstruction
- 0.63 ha / 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 ha / 2013
- Additional planting of ash saplings on older clearings where lacking.

Tab. 1. Overview of realised measures.
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 saplings has only been 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 butterfly. 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.

Additional planting of ash trees (ordinary ones and large saplings) on older clearings is realised despite the spread of ash wittering 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 (imagines) 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 imagines 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 butterfly.

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.

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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 Dománovický lies 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.

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

**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)
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.

References
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 (Karkonosze, 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 (mellaphyre) 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.
This pressure is expected to rise considerably in the coming years because of worsening snow conditions at lower elevations. In the Krkonoše Mt 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 been resumed in large plots of flower-rich subalpine tall broad-leaved vegetation and expanding Vaccinium myrtillus. 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 Hartlánk, 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 rutherfurdisation 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 Jeseník FLA 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 incana 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 (conservation terraces of Petrová 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. 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. 2. View of the Vysoká hole ridge from Mt Blišťná hora on; left on the horizon: Mt Peadříč. (L. Bureš)

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

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

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)

Fig. 6. Reparation of a log path through the Úpa peatbogs in 2000. (J. Harčarik)
Restoration of alpine vegetation in the Krkonoše Mts

Josef Harčarík

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 restor 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).

The restoration area consists of a mosaic of various types of alpine treeless vegetation, particularly natural dwarf pine scrub (Pinion mugi), alpine grasslands (Juncion infelix, Nardo stricte-Caricion bigelovii), alpine and subalpine shrub vegetation (Loiseleurius pseudemem-Vaccinion, Genisto pilosae-Vaccinion), and subalpine tall herb vegetation (Calamagrostion villosae, Calamagrostion arundinaceae, Adenostyli alpinae).

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, Harčarík 2002, Sekyra et al. 2002, Wild & Wildová 2002).

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 (Harčarík 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...
Alpine and subalpine habitats

52

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 (Harčarík 2007).

**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**

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Elimination of dwarf pine plantings on north slope of Mt. Studniční hora, 1 ha</td>
</tr>
<tr>
<td>1994</td>
<td>Elimination of dwarf pine plantings N of Harrachova kamenny in 3 experimental monitoring plots, 0.72 ha in total.</td>
</tr>
<tr>
<td>1997</td>
<td>Reduction of dwarf pine on north slope of Mt. Studniční hora, 1 ha.</td>
</tr>
<tr>
<td>2005–2008</td>
<td>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.</td>
</tr>
<tr>
<td>2010–2011</td>
<td>A 10–90% reduction of dwarf pine plantings in the area of Pančavská louka and Labská louka, 37.7 ha in total.</td>
</tr>
<tr>
<td>2015</td>
<td>A 10–90% reduction of dwarf pine plantings in the area of Labská louka and Harrachova louka, 47.4 ha in total.</td>
</tr>
</tbody>
</table>

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

**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.
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)

References

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 was 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 heartscuts to Mt Vysoká hole in August in order to collect hay. From several credible historical sources it follows that the structure of the Avenella flexuosa grasslands on the entire ridge of Vysoká hole has rapidly changed over the past 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 Cetraria-Festucetum supinae association known of the Krkonoše Mts, which is associated with shallow and desiccative ranks. This is generally true for Krkonoše, but in the Jeseník mts...
Alpine and subalpine habitats

Mts mostly deep humus and never desiccating podsol soils 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 tricuspis 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 hacked 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.

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.

**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 unvegetated sites, and often just a little stronger at shallowly disturbed raked sites, while changes in deeply hacked 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 Polytrichum 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 hacked 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.
The structure of the restored vegetation is illustrated in Fig. 8. For comparison, Fig. 9 is added, showing details of the mown plots. As the plants grew, they covered more ground, making it more difficult for sunlight to reach the soil layer below. This led to a decrease in bryophytes and mosses, particularly in the shaded areas. The mown plots became thinner over time, and the dead biomass started to rot off from below in some places. This process is illustrated in Fig. 10.

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 started to appear in 2013.

In Quadrat 6, mowing caused a clear decline of Calluna vulgaris. 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).

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.

Open plant communities with a high rate of floristic diversity, e.g. Hieracium chrysostyloides, and sometimes even endemic hawkweed species, e.g. Hieracium chrysostyloides, are highly valued because they provide shelter and food for a wide range of wildlife. However, the management of degraded subalpine grassland communities in the Jeseník Mts and to find practical methods of restoring degraded subalpine grassland communities is a challenge. The study of the effects of mowing and fertilisation on the vegetation dynamics and succession in these communities can provide valuable insights for future conservation efforts.
SECONDARY GRASSLANDS AND HEATHLANDS
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 20th 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.
Nardus grasslands are being restored under LIFE project Corcontica (2012–2018). Management activities: Plot A – manual haymaking and fertilisation with composted dung is locally supplemented on a total area of ca 490 ha of grassland, approx. one third of which is mown. At the most nutrient-poor sites, restoration of farming in the Krkonoše Mts is taking place in Zones II and III of Krkonoše NP, where integrated 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 rostrata, 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 dry grasslands is incomparably better than arable land. Grassland communities are traditionally associated) as well as in other habitats stored in agricultural areas (with which meadows and pastures are traditionally associated) as well as in other habitats stored in agricultural areas (with which meadows and pastures are traditionally associated) as well as in other habitats stored in agricultural areas (with which meadows and pastures are traditionally associated) as well as in other habitats stored in agricultural areas (with which meadows and pastures are traditionally associated) as well as in other habitats stored in agricultural areas (with which meadows and pastures are traditionally associated).

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. Carex rostrata, Filipendula ulmaria), 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 not disregarded. Grasslands capture nutrients and other chemicals (e.g. from field runoffs or groundwater) effectively, making them an important filter around drink wa-

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 quantita-
tive 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 par-
ticularly important to maintain the species-rich composition. In the immediate surroundings from where they can eas-
ily 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 ex-
pected 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.

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 dom-
inant 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, espe-
cially if at least some of the original species have remained in the vegetation (e.g. in the form of seeds in the soil) or oc-
cur in the immediate surroundings from where they can eas-
ily 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 ex-
pected 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 manage-
mentmeasure 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. Carex rostrata, Filipendula ulmaria), at least in the first years. On the other hand, not all shrubs have to be removed. Some re-
tained 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
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 is used to be secured by fragment-
ed 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 (Kovíčka et al. 2008).

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 (Kovíčka et al. 2005). Farmers making use of agri-environmental measures under the Rural Development Programme for the period 2014–2020 are obliged to post-pone 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 vegeta
tion as a whole to obtain a savannah-like character.

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 (Honslová 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 (Lammers 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 prob-lem. 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 & Bílohlávek 2012). Presently, psammophytic vegetation in Válší písky NNN (see Řehounková & Jongepierová, p. 99), Vojenské cvičiště Bzenec NM (Fig. 7) and Pánov NM is re
tored 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 exam-
ple by filling up drains or making them dysfunctional in oth-
er ways, which locally happens spontaneously. On the other hand, the species richness of some meadows was condi-
tioned 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 accumula-
tion of litter or influence the nutrient regime. Moreover, it reduces competition and enables generative reproduction of some species, which is otherwise markedly limited in densely grassland communities. Burning of ‘grass’ was commonly practised in the past, but is today hindered by fire safety leg-
islation. However, burning is more and more considered as a tool in conservation management (Péclut 2016). It was officially applied in e.g. the Brdy PLA in 2016 when restoring heathlands (see Filter et al., p. 107). Burning was already promoted as an appropriate tool for the restoration of heath-
lands in the Czech Republic in the 1980s by Jaroslava Kubí
ková. The option of small-scale burning has been included in the new draft management plan for Válší 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 sim-
ilar communities in Ukraine to date (Robieč, in verb.). It is,
Transfer or sowing of desired plant species

Presently degraded meadows can in particular cases be converted arable land to species-rich grass-herb vegetation, e.g. by 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 Calamintha epigaea 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 in the root system. Even in plant communities where several 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 exception 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 expenditure). 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 Calamintha epigaea 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 in the root system. Even in plant communities where several 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 exception 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 expenditure). Moreover, it is necessary to have perfect knowledge of the biology of the species in question.

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 important for keeping the vegetation in an undisturbed state. 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 genotypes and ‘dilute’ the original genetic diversity and resistance of a population.

Seed collections

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).

<table>
<thead>
<tr>
<th>Secondary grasslands and heathlands</th>
<th>69</th>
</tr>
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<tbody>
<tr>
<td>Secondary grasslands and heathlands</td>
<td>68</td>
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</table>
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 restoration 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 from a source site helps the desired (target) plant species to spread to the degraded surrounding vegetation. 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 regions and further regenerate 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 dry grassland 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.

Conclusions

There is a variety of options to restore grassland ecosystem, 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 regions and further regenerate 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 dry grassland 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.

References

Restoration of a floodplain meadow on the Morava river

Dagmar Uhýrková, Karel Fajmon & Ivana Jongepierová

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 grey 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 river. At a distance of 3.7 km to the southeast of the church stand the ruins of Vlčí hrdlo. In 2008, ploughing was ceased and the arable field became fallow land, which has been developing back to the unploughed part of the permanently waterlogged parts of Vlčí hrdlo itself.

Kvartér řeky Moravy Protected Natural Water Accumulation Area (http://heis.vuv.cz/), which may influence the hydrology of the site in the future.

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 Carex elatae-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 to 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.

Abstract

Financial support
Rural Development Programme

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

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

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. Monitoring within the permanent plots.
Secondary grasslands and heathlands

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 postponement 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. eurhina) trees will successively be planted in the area.

Checks for the initial state in 2008.

References


Acknowledgements

We want to thank the Czech Union for Nature Conservation, which purchases parcels of interest under the Space for Nature programme, and the Naďace Veronika foundation, which has provided a financial contribution to the purchase of plots. We thank the VSV, a.s., Vracov company for managing the site. Anoška Bartošová is acknowledged for monitoring the initial state in 2008.

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 passive- ly projected means of Ellenberg indicator values (Ellenberg 1981, Tichy 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 aluvial 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 nigra, 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 permanent 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 unknown margins.
Restoration of species-rich grasslands in the White Carpathian Mts

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

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 Bílé Karpaty Mts in 2009–2014. The study included a comparison with reference sites, i.e. long-existant meadows in the surrounding. The results showed that the re-established grasslands become gradually enriched with uncrown 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 woodten 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.

Initial state

In the Bílé Karpaty Mts, several thousand hectares of meadows were ploughed up in the second half of the 20th century. Since 1989 (certain 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-term 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 fly 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.

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 694–7,420 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.

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

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

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

Measures applied

<table>
<thead>
<tr>
<th>Year</th>
<th>Restoration measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>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. Start of large-scale conversion to grassland by means of commercial grass-legume seed mixtures.</td>
</tr>
<tr>
<td>1994 – present</td>
<td>Producing seeds of herbs in seedbeds.</td>
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<tr>
<td>1999–2006</td>
<td>Utilisation of a combine harvester to collect local grasses, particularly Bromus erectus.</td>
</tr>
<tr>
<td>2007 – present</td>
<td>Harvesting of (mainly grass) seeds with a brush harvester, constructed after a model developed by the British company Emorsgate Seeds.</td>
</tr>
<tr>
<td>1999 – present</td>
<td>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.</td>
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</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Botany</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009–2014</td>
<td>Monitoring of succession (vascular plants) at 35 large sites restored with regional seed mixtures (Prach et al. 2013).</td>
</tr>
<tr>
<td>2010–2013</td>
<td>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 &amp; Prach 2014, Jongepierová et al. 2015, Johanedisová et al. 2014). 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 35 years.</td>
</tr>
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</table>
Alliance). In the last one, 43 of Bromion erecti rion elatioris alliance) appear to a greater extent, whereas Arrhenatheretum species). 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 mesophytic grasslands (Aenleaete- rion elatiori 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 (Brionion 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 surroundings (Prach et al. 2015, Jaugjepio et al. 2015). At all studied restored sites, a total of 326 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 refer-

Indirect gradient analysis (DCA ordination method) of relevés from former arable fields restored with a regional seed mixture and two permanent grasslands were monitored repeatedly in the period 2012–2014. Data on butterflies and burnet moths were obtained by timed surveys (Kadić et al. 2012) during two visits to each site in early and late summer.

Monitoring of communities of phytophagous insects (butterflies incl. leafhoppers, true bugs, weevils) at 17 sites (selected from the set of sites where vegetation development was observed) was done with a commercial mixture, four left to sponta-

<table>
<thead>
<tr>
<th>Year</th>
<th>Zoology</th>
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<tr>
<td>2012–2013</td>
<td>Monitoring of communities of phytophagous insects (butterflies incl. leafhoppers, true bugs) at 16 sites restored with a regional seed mixture and at 16 reference grasslands (Masaniková 2016).</td>
</tr>
</tbody>
</table>
| 2014 | Monitoring of communities of phytophagous insects (butterflies incl. leafhoppers, true bugs, weevils, phytophagous beetles) at 17 sites (selected from the set of sites where vegetation development was observed) was done with a commercial mixture, four left to sponta-

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 leafhoppers (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.

Fig. 5. The burnet Zygaena vicina 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. Hrabáč, archive of Moravian Museum, Brno)

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

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 plant hopper Tettigometra impressipunctata. Newly restored sites thus may increase the diversity of the respective insect groups in the study area. 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 gen-
erally 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 com-
mercial seed mixture (average age 22 ± 8 years at the time of monitoring) resembled the preserved grasslands in this re-
gard 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 re-
stored sites were meadow brown (Maniola jurtina) and small heath (Coenonympha pamphilus), which have the charac-
teristic ability of colonising even intensively managed grass-
lands 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 unfavour-
able 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 grass-
lands and apparently also from each other, which adult butterflies demand as a food source are miss-

Nevertheless, here and there weak populations of some
Restoration of diversity in vegetation dominated by Calamagrostis epigejos

Jákub Těšitel & Jan Mládek

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 experimental results, we demonstrate here that sowing of hemiparasitic species of the genus Rhinanthus may be used to suppress dominance of this grass and support characteristic plant species of species-rich meadow vegetation at the same time.

Introduction
Wood small-reed (Calamagrostis epigejos) is a competitively strong grass. It has massively spread over the landscapes 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 suppressed 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 Svihov 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 been managed as hay meadows for 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.
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 epiglottis was used in the experiments at Švihov, České Budějovice and Návojná, whereas P. 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: consistently 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 Climatis recta 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 either can be collected from a local population (realistic for sowing hundreds of m²) or be obtained as commercially available seed supply, because e.g. Rhinanthus epiglottis was a common weed in arable fields a hundred years ago and no genotypes have been described in the Czech Republic.

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References

Grazing of dry grasslands in the Bohemian Karst

Hana Mayerová & Tomáš Tichý

Abstract
In 2005, dry grassland and steppe sites in the Bohemian Karst PLAs were established as part of a national project. Grazing 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 (Poschold & 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 (Kučík 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 & Plapak 1974). With the decline in grazing, the area of open patches decreased due to site fragmentation and succession into woodland.

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 Alyssino-Festucion pannetenitis and Seslerio-Festucion pannetenitis 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. The remaining patches of grasslands were degraded due to a lack of grazing, with the tussocks becoming bare soil patches, 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 Pani hora (grazed since 2005) and Šandava (since 2006) in Karlovy Vary, NNM, 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, 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., Pani 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).
86 | Secondary grasslands and heathlands

**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 expasive 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 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.

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**References**


Münzbergová, Anna Šlechtová, Zita Červenková and Tereza Klinerová

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 campestrae, Festuca rubra, F. valesiaca, Pilosella officinarum, Potentilla arenaria, Scabiosa ochroleuca, Thapsi pratensis). A few competitively strong species of grasslands with a dense sward prosper in the ungrazed plots, particularly grasses and taller forbs like Artenatherum elatius, Brachypodium pinнатum, 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. Münzbergová et al., 1988, Dostálek & František 2008).

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

**Fig. 7. Grazing hard 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 Vlachů

Abstract
The dry steppe grasslands at the sites of Raná and Oblik 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.

Site description
The occurrence of species-rich extrazonal steppe communities at SAC Raná-Hrádek and SAC Oblik-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 has been recorded. Helichropitrum desertorum and Stipa glabrata are phytogeographically the most significant, as they occur in an eutaxie 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 Oblik (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 20th 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 Tobíčák’s 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 1995) 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. 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 illyago. 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, slopes 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 Malus steboni (Kubát & Machová 2010).

In large pasture areas, overall degradation of steppe grassland was recorded caused by mesophytisation of the environment, 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 weed 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 escapecus, A. austriacus and A. danicus, Adonis vernalis, and Pulsatilla pratensis subsp. bohemica. These changes led to a spread of aggressive, tall grass species, particularly Arthenatherum elatius, Dactylis glomerata and Calamagrostis epigejos. Expansion of com-
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 composi- tion 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 ephemeral species like Holosteum umbellatum and Eryphila verna. The following year, abundance of the species Rapistrum perenne, Verbasctum phoebe, V. ychinius, Oxytropis pilosa and Astragalus excapus sharply increased. In the flowering time of Rapistrum perenne and Verbasctum phoebe, 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 den- sity of Stipa tussocks had increased. The changes remained visible until five years after the fire, when old biomass gradu- ally built up again.

Changes in vegetation and populations of threatened plant species at Oblík, caused by grazing, were monitored in the years 1999–2003 (Hammersky & Bělohubcova 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 steps (narrow-leaved dry grasslands of the Festucion valesiacae alliance) and ‘white slope’ areas (broad-leaved dry grasslands of the Bromio erecti and Cirio 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 NRs, their buf- fer 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.

3. Degraded areas with shrub and tree cover locally reach- ing up to 100%, almost without steppe species (former or- chards, 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.

Monitoring methods

The influence of restoration on the habitats is monitored in several permanent monitoring plots according to the NCA methodology. In 6 permanent 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 (Helichrytonich desertorum, Astra- galus austriacus, A. danicus, Adonis vernalis, Stipa pennata and S. tira) 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 squir- rel 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 – espe- cially 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 xerothemic species and a decrease in mesophili- ous species (suppression of aggressive spread of Arhen- athenum elatius). An example was the white slopes at the base, where the rate of broad-leaved grasslands (Scaliciolo ochroleucocitri Brachypodietum pinnati) had increased.

Also historical cherry and pear orchards with a rich under- growth of needle-grass (Stipa pulcherrima, S. pennata) and other rare xerophytic species were largely restored (remov- al of expansive shrubs, planting old varieties of fruit trees, grazing). Scrub was reduced less only at boundaries with in- tensively managed cultures, where it forms a barrier against the dispersal of pest insects. Another result of the measures is the growth of the European ground squirrel popula- tion (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 herms (Cotoneaster spp.), but did not slow down the increase in Dronis spinosus plants. The main effect was a decrease in grass height by suppressing the aggressive Ar- rhennatherum elatius (Fig. 6). Under a reduced rate 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 com- pact needle-grass populations and their degree of fertility. In comparison to additionally grazed sites, however, the abun- dance of needle-grass is lower in the first years. The species Veronica beucae, V. prostrata, Dianthus carthusianorum, Sangulotubus minor, Agrimonia eupatoria, Stachys recta and Ptilosella officinalis were found to spread rapidly. Already three years after mowing was resumed, the amount of moss had increased (even on carbonate substrate), which pre- vents 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 composi- tion was directly proportional to the chosen restoration in- tensity. Some species, e.g. needle-grasses, reacted better than others. Besides a generally lower vegetation, the grass- lands saw a division from more mesophilous to xerophilous species. Clear population growth was recorded for the spe- cies Festuca valesica, Astragalus danicus, Artemisia pon- tica, Salvia verticillata, Agrimonia eupatoria, Cynoglossum officinale, Nonea pulla and Erysimum reiparum (Tab. 1). Through more intensive grazing, Arhenatherum 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 da- nicus 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 produc- tion 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. De- spite, the sheep had to acclimate 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 natu- ral spread of needle-grasses to restored tracts in the nearby surrounding.

More intensive grazing had a positive effect on the expansion of Stipa tirsia, Vincetoxicum hirundinaria and Helichtrichton desertorum (Fig. 6). It strongly reduced Rosa canina popu- lations, but individuals of the rarer Rosa elliptica were not grazed much. A higher grazing intensity also supported spe-
The realisation of some specific measures evoked also other changes in the extent and way of spreading of selected species 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 festuca valesiaca grew in number. The abundance of Astragalus exscapus, 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, ephemorous species like Holostemma umbellatum and some speedwells (Veronica spp.) expanded already in the second year.

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.).

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.

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The abundance of Festuca valesiaca (dominated by Festuca valesiaca) grew in number. High grazing intensity led however to degradation of areas with sheep-folds. Here, and in other strongly disturbed places, ephemorous species like Holostemma umbellatum and some speedwells (Veronica spp.) expanded already in the second year.

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New insights and recommendations

- For dense shrub and tree stands, multiple rigorous inter-
  ventions need to be planned, as new shoots reach heights of up to 1 metre per year in the Thermophile.
- 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 ap-
  peared already in the second year.
- Restoration management intensities made an essential
  difference as for impact on the development of steppe
  species. Helenacon desertion was found to spread
  better after more rigorous disturbance of the soil surface.
- The ability of sheep to also graze dry, leaved plants
  at these sites manifested itself after adapting the herd
  structure or as in late as the third generation of the origi-
  nal breed.
- The proximity of species-rich source sites and partly also
  older supplies of germinal deposits 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 collabora-
tion with the NGO, concerned municipalities, landowners,
NGOs and private individuals. The public was involved by
promoting restoration management (e.g. organisation of a
'Steppe Festival' at Randá, publication of information materi-
als, competitions at schools, a permanent exhibition on the
'Steppe Festival' at Raná, publication of information materi-
al, competitions at schools, a permanent exhibition on the
'steppe sites at restored sites in a natural way.

Acknowledgements

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

References

Anon. (2011): Metodika monitoringu efektivity opatření
zvláště chráněných druhů (Methods for monitoring the
effectiveness of measures funded by subsidies - category A2, measures to support species diversity in permanent
grasslands; category A2, mowing, grazing and shrub re-
moval aimed at preserving or restoring habitats of pro-

Restoration of heath vegetation

The heathland and low grassland vegetation of Křížky
NNM long suffered from expansion of tall grass vegetation due to
the non-intervention regime introduced in the 1960s. There-
fore, the next expansive 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 monitor-
ing 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 effec-
tivity.

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 howev-
er 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, Polygalas chamaebuxus and Vaccinium ulgi-
nosum 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 vil-
lage of Prameny, which was historically documented already
in the 14th century. The oldest primary evidence of non-forest
vegetation at Křížky is a Stara starostelska map from the first
half of the 19th century. In the first half of the 20th century
(and probably also long before) Křížky was an extensive-
ly 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 start-
ed to encroach the area, and tall grasses gradually expand-
ed 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.

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

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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. There-
fore, the next expansive 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 monitor-
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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 effec-
tivity.

Initial state

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

Location
Slavkovský les, Mnichovské hůrky, Křížky NNM; elevation 790–817 m

Conservation status
PLA, NNM, SAC

Restored area
4.5 ha

Financial support
ME Landscape Management and Restoration Programmes
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 Plantanthera biflora, increased here. All in all, we can conclude that shee 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, Cal- luna). 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 attrac- tive 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.
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; Mären 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 regu-
lar intervals of 3 m) especially made to repel deer was set up around the whole circumference. The dwarf-shrub communi-
ties however had 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 flow-
ering winter heath plants.

Winter grazing by overbred silka 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 re-
juvetation of this legally protected species in the adjacent Upolínová louka NNM.

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

References

Tájek P. (2010): Mnichovské hadce – jedinečná ukázka hadcového fenómu (Mnichovské hadce, unique show-

Tájek P., Klausiaková A. & Víš P. (2012): Vývoj populace různé kulíškovitých (Cerastium alpinifolium) v NPR Klížky v le-
tech 1984–2012 (Development of Cerastium alpinifoli-

Tájek P., Janovský Z. & Lampej Bucharová A. (2015): Florá a vegetace národní přírodní památky Klížky a její vývo-
je také těsně spojeného deštníku (Flora and vegetation of Klížky National Nature Monument and vegetation de-

Tájek P., Janovský Z. & Víš P. (in prep.): Habitat differentiation and distribution of serpentine endemic Cerastium alsi-
folium, C. arvense and their hybrid.

Ter Braak C.J.F. & Šmilauer P. (2012): Canoco reference man-

Víš P., Wolfová K., Urus T., Tájek P. & Suda J. (2014): Inter-
specific hybridization between rare and common plant 
congeners inferred from genome size data: assessing the threat to the Czech serpentine endemic Cerastium alpinifolium. – Plosa 86: 95–117.

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

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

Restoration of open sand communities in southern Moravia

Klára Řehounková & Ivana Jongepierová

Abstract
In Váté plísky NNM, restoration and monitoring of open sand communities has been carried out since 2010. In degrad-
ed 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 de-
velopment 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 af-
ter 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, re-
moval 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. Dur-
ing the Holocene, oak forests – apparently with Scots pine (Pinus sylvestris) – developed here. However, in the Middle Ages these were felled and intensively grazed, thereby re-
leasing sand again, and sandstorms even started to occur. In the 19th century, the entire area was gradually purposely afforested with Scots pine. Open sands with Pannonic psam-
mothyric steppe vegetation (Festucion vaginatae alliance, Naturschutzverband, 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 plísky 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 conserva-
tion authorities and NGOs.

Abiotic conditions
The sand contains a large proportion of silica and is charac-
terised by an acidic soil reaction (pH 4.5–5.5). Arenic camb-
isol and locally also arenic regosol have developed on them 

Financial support
ME Landscape Management and Restoration Programmes

Location
Váté plísky 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 180–100 m

Conservation status
NNM, SAC, SPA

Restored area
Total of 11 sites covering 2.7 ha (until 2015)

Initial state
On several hectares throughout the NNM territory, dense Calamagrostis epigejos populations used to occur. They 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.
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 epiglaeos 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 Pirus sylvestris, Solidago gigantea, Populus tremula and Robinia pseudoacacia.

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 Vátlé 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 from 8.2 ± 3.2 to 4.2 ± 2.95) as compared to the 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. 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 results of indirect gradient analysis (Fig. 4) show that the spontaneous vegetation development in disturbed plots rapidly directs towards psammophytic vegetation.

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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References


Secondary grasslands and heathlands
Restoration management of Molinia meadows in a military training area

Alena Vydrová & Vít Grulich

Abstract

The decline in Molinia meadows 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 metamorphic rocks (gneiss and granulites) often play a role, has caused the formation of hard podsol 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 cereals. This mostly led to an impoverished species composition.

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 (Hartel 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 Molinia 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 Molinia meadows became one of the objects of protection. Both Molinia meadow types known from the Czech Republic (Chytry 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 effusus Molinion- turn 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.

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 degeneration 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 Pavlíčková (1998) monitored at the site of Olšina. Other declining species are Dactylorhiza majalis, Laserpitium pteronicum, some rare sedges and dicotyledons plants. On the other hand, grasses were found to have spread.

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

Reference

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.

Rehabilitation 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 necessity of the Czech Armed Forces to perform the management was a certain restriction; therefore no sites in target areas of military ‘polygynia’ could be selected. In the course of the year 2008, a total of seven partial sites were selected, including both types of Molinia meadows with 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.

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, Alpoeperus pratensis, Dactylorhiza majalis, and Gentiana pneumonanthe and partly also Dactylorhiza majalis’ plants are individually marked and exempted from intervention.

After the intervention, the sites are carefully raised 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 Ósi, 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 didn’t 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 masses 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 became much denser. By contrast, in the year 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.
Management leads to regeneration of the moss layer, which is evident especially at wetter sites.

Germinata pneumonanthe clearly dislikes a higher moss cover.

Populations of sensitive species producing little bio-

mass, especially Carex davalliana, C. pulicaris, Eriopho-

rum 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 support-
ed successional change towards mires to peatland types of
the habitat of acid moss-rich fens: low sedges prevail in
the vegetation at present, at the site of Mošíný u Děčína
the measure has strongly supported the vitality of Carex davalliana.

At the site of Mošíný u Děčína, 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 showed weakness;
some of the diagnostic species of the Molinion al-
lance, e.g. Molinia caerulea and Stipa capillata, have gradually started to enter the vegetation.

Diagnostic species of nutrient-rich Molinia meadowss,
particularly Serratula tinctoria, Betochnos offins and
Lasiocleron pseudofruticosum, reacted markedly at mown
sites. We have not been able to explain this phenomenon
clarity; 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 organ-

isation over a longer period of time, during which it learns to
understand the specificities of the measures. Yearly alter-
nation of firms performing the assigned work is necessary to
monitor the success of management measures perma-
nently, to assess them and to implement the monitoring re-
sults 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-di-

verse plant communities.

References
Albrecht J. et al. (2003): Českobudějovicko (České Buděj-

ovice region). – In: Machkovič P. & Sedláček M. [eds],

Chválená území ČR, Vol. 8. – AOPK ČR & EkoCentrum

Brno, Brno.


Soubor doporučených opatření pro evropsky významnou

lokalitu Boletice (CZ0314123) (Summary of recom-

mended measures for SAC Boletice (CZ0314123)). –

Unpublished, AOPK ČR, Praha.


biotopů v České republice. Východiska, výsledky, pers-

pektivy (Habitat mapping in the Czech Republic. Princi-


Pavlíčka A. (1998): Gentianaceae – hořcovité na Prachatic-

ku (Gentianaceae – gentians in the Prachatice region).


Roudr J. [ed.] (2006): Vojenské území Armády České repub-

liky (Military training areas of the Czech Armed Forces),

– Ministerstvo obrany České republiky / AVIS, Praha.


biotopů v České republice. Východiska, výsledky, pers-

pektivy (Habitat mapping in the Czech Republic. Princi-


Pavlíčka A. (1998): Gentianaceae – hořcovité na Prachatic-

ku (Gentianaceae – gentians in the Prachatice region).


Roudr J. [ed.] (2006): Vojenské území Armády České repub-

liky (Military training areas of the Czech Armed Forces),

– Ministerstvo obrany České republiky / AVIS, Praha.

Heathland restoration by means of controlled burn

Bohumil Fišer, Hana Mayerová, Martin Adámek & Jan Hora

Abstract

Expansive heathlands are among the most valuable habitats
in the Brdy PLA. Their existence is the result of military train-
ing 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
physiocoenological relevés, including comparison with phy-

tosociological 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 fenced,
each with an area of almost 500 ha – Brda, Jordán and Tok
(Čapek 1998). Continued military training then led to the crea-
tion of open heathland with Calluna vulgaris, Vaccinium myr-

tillus, V. vitis-idaea and acidophilic grasses which is unique

in the Czech Republic. Artificial 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 heath-

Calluna vulgaris). Heather plants grow old in about 25

years, lose their ability of vegetative reproduction and the

heathland then degenerates gradually (Gimming 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, Malik et al.

1984). On the other hand, long exposure to high tempera-

tures can reduce germination rates (Schimmel & Granström

1996).

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

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

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

The heathland in the Jordán target area is approximately in

the middle of its life span, with few seedlings, located main-

ly in craters created by ammunition explosions. Keeping the

ecosystem in a favourable state requires active manage-

ment (Peleot & Fišer 2016). The Brdy PLA management

plan recommends prescribed burn of target areas as a suita-

ble 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 sev-

eral incidental fires, located in the SW part used for air force

training. Large areas of Jordán are therefore overgrown by

birth (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.
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.

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, Cypripedioideae 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 vegetative 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.

Restoration objectives  
Restoring heathlands in former military target areas by prescribed burn.

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 nearby area of the experiment with known fire history were localized. 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).

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

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)

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 3×, 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 uncontrollable 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 disadvantage is the higher cost.

Vegetation retreats 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 complicating issue due to explosive loads). On the other hand, it is necessary to repeat burning in a certain cycle to prevent heathland degradation.

Acknowledgements

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References


Regeneration of Vaccinium myrtillus two weeks after controlled burn. (B. Fíšer)
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 effectiveness 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 2–3 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).

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.

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 be-
came 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 increased the cover of herbs, 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.

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References
Henning K., von Oehimb B, Hardtle W, Fichtner A & Tischew S. (2017): The reproductive potential and importance of key management aspects for successful Calluna vulgaris rejuvenation on abandoned Continental heathlands. – Ecolo-
gy and Evolution 7: 2091–2100.

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 2018 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)

Restoration of heathlands in Podyjí National Park
Lenka Reiterová & Robert Stejskal

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 Euphorbia cyparissii-Callunetum vulgaris association (with dry steppe grasslands of the Pteridium aquilinum-Festucetum rup- colae association (Xerothermic-Pine forest association). 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).

The environmental conditions are currently, due to increasing nitrogen concentration in the atmosphere and, by extension, in the precipitation, namely considerably different from those prevailing in the past. The precipitation, in the precipitation, namely considerably different from those prevailing in the past. Monitoring objectives
Preserving and restoring heathlands over an area registered since 1992 has been monitoring by Iva Kei-

Abiotic conditions
The subsoil under the heathlands near Znějmo consists of acidic rock, predominantly of granodiorites of the Karpathian Foredeep. The soil horizon is generally very shallow. A low nutrient soil content and water deficiency are limiting factors. The area of the Znějmo heathlands is 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 1998). 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 (Gilpin 1994) indicate that regeneration of heather (Calluna vulgaris) is significantly supported by burning. This information could not be used for regular health 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 Znějmo. 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 periodical-ly translocated enclosures). Gradually, at least occasional grazing has been introduced on heaths with a total area of 150 ha. Kraví hora near Znějmo 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 for birds, small mammals and insects, the shading and litter accumulation gradually leads to degradation and extinction of the original oligotrophic xerothermic community. In most appropriate areas, methods of shrub reduction in Podyjí have been falling, initially in winter, 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 Znějmo 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 the limiting of national subsi-
diaries 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 prepara-
tion 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 20–50 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 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 Kei-
zer-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 Znějmo, 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 mow-
ing 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 cyparissae-

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

Grazing
Aggressive tall grasses are reduced only by high-intensi- ty 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 are- as 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 impor- tant 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 in- tensity is not sufficient to suppress tall grasses. Especially a later start of grazing significantly reduces its effectiveness. It is appropriate to add goats to the herd in order to control the expansion of shrubs and trees. In order to diversify the veget- ation, 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 already de- veloped towards other communities than heathlands or dry grasslands of the abovementioned associations.

Experience from Podyjí thus supports the acknowledged the- ory 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 sub- montane regions, however, needs to be raised in warmer re- gions and particular attention should be paid to starting the grazing as early in the season as possible (already in Febru- ary 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 thin- ning, in some cases to uproot the shrubs and trees, before grazing. 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 ex- perimental 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 treat- ed 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 en- croached 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 devel- opment of shoots after cutting black locust, even without her- bicide treatment of the trunks. It was also significantly bene- ficial 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 Balata nigra, these aggressive spe- cies strongly declined during one season of forced grazing, starting steppe grassland regeneration. If grazing is intro- duced 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 Arrhenatherum grassland. Very intensive mowing (min. 10× per season) helps reducing the abundance of Calamagrostis epigejos. If a site is mown every time Calama- grostis reaches a height of max. 25–30 cm (i.e. before flow- ering), 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.

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 num- ber of target species, e.g. Genista pilosa, Pikesella spp., Agrostis capillaris and also seedlings of Calluna vulgaris, ap- peared 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 Calama- grostis tillers. Sod-cutting also gives good results in hither- to preserved heath vegetation, where not only seedlings germinate but also old tussocks regenerate from the roots. Sod-cutting leads to a removal of the topsoil layer, where the accumulation of available nitrogen is the strong- est. 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 tem- porary, 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 differ- ent 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 dis- turbances (burning or sod-cutting). Disturbance by burning and also sod-cutting must be carried out with sufficient fre- quency, repeating it once every 10–20 years. In both cases, sufficient intensity is also important: burning at medium in- tensity, 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 experi- ments – is still restrained by legislative obstacles.

Practice shows that principally any measure leading to a lim- itation of aboveground biomass accumulation can prolong the existence of a heathland and its ability to restore. There- fore no available management approaches need to be reject- ed, whether cutting, raking, vehicle traversing or other ones. However, a special attention should be attached to the biomass from the heath as possible, and the intensity of the measure must always be indirectly proportional to the frequency of its application.

References
WATERCOURSES AND WETLANDS
Wetlands have an irreplaceable function in the water retention of a landscape and in improving the water balance. Besides these vital 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 fundamentals 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 & Skalů 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-

Introduction

Tomáš Just & Pavel Pešout

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

Ter courses, 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...
are removed from the riverbed, and bank breaches are land-
ed up even in places where this is unnecessary. Drain sys-
tems 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 Op-
erational 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 Restora-
tion 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 Podbabičko regions and a
range of other regions. Peak restoration projects are running
successfully in the Sumava NP and PLA (Bučková 2013), in
the Slavkovský les PLA, Jizerkště hory PLA, Kokořínské NP, the
Krčuňský hory Mt., etc. Pools are an integral part of the re-
tvalisation of quarries, e.g. in the Třebíč and Most regions
(Řehounek et al. 2010, Uhlířský 2013). Recently also ex-
tensively managed fish lakes aimed at biodiversity support
are being restored. Examples are the extensive revitalisation
of Bohdanečský rybník lake (Franiková & Peřina 2014) and
the restoration of Lake Kojedin in the Polabí region (Ríma et
al. 2014). Attention is also paid to the restoration of mead-
ow marshes, fen meadows and salt marshes (Lyšák 2016,
Dedek 2016). Successful projects improving the morpho-
logical-ecological state of watercourses include the revital-
sation of the Bílovka and Sedlnice rivers in the Poodří PLA
(Bírková & Stěnka 2014; Jarošek & Čermák 2012) and the
Jizerka river (Holčík & Páti 2016). The revitalisation of the
Krušněné stream in the Beskid Mt., including the subsequent
elimination of a river structure, was ground-breaking also
from the administrative point of view (Nešťalová & 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 prepar-
ing restoration projects are sufficiently motivated, they man-
age 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 appro-
priate corrections.

• Collaboration with municipalities. If a municipality is in-
terested in realising a plan, it will be able to use some of
its competences in land questions better than e.g. a na-
tional 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)

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 Pro-
grame Environment. As a whole however, we still strong-
ly 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 plan-
ning 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 unfortu-
nately insufficiently spread among planners, who are more-
over not much inspired by river morphology and floodplain
ecology. This is to a considerable extent the fault of their

Fig. 6. In the restoration of Lake Kojedin (Růžďalovice region) in Rybník Kojedin NMa, realised by the NCA, adjacent wetland communities
were supported by creating bypass 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. Týs,)

education: wetlands, lake and river morphology and ecology are mainly studied by natural scientists, who hardly come in
contact with designers, whereas hydraulic engineers tradi-
tionally rather learn about conservative approaches to water-
course 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 develop-
ment of a revitalisation and for its persistence in unfavour-
able 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 some-
thing 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 revetted de-
velopment, which — according to the operating regulations — should lead the authority to carry out corrections in case the conditions 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 subsequent maintenance.

Equally, in the case of creating wetlands, pools or peatbogs, landowners and farmers who restore or create wetlands as a means of preventing their destruction and, conversely, farmers are motivated to manage them, which is basically not supported by subsidies. Recent programmes, in which registered wetlands enjoy protection and are rewarded, are not able to eliminate the mentioned problems of current management, which has 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)

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 canalised watercourse or geometrised riverbeds, riverbeds filling up with sediments or vegetation, are considerably higher than e.g. the maintenance of a canalised watercourse or a pool. Riverbeds have particular processes to their high costs and demands for land. To achieve a revitalised riverbed back to a natural state. Partial processes changes caused by natural forces which lead technically adequate riverbeds back to a natural state. Partial processes include disintegration of reinforced embankments, erosion of geometrised riverbeds, riverbeds filling up with sediments or vegetation, or degradation of the shape and features of floodplains and trees and shrubs. Changes may be very quick if caused by floods. Watercourse authori- ties, led by conservative ideas, have however destroyed the results of partial processes. 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 naturalisation which are absolutely indispensable (Just 2016).

References

Anon. (2015): Výbrané problémy ochrany přírody a krajiny a možnosti nápravy s využitím dotací pro odborné a pobočné práce, Sborník z konference. – AOPK ČR a ČZU, Praha.


Restoration of a drained mire in Šumava National Park

Ivana Buřková & František Stíbal

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 Anacamptis 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 disticha and Trichophorum alpinum) and plant assemblages.

Financial support
Operational Programme Environment; €200 thousand

Location
Open valley in upper Zhůřský potok stream (Křemelná), NW part of Šumava National Park, 49°11’10”N, 13°38’55”E; elevation 925 m (name also abbreviated to Zhůří)

Conservation status
Šumava NP (Zone II), SAC Šumava

Restored area
3.1 ha, total of 7.4 km of blocked drainage channels

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 ⅔ 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 trifidus 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.

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.
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 drainage channels 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 deeper 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 terrestrialization of ditches and establish appropriate wetland vegetation. Shallow ditches, especially under good light conditions, usually started to revegetate spontaneously from the banks.

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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$_2^-$, NO$_2^-$, NH$_4^+$, PO$_4^{3-}$, 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 distances. 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

<table>
<thead>
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<th>2009–2013 (pre)</th>
<th>2016 (post)</th>
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<tr>
<td>V-r</td>
<td>1</td>
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<tr>
<td>V-p</td>
<td>-36</td>
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<tr>
<td>LR-r</td>
<td>-38</td>
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<tr>
<td>LR-p</td>
<td>-23</td>
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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 milligrams 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).

References

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.

Fig. 8. Blocked draining channel after restoration. (I. Bufkova)
Restoration of an extracted peat bog – reintroduction of two target species

Ludmila Viková & Karel Prach

Location
Šumava, part of Vitavský luh wetland and peatbog complex, 48°54'45" N, 13°49'33" E; elevation 745 m

Conservation status
NP Zime III, SAC

Restored area
5.3 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 oxycoccus were experimentally sown and planted in Soumarský most peatbog in the Šumava NP, formerly industrially exploited but restored in 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 (Zyvol 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. 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 fuscum 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).

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 grew 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 ground-water 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. 1. Eriophorum vaginatum is the most successful colonist of the extracted peat bog. (L. Viková)](image-url)

![Fig. 2. Comparison of annual fluctuations in groundwater level for the same boreholes (Nos. 1–7) before (a) (Zyvol 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.)](image-url)
when many plants on peat and in sphagnum dried up. A reduction in seedling survival was found in the summertime, at −6.9 cm (Vlková 2016). The strongest mortality of plants is expected at water levels −29.4 cm, at −20.3 cm, and at −12.4 cm. Lower mortality is evident at water levels −1.8 cm, −0.4 cm, and +0.6 cm. The remaining peat layer (unexploited bog margins) typically grow. The groundwater level rises with declining peat depth. The groundwater level optimum is −30 cm, −9 cm, −4 cm, −2 cm, and +1 cm. 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 dispersers reach them – in other words, their absence hitherto is explained by dispersal limitation.

Acknowledgements
The project was partly supported by grant GA ČR 311915031S.

References

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 dispersers reach them – in other words, their absence hitherto is explained by dispersal limitation.

Restoration of rich-fen bryophyte populations
Ester Ekrtová, Eva Holá, Jan Košnar & Táňa Štechová

Abstract
A project of restoring populations of rich-fen bryophytes in the Vysocina area was aimed at supporting microstructures of rich-fens in which rare bryophyte species occur. Moss-cutting and moss layer removal were performed to achieve a vital population. 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, whose composition 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-
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 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. *Mossia triquetra*, *Hamatomatrichocaulis vernicosus*, *Calliergon giganteum*, *Campylium stellatum*, *Tomentypnum nitens*, and rare sphagnum species, e.g. *Sphagnum obtusum*, *S. contortum* and ‘brown mosses’ (*S. platyphyllum*, *S. flexuosum* and *S. caespitosum*).

The treatment was to create small open waterlogged microhabitats, which could be colonised 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 small hand swards, 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. The frequency of various species monitored in the quadrats after 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 *Straminigeron straminium* as well as less common species like *Pseudocampylium radiatum* and *Plagiomnium elatum*. In some plots even the rare species *Hamatomatrichocaulis 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 radiatum*. 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’ *Hamatomatrichocaulis 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. pratense*, which is explained by the fact that these species formed the highest percentage of biomass removed in the treatments. The reaction of *Sphagnum teres* to the treatment was very mixed; 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. *Polypodium

**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). Now, 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 *Straminigeron straminium* as well as less common species like *Pseudocampylium radiatum* and *Plagiomnium elatum*. In some plots even the rare species *Hamatomatrichocaulis vernicosus*, *Calliergon giganteum* and *Campylium stellatum* appeared.
commune, P. strictum and Aulacomnium palustre. Partial reduction was also recorded for the relatively rare species Ditosanthes borjiandii, 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.

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 triqueta was restored after more than 50 years. Soon after a compact sphaignum 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. Further, populations of Trichophorum alpinum, Eriophorum latifolium, Eriophorum angustifolium and Pedicularis palustris (Fig. 7). The positive reaction of Carex ilisiosa 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 removal of old biomass, fen vegetation immediately regenerated, in all 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 effectiveness, treatments need to be located in the immediate proximity of standing target species populations. Their extent should vary from 2 to 25 m².
- 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 minimised 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 hardly to estimate the depth of the treatment. In dry weather, target bryophyte species regenerate badly.

New insights and recommendations

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### 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.

<table>
<thead>
<tr>
<th>Quadrat segments</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryum pseudotriquetrum</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Campylium stellatum</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Calliarthron cuspidatum</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Hamatocaulis vernicosus</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sphagnum palustre</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Tolypodiscus flexuosum</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Straminergon stramineum</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Fig. 4. Numbers of species recorded at the different sites (VL – V Líšovice, NO – Na Oltice, K – Rašeliniště Kaliště, S – Šmarsová rašeliniště, CH – Chvojnov, j – Jindřichov rašeliniště) before (spring 2014) and after treatment in summer 2014 (Time 1), spring 2015 (Time 2) and summer 2015 (Time 3).

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 prostrata, Campylium stellatum, Calligorgia giganteum, Hamatocaulis vernicosus, Sphagnum contortum, Tomentypnum nitens – species indicated in green).

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 nearby varied waterlogged depressions. After the operation, Meesia triqueta, not found here for decades and regarded to be extinct, started to regenerate spontaneously. (V, Kudel, L. Dirt)
Horse grazing as a way of restoring inland salt marshes

Jill Knet, František Foltýn & Helena Prokešová

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 (Zapleták 1959). 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.

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 Mýtiny lake complex (Danihelka & Hamušová 1995).

After 1990, the site was yearly mown manually or mechanially (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...
first time in many years. As the grazing took place in sum-
mer, 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 grass-
land denser and denser, so that the most sensitive halophytes
centered in artificially deepened rills or spot-
radically maintained themselves on a field road and in its
marshes. 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.

Measures applied

<table>
<thead>
<tr>
<th>Time</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008–2012</td>
<td>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</td>
</tr>
<tr>
<td>2009</td>
<td>Building stable wooden fences in the western part of the site (2.68 ha), initiation of more permanent grazing</td>
</tr>
<tr>
<td>2009–2012</td>
<td>Eastern part: mowing strips, leaving 1/3 of the area unmown for the entire season</td>
</tr>
<tr>
<td>2009–2014</td>
<td>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)</td>
</tr>
<tr>
<td>2012</td>
<td>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</td>
</tr>
<tr>
<td>2013</td>
<td>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</td>
</tr>
<tr>
<td>2014</td>
<td>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)</td>
</tr>
<tr>
<td>2015</td>
<td>Rotational grazing by 8 Kladušer horses 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.)</td>
</tr>
<tr>
<td>2015/2016</td>
<td>Cutting reed strips in the eastern part of the site, connecting salt marsh and Nesyt pond (1.2 ha; Nov. to March)</td>
</tr>
<tr>
<td>2016</td>
<td>Rotational grazing by 8 Kladušer horses (9.06 ha; April to Oct.); deepening 5 shallow pools</td>
</tr>
</tbody>
</table>

Monitoring methods
Since grazing was introduced in 2009, the flora at the site
has been monitored in roughly monthly intervals. Particular-
ly 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 com-
pare 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.

Average Borhidi indicator values for salinity (Borhidi 1995),
calculated for each relevé using values assigned to the dif-
f erent species, were used as a tentative indicator of the sa-
limity 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 inten-
sive, 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 stagnat-
ed or slightly improved (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 tenuissi-
num, Plantago maritima and Tripolium pannonicum, which occurred rather as an admixture in dense salt marsh grass-
lands 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 in-
tensive rotational horse grazing of the salt marsh. In 2015, two critically threatened grasses, Cynips schoenodes (see Fig. 2) and Cynips 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 previ-
ous years. 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, sev-
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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 pres-
sure is maintained.

Fig. 2. Cynips schoenodes is a species typical of exposed saline 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)

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 improved (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, Cynips schoenodes (see Fig. 2) and Cynips 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. Cynips 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 (Dedok 2015)
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 best results. The reserve has six separate enclosure segments, which can be divided into smaller units according to need, creating new 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 paviflora, 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.

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 of 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 Weisser for his practical contribution to the management of the site, his patient collaboration and great willingness to meet our requirements.

References


Revitalisation of a formerly canalised river

Zdenka Herová & Karel Prach

2.65 km section of the Stropnice river near the town of Nové Hrady, southern Bohemia, 48.82° N, 14.80° E; elevation ca 410 m

Conservation status

SAC, Landscape Heritage Zone

Restored area

Approx. 20 ha (area directly effected)

Financial support

Operational Programme Environment; Povodí Vitavy, 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 Alnus glutinosa 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. acutus. 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 Vitavy, s.p. revitalised a 2.65 km long section of the river. Later other sections of the river were revitalised.

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 Querexus robur, Alnus glutinosa, Salix aurita 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 Strupnice river, 2017. (K. Piach)](image)

- **a) Synanthropic species,** most often Chenopodium polyspermum, Echinochloa crus-galli, Rumex obtusifolius and Trifolium hybridum;
- **b) Species of exposed bottoms,** mainly Alnus incana, Bidentis radiata, Carex borekiana, Cyperus fuscus, Eleocharis ovata, Glyceria fluitans, Juncus bufonius, Potentilla supina, Paspalum dilatatum, P. pratense, Phalaris arundinacea, Poa palustris and Ranunculus fluitans;
- **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, especially Agrostis capillaris, A. stolonifera, Alnus incana, Carex acuta, C. nigra, Cirsium palustre, Holcus lanatus, Juncus efusus, Phleum pratense, Poa palustris, the latter dominating in a considerable area, further P. pratense, P. trivialis and Ranunculus reptans. 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, while it often grew together with Juncus efusus, 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. aurita, established already from the 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 Strupnice 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 admixture 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 effectiveness of spontaneous succession in the restoration of floodplain ecosystems, but some management is desirable.

Acknowledgements

We are grateful to the employees of Povodí Vitavy, s.p. for providing documents for the project and other information. Our personal research was financed from sources of the Restoration Ecology Group of the Faculty of Science of the University of South Bohemia.

References


Near-natural flood control measures on a river in an urban environment

Tomáš Just & Miroslav Barankiewicz

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.

Initial state
The Blanice river channel in Vlašim had canalised shapes: it was markedly straightened and had a predominantly geometrically simplified shape, 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 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 Všim 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 m³/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.
- 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 construction in Vlašim was carried out by investor Povět Všim, 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 grates 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.

### 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; Povodi Vitavy, s.p.; Municipality of Vlašim; €3.25 mil.
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. This should be surmountable by means of electrofishing at the four sites, of which 2,762 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, Abramis brama and Salmo trutta. Fish measuring 110 mm to 262 mm were found to migrate. The VAKI bisscanner 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 (6–10 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.

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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.

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 the 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 function­­ability 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 Cyprinidae, two to the Percidae and Salmonidae, and one species to the freshwater eels (Anguillidae), 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.

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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 stages. Differences in the size selectivity of the fish passages is negligible and that differences between size classes migrate through the passages with similar success. By means of telemetry, three species (Doblo 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 Pověděl 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.

References

Just T. (2010): Přírodě blízké úpravy vodních toků v intra-městské třetině (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 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 (Doblo gobio, Leuciscus leuciscus, Squalius cephalus) were also found to be able to overcome the entire array of four fish passages.

Elimination of knotweeds in a river basin

Renata Vojkovská & Martin Krupa

Abstract

The Morávka river is unique not only from the geomorphological perspective. 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 is the Beskid Mts is, mostly in the section of Skalička 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 (Sindlar 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.

Through water management measures since the first half of the 19 th century, approx. 1200 ha of gravel banks in the Morávka basin have disappeared. The width of the active riverbed often used to exceed 300 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 Myrrthia jarmarica. 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 Morávka 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).
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 Myrtica 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.), which are mostly encountered less often during the years 1930–1996. In 2006 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 Olše. For larger areas of wetlands, the knotweed spread 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.

The places cleared after knotweed elimination were rapidly covered 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 (Modry 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 restocking 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.

**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 (Modry et al. 2008).

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**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.
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.

Acknowledgements
Our work was made possible thanks to projects LIFE06 NAT/CZ/000121 Preservation of Alluvial Forest Habitats in the Morávka River Basin, 12/FEO/2012 Management Programme for Threatened Plant Species of Carpathian Watercourses, and the project Phenomenon Moravka in Danger, supported by the Hyundai Endowment Fund and The Open Society Fund Prague.

References


Fig. 5. Oenothera biennis and impatiens glandulifera. (R. Vojkovská)

Fig. 6. Exposed gravel bank after floods in 2010. (M. Krupa)
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.
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 by species from the surrounding area 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 biodiversity 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 reclamation (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).

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 (Kovalí 2004, Tropak & Řehounek 2012). A study dealing with this habitat is included in the previous (Kovalí et al. 2012) as well as this project (Kovalí et al.). One and slags 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 (Ostárnová 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 other hand, forests and grasslands do not have to be concerned.

![Fig. 2. Fifteen-year old rock steppe at Dálky, a former limestone quarry near České Budějovice, 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 Čeřinka at a distance of one kilometer, where most of the original vegetation has vanished by advancing mining. (L. Tichý)](image)

![Fig. 3. Quarry near Ondřejov, Vysočina region, where vegetation is spontaneously establishing. (K. Prach)](image)

![Fig. 4. Former field at moderately humid site near Málno, abandoned for approx. 20 years and encroached mainly by Acer pseudoplatanus. (K. Prach)](image)

![Fig. 5. Example of spontaneously revegetating road verge near Hrádek nad Nisou. (K. Prach)](image)

![Fig. 6. Diverse marshes spontaneously formed in abandoned sand quarry near Nová Bystřice. (K. Prach)](image)
other hand in the wettest places, wetlands may success-
fully 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 di-
versifying the landscape and provide a refuge to a range of
threatened organisms, plants as well as animals (Vitek
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 succes-
sion towards woodland. Examples can be found in the works
by Lenčová & 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 bi-
omass for several years, he will soon (to see a cargo of
harvest of high nutritional quality. Even in the case of sowing
a commercial, species-poor grassland mixture there is a cer-
tain 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
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 drier and wetter 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 trans-
fer from an adjacent preserved meadow.

If possible, arable land should not be artificially affor-
ested 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 spe-
cies of open landscapes and an impoverishment of the
landscape as a whole. On the other hand, planting line-
ar landscape elements (lines of trees etc.) and solitary
trees is an appropriate measure everywhere.

Grasslands and wetlands in an advanced stage of suc-
cession are often re-ploughed. This concerns especially
spontaneously restoring minor field wetlands. According to
Government Decree No. 307/2004, effective since 1
March 2016, field wetlands can be included in the ag-
ricultural land register as ecologically significant land-
cape elements with the aim of securing their protection.

Notes on other anthropogenic habitats

Rather detailed information on the process of spontaneous
or alternatively assisted succession is available. We therefore
know of the possibilities of using succession in near-ecologi-
cal 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 fertili-
se, 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 ab-
solutely inappropriate, because indigenous trees mostly es-
tablish 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 en-
tirely left to spontaneous succession, which has already pro-
gressed towards woodland after all these years. An exception
may be formed by places where rare and threatened light-de-
manding species occur. It is then good to locally reduce tree
stands. This also relates to fishpond sediment dumps, which
arose mainly in the 1970’s to the 1990’s. Other anthropogen-
ic habitats to be mentioned are ditches of domestic and
other waste (landfills). These places are usually quickly rem-
edied by isolating them and covering them with inert materi-
als (which is also necessary with regard to possible seepage
and erosion). They can then be 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
grazing systems and swards of meadow grasses 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 ser-
ices, 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 sce-
nic 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 establishment of landscape corridors
on arable land. Any permanent vegetation protects the soil better than till-
age. Vegetation on former arable land can also create suit-
able buffer zones along streams, around towns and villag-
es, 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 includ-
ed in this publication.

With the growing spatial scale of any ecological restoration
we reach the landscape scale. In other words, most restora-
tion 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 giv-
en 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 real-
ised territorial systems of ecological stability (TSES) could
offer a chance to increase the ecological value and main-
ly functionality of the landscape. To the detriment of this,
non-ecologists often engage in these systems, turning the re-
allocation of proposed biocorridors and other TSES elements into techni-
cal 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 changes have occurred 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, relies to a great extent on political will, ad-

...depending on the number of species because such parts naturally turn into marked

...colonised by organisms from the surrounding landscape. In quarries and sandpits, spoil banks tend to be spontaneously colonised by other species than at technically reclaimed sites. Despite the undisputed ecological value of unreclaimed post-mining areas, rigorous technical reclamation with negative effects on biodiversity is not an option. The next step of our study was to compare the proportion of water environments on spoil banks spanning hundreds of hectares – formed by the dumping of material – with those created by technical recla-


Koval P. et al.: III. Ozorodé substráty v krajině (Alioth-

Prach K. et al.: IV. Obnova travinných ekosystémů (Res-


restored post-mining sites. From an ‘am-
phibian’ perspective. Therefore, we compared the proportion of water habitats at reclaimed and unreclaimed post-mining sites from the North Bohemian brown coal basin in the Czech Republic. We found that primary succes-
sion 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 unre-
claimed 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, similarly 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 num-

ed by water habitats on spoil banks

Jill Vojar, Jana Doležalová & Milič Solský

Abstract

Ecological value and abundance of water habitats on spoil banks

The ecological value and conservation potential of post-min-
ing areas have been increasingly recognised by scientists and conservationists during recent decades. Especially valu-
able is the potential to spontaneous succession, which consti-
tutes 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 ‘am-
phibian’ perspective. Therefore, we compared the proportion of water habitats at reclaimed and unreclaimed post-mining sites from an ‘am-
phibian’ perspective. Therefore, we compared the proportion of water habitats at reclaimed and unreclaimed post-mining sites from the North Bohemian brown coal basin in the Czech Republic. We found that primary succes-
sion 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 unre-
claimed 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.

Fig. 1. The rugged morphology of brown coal spoil banks is caused by the method of their establishment and the diversity of habitats created there. Internal spoil bank of the Svéma quarry in an early succession stage. (M. Hendrychová).
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 water-filled troughs, drainage ditches, and numerous small water surfaces created by the movement of heavy machinery (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 km². 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.

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 Rana 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.

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.

<table>
<thead>
<tr>
<th>Name of spoil bank</th>
<th>Recl.</th>
<th>SB area [ha]</th>
<th>WH area [ha]</th>
<th>WH / SB [%]</th>
<th>Average WH area [ha]</th>
<th>n WH</th>
<th>n WH / ha SB</th>
<th>n clutches</th>
<th>n clutches / ha SB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technically reclaimed spoil bank sites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Blíženy</td>
<td>TR, A</td>
<td>213.36</td>
<td>1.61</td>
<td>0.70</td>
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<td>4</td>
<td>0.02</td>
<td>0</td>
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<tr>
<td>Čepínov</td>
<td>TR, A-P</td>
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<td>39</td>
<td>0.08</td>
<td>15</td>
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<tr>
<td>Horníhřetínská – TR</td>
<td>TR, F, H</td>
<td>351.28</td>
<td>16.37</td>
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<td>8</td>
<td>0.02</td>
<td>24</td>
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</tr>
<tr>
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<td>TR, A, A-P</td>
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<td>4.74</td>
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<td>2.37</td>
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<td>Luchovice</td>
<td>TR, A-P</td>
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<td>2.13</td>
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<td>0.30</td>
<td>7</td>
<td>0.01</td>
<td>8</td>
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</tr>
<tr>
<td>Malé Bílčice</td>
<td>TR, A-P</td>
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<td>0.44</td>
<td>0.23</td>
<td>6</td>
<td>0.02</td>
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<td>0</td>
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<td>Merkur</td>
<td>TR, A-P</td>
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<td>3.95</td>
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<td>Ponečí</td>
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<td>Pravčice</td>
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<td>TR, A-P</td>
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<td>501.22</td>
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<td>0.01</td>
<td>26</td>
<td>0.29</td>
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<tr>
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<td>9.47</td>
<td>0.14</td>
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<td>0.69</td>
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<td>0.04</td>
<td>334</td>
<td>0.93</td>
<td>1,294</td>
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<td>Radovesická – N</td>
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<td>57.54</td>
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<td>9.45</td>
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<td>0.57</td>
<td>506.50</td>
<td>1.93</td>
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</table>

Fig. 3. A large number of various waterbodies occur on spoil banks left to spontaneous development. Technically reclaimed part of the Radovesická spoil bank. (M. Hendrychová).

Fig. 4. Agile frog (Rana dalmatina) is one of the most frequent amphibians on the Most spoil banks. (J. Doležalová).
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 can accommodate numerous ponds with conditions suitable to amphibians, thus resulting in greater diversity and abundance. Other studies on particular taxonomic groups in various types of post-mining areas have reached similar conclusions (e.g. Harabis et al. 2013, Hendrychová et al. 2008, Hodáčová & Prach 2003, Holeš & 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 (Rehounková et al. 2010, Tropek & Rehounková 2010, Zavadil et al. 2011).

Acknowledgements

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References


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 exploitation, 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 (Rojik 2004).

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.

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 CaCO₃ 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). 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 (CaCO₃). 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, Dendrobena 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 (Pišt 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 (Čepěk et al. 2013).

Incorporation of organic matter into the substrate fundamentally alters substrate properties. Shortly after deposition, the pH (H₂O) 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 1,200 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).
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 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 is deposited, ruderal plant species such as Poa compressa, Taraxacum vulgare, Tussilago farfra 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.

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. 3). 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 (Mudrak et al. 2016b). Later (between the 20th and 30th year of the succession) S. caprea stands are replaced by birch and aspen with a richer understory. At this time, also the activity of soil macro fauna creates more favourable soil conditions. The suppression of early succession species together with soil improvement promotes the establishment of more sensitive, late-successional tree 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 understory (up to 51 species per 25 m²). In this stage, meadow species such as Anthrrenatherum 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 (Mudrak et al. 2016a). At the same time, seedlings of late-successional tree species, especially oak (Quercus robur) and beech (Fagus sylvatica), appear in the understory. 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 understory.

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), 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 understory of oak (on average 19 species per 25 m²). Reclaimed sites planted with oak did not differ statistically from areas with spontaneously established trees (on average 17 species per 25 m²). The lowest number of species was found in alder plantations (on average 10 per 25 m², Mudrak 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 is 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.

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 improve ment 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) is unnecessary 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 macro fauna (e.g. oak).

Acknowledgements

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References


Plant-ant interactions in habitat restoration on abandoned tailings

Pavel Kovář, Ota Rauch, Pavel Pech, Romana Prausová, Markéta Dvořáčková, Michal Štěfánek & Pavel Vojtíšek

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 containing metalliferous sediments 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 construct-ed later at the power station of the 1970s) of three ore tailings as the remains of former pitte 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 coloni- sation 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 domi-nated by Betula pendula, locally with admixed Betula pubes-cens, 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, Pech et al. 2016). The surface of the substrate is periodically and massically covered with efflo-rescences (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 retrongrading of reseeded pedons of the abandoned sedimentation basin with visible route of Lasius ants. (P. Kovář)

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

Fig. 7. Approx. 55-year old spontaneously vegetated spoil heap in the Sokolov region, (K. Prach)
substrate, a strongly consolidated horizon with brown-red iron oxides and gypsum developed (Rauch 2004). The un-claimed deposit, whose development was not influenced by any management measures therefore remained treeless for a long time. In such a toxic environment, vascular plant di-versity 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 & Johannsen 1999, Hrudová & Zákravský 2004). In both types of environment, the crusts are typically formed by mushroom mycelium, cy-anobacteria, algae, lichens, mosses and liverworts (Neustu-pa 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 dy-namics support the transport and building activity of ants (Jarešová 2001), which become one of the most important factors contributing to an acceleration of vegetation succes-sion 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 biosturbation activity at the substrate surface on plant diversity and vege-tation development.

**Monitoring methods**

The site with two reclaimed and one abandoned (un-reclaimed) 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, mosses, herbs and shrubs; Jarešová 2001, Jarešová & Kovář 2004) and 2011–2012 (more differentiated vegetation ma-saic 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 activ-ity of ant workers, the removal of seeds of each plant species was quantified.

We also compared the increase in plant species when en-larging the sampling in a part of the waste pond densely cov-ered 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 hisuri-ta, Plantago lanceolata, Agrostis capillaris, Trifolium repens and Rumex acetosella) from the surrounding of the sedimen-tation 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 possi-bile changes in chemical parameters period. Several in ant the nests is currently conducted by Jílková et al. (2017, see also Frouz & Jílková 2008).

<table>
<thead>
<tr>
<th>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).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set One</td>
</tr>
<tr>
<td>Potentilla argentea</td>
</tr>
<tr>
<td>Rumex acetosella</td>
</tr>
<tr>
<td>Holcus lanatus</td>
</tr>
<tr>
<td>Calamagrostis rubra</td>
</tr>
<tr>
<td>Trifolium subterraneum</td>
</tr>
<tr>
<td>Pisum sativum</td>
</tr>
<tr>
<td>Trifolium repens</td>
</tr>
<tr>
<td>Vicia hirsuta</td>
</tr>
<tr>
<td>Agrostis capillaris</td>
</tr>
<tr>
<td>Plantago lanceolata</td>
</tr>
<tr>
<td>Lychnis xee-cucullata</td>
</tr>
<tr>
<td>Lathyrus tuberosus</td>
</tr>
<tr>
<td>Cicuta vulgaris</td>
</tr>
</tbody>
</table>

Results

Myrmecochory, i.e. the distribution of seeds by ants, tested here by means of supply dishes, was based on seed attrac-tiveness, put in different amounts in the proximal of 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 succes-sion stages with a tree layer. Lasius niger and Tetramorium caespitum did not differ 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 medi-um-sized Lasius niger. It is however a fact that of the large-sized ants (genus Formica), the ‘consumers’ were each time other species than those than in an analytical 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 in-crease in their diversity. Their latest known state (2015) in-cluded 24 species (see Tab. 2 for a list).

Formica sanguinea, F. pratensis and Lasius umbratus repre-sent a group of temporarily parasitic species exploiting nests of already settled pioneer species, such as Formica cucu-liaria, F. fusca and F. rufibarbis, Lasius niger, L. platythorax and related species, to take control of the space.

<table>
<thead>
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<tbody>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Formica sanguinea</td>
</tr>
<tr>
<td>Formica pratensis</td>
</tr>
<tr>
<td>Lasius niger</td>
</tr>
<tr>
<td>L. fusca</td>
</tr>
<tr>
<td>L. platythorax</td>
</tr>
<tr>
<td>L. umbratus</td>
</tr>
<tr>
<td>Leptothorax acervorum</td>
</tr>
<tr>
<td>L. gryneri</td>
</tr>
<tr>
<td>L. muscorum</td>
</tr>
<tr>
<td>Myrmica rubra</td>
</tr>
<tr>
<td>M. nivosa</td>
</tr>
<tr>
<td>M. rubra</td>
</tr>
<tr>
<td>M. sabuleti</td>
</tr>
<tr>
<td>M. astrioides</td>
</tr>
<tr>
<td>M. schencki</td>
</tr>
<tr>
<td>Tetramorium caespitum</td>
</tr>
</tbody>
</table>

The curves showing dependence of number of plant spe-cies 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 occu-pied 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 moni-tored plots, were excluded experimentally; seedlings of 6 selected plant species from the surrounding of the waste pond, grown 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 develop-ment (2011–2012) on an unoccupied ore waste pond (in comparison to the years 1998–2001), the following conclu-sions can be drawn:

- Experiments with supplying seeds of plants from the sur-rounding 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. La-sius niger and Tetramorium caespitum removed about the same amount of seed. Part of the transported seeds germinated in the proximity of their nests, and some to the seedlings survived. Some species are able to create a viable population completing the succession stage of the
Plots with ants

Plots without ants

Number of plant species in plots with and without ants

<table>
<thead>
<tr>
<th>Area in m²</th>
<th>Number of plant species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>64</td>
<td>20</td>
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<tr>
<td>256</td>
<td>40</td>
</tr>
<tr>
<td>1024</td>
<td>80</td>
</tr>
<tr>
<td>4096</td>
<td>160</td>
</tr>
<tr>
<td>16384</td>
<td>400</td>
</tr>
</tbody>
</table>

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)

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).

Acknowledgements

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References


Acknowledgments


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).

Conservation status: NNM, SAC

Management and Restoration Programmes, Central Bohemian Region

Abstract
One of the populations of the Czech endemic sandwort Minuartia smejkallii 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.

Hana Pánková, Zuzana Münzbergová & Karel Kříž

Fig. 1. Initial state of the site in 2006: illegal waste dump.
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 ČL Vlasim. The first measure was carried out in 2007, when the illegal dumpsite was removed from the quarry and spontaneously established spruce was eliminated in the southern part of the quarry. This operation appeared to be insufficient and, moreover, dumping was resumed in 2010.

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 serpentinite 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 tufts, 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 (tuft 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 & Murzíbiová 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, Pylé 2012), and species of near-natural habitats (further referred to as target species) typical of preserved parts of Hradec 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 water body (Ellenberg value for humidity above 6) were exempted from the analyses. Alloetic conditions at the site were assessed by determining tree layer shading, total irradiation, chemical soil composition and depth of the soil horizon.

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 neralisation 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 serpentinite rocks completely, Grimnizal and ruderal plant species (e.g. Circaea lutetiana, Rubus idaeus and Galium aparine) dominated the vegetation here, see Fig. 2. The serpentinite bedrock was covered with a deep humus layer. Minuartia smejkalii only grew on serpentinite rocks protruding at the periphery of the quarry (except for the area of the illegal waste dump, where it did not grow at all).

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%.

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—as 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 seasons, many of species characteristic of preserved sites, e.g. Potentilla cryzantplis subsp. serpentini, Knautia versicoloris, Thymus praecox, Festuca ovina, Pimpinella saxifraga, 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. 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)

Fig. 4. Shading by the tree layer in the years 2007, 2008, 2016 and 2017.

Fig. 6. Percentage of species of anthropogenic habitats, i.e. species characteristic of X habitats or included in the Catalogue of Alien Plants (Pylé 2012), and target species characteristic of the preserved part of Hradec u Želivky NNM and regarded to be indicators of the quality of the habitat (brown).

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 Protektorate motorway and a small rural serpentinite 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 microlatitude after the water reservoir was filled and the increase in NOx deposition from the nearby D1 motorway have caused enrichment of the soil with nutrients and led to neralisation 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 serpentinite rocks completely, Grimnizal and ruderal plant species (e.g. Circaea lutetiana, Rubus idaeus and Galium aparine) dominated the vegetation here, see Fig. 2. The serpentinite bedrock was covered with a deep humus layer. Minuartia smejkalii only grew on serpentinite rocks protruding at the periphery of the quarry (except for the area of the illegal waste dump, where it did not grow at all).
Succession of woody plants in a military training area

Jaroslav Vojta, Josef Brůna, Eva Horčičková & Lucie Kačmarová

Abstract

The extensification of agriculture results in abandonment of relatively large areas on which shrubbery 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.

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. 1. Development of open and wooded vegetation percentages around the abandoned village of Tocov. (Brůna 2009)

Fig. 2. Woodland rich in structure on former farmland. Uprooting and crown breaking are caused by heavy wet snow. (J. Vojta)

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-rich 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 < 0.005) 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 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.

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 CLUC LC Všátek for their voluntary management work.

References

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.

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, Persistent 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 shrubs 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 shrubs, heliophilous species like Koeleria pyramidalis, Festuca rubra, 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 Geum urbanum, Mercurialis perennis and Hordelymus europaeus. Surprisingly, grassland species were found to maintain better than in the surrounding farmed landscape. A more detailed analysis has shown that species of nutrient-poor habitats (characteristic of the Koelerio-Phleion phleoidis and Hyperico perforati-Salanierrion peregrini 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 competitive 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).

Open grassland 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 higher, 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 Gaium odisratum, Hordeum 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 considerably speeded up by 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,
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 scrub 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.

References

Drhovská L. (2007): Význam historické struktury krajiny pro planting and large-scale felling. (J. Vojta)


Horčíčková E. (2010): Vliv prasete divokého na vegetaci se-

Fig. 8. Thickets with hawthorn and ash on former crop field. (J. Vojta)

Fig. 9. Woodland rich in structure on former farmland. (J. Vojta)
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 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 (Dobrovolcová et al. 1990, Prach et al. 2007, 2014, Jirouš 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 Saxifrages 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, Populus tremula, and Pinus sylvestris may establish soon after abandonment. In the Czech circumstances, grasslands may re-appear 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 (Jirouš 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.

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 shrubs 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 archaephytes) 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 archaephytes). In general, the percentage of woodland and steppe species increases during succession, while that of archaephytes, 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 Calamagrostis epigejos dominates 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 cespitosa alliance here. On the example of a large number of mown old fields in the preserved landscape of the Polish Giant Mountains 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 spinny 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

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**Table 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).

<table>
<thead>
<tr>
<th>Abandoned fields</th>
<th>Dry</th>
<th>Mesic</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient-poor</td>
<td>Betula pendula, Pinus sylvestris</td>
<td>Betula pendula, Pinus sylvestris</td>
<td>Data missing</td>
</tr>
<tr>
<td>Nutrient-rich</td>
<td>Betula pendula, Populus tremula, Crataegus spp.</td>
<td>Salix cinerea, Alnus glutinosa</td>
<td></td>
</tr>
<tr>
<td>Moderate-rich</td>
<td>Calamagrostis epigejos, Festuca rupicola, Bromus erectus</td>
<td>Phragmites australis, Salix cinerea, Alnus glutinosa, Tilia cordata</td>
<td></td>
</tr>
</tbody>
</table>
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.

References


Restoration of landscape structure on farmland in the White Carpathian Mts

Hedvika Psotová

Location

NE part of Bílé Karpaty (White Carpathians) PLA; municipalities of Brunov-Bylnice, Jestrabí, 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 farmlands, 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-20th 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 parcelation (field lay-out) have remained in the described area:

- Pseudo strip parcelation, 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 cadaster);

- Block parcelisation, 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 hedge rows 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)
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.

**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 down with the White Carpathian seed mixture were excluded from pastures and mown three times annually. Sites with the critically threatened Tephrosia subsp. marovica were fenced off.

To support valuable species, grazing was initiated on restored grasslands according to recommendations by Mádekov 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 completion 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).

**Conclusion**

By partitioning land blocks with linear tree plantings, restoring sections of historical parcelisation and supplementing dispersed shrubs and trees, a considerable refinement of the

<table>
<thead>
<tr>
<th>Cadastral municipality</th>
<th>Braničov</th>
<th>Jiřetín nad Vltavou</th>
<th>Navrášek</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit trees</td>
<td>303</td>
<td>230</td>
<td>219</td>
<td>752</td>
</tr>
<tr>
<td>Non-fruit trees</td>
<td>475</td>
<td>130</td>
<td>418</td>
<td>1023</td>
</tr>
<tr>
<td>Shrubs</td>
<td>213</td>
<td>84</td>
<td>102</td>
<td>409</td>
</tr>
<tr>
<td>Total</td>
<td>990</td>
<td>450</td>
<td>480</td>
<td>1929</td>
</tr>
</tbody>
</table>
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 Česká obora dobrovolných jednateleů, 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 break-down 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 unmanaged or grazed, 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. Those 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 destining 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 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, due to a few interest 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, retaining wetlands, channels and floodplains, and repatriation of the landscape by means of hedgerows, alleys, 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 not 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

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 perspective 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 considerable effort 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 management (in the case of land 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 BÍLE Karpaty PLA Authority, but also with staff of the National Agricultural Intervention Fund Zlínský, the municipality authorities concerned and workers of the Renards Group. We are grateful to project contractor Zlinske stavby a.s., and particularly to employees of the Jaromík-ZC 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.

References


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 scrubs, creation of small ecotones. Section 4: Restoration of old orchard, treatment of full-grown trees and additional planting of young trees. Section 5: Thinning in ecotones.

Fig. 9. Unmanaged site, encroached by shrubs and trees before realisation of the measures in 2013. (H. Puotova)

Fig. 10. Restored site near Jestřabí, 2015. (H. Puotova)

Fig. 11. Vegetation on the restored site, 2015. (H. Puotova)
//Přírodovécká fakulta  
Faculty of Science
//Všechny v Českých Budějovicích  
University of South Bohemia in České Budějovice

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/

WE MANAGE
- 24 Protected Landscape Areas
- about 800 other types of protected nature areas

WE MONITOR
- distribution of plant and animal species
- changes in wildlife and landscape

WE DEVELOP
- management plans for protected areas
- action plans for endangered plant and animal species
- nature conservation standards and methodologies

WE SUPPORT
- wetland and natural pond restoration
- shrub and tree planting in the countryside
- river and stream revitalization
- landscape management
- restoration of natural forest structures

WE INTERPRET
- natural beauty to the public (visitor centres, interpretive trails, observation hides)