Biologia **70**/3: 349—355, 2015
Section Botany
DOI: 10.1515/biolog-2015-0034

Restoration mowing of a calcareous fen – response of species to re-applied management measures

Dobromil Galvánek[1], Marta Mútňanová[2] & Daniel Dítě[1]

[1] *Institute of Botany of Slovak Academy of Sciences, Dúbravská cesta 9, SK-84523 Bratislava, Slovakia; e-mail: dobromil.galvanek@gmail.com, daniel.dite@savba.sk*
[2] *State Nature Conservancy of Slovak Republic, Tajovského 28B, SK-97401 Banská Bystrica, Slovakia; e-mail: marta.mutnanova@sopsr.sk*

Abstract: Calcareous fens are habitats that are well-adapted to extreme ecological conditions (water with a very high calcium content). The vegetation response following the application of restoration measures (mowing, removal of shrubs) in a calcareous fen (site Sliačske travertíny, western Carpathians) was observed over six years in six permanent plots. Three plots were established in an area strongly invaded by reeds (*Phragmites australis*), where restoration mowing was introduced, and three plots were established in an area overgrown by willows, where the shrubs were partly removed at the beginning and no other management measures were subsequently applied. Indirect and direct gradient analyses (Principal Component Analysis and Redundancy Analysis) and General Linear Models showed that species composition in the mown reed area evolved towards the typical composition of calcareous fens, although reeds were still dominant in the canopy. The overall species richness, as well as number of fen indicator species increased here, especially on the most-detailed scale of 0.25 × 0.25 m. In contrast, the species composition in the unmown area with willows developed towards a higher abundance of wetland generalists. The species richness of vascular plants increased on the scale of 2 × 2 m, but the number of bryophyte species decreased on the scale of 0.25 × 0.25 m and the number of fen indicators species remained unchanged. Our survey showed that mowing can be used for the restoration of calcareous fens invaded by reed, but the total supression of reed can not be achieved in short time period. Furthermore, the occasional removal of shrubs on overgrown calcareous fens is not a feasible method of habitat management.

Key words: *Caricion davallianae*; invasion; mineral-rich spring; sub-halophytes; Slovakia.

Introduction

Peatlands are very specific natural habitats, where organic matter accumulates on the surface. Peatlands occur in Central Europe, but only in small islands situated on the edge of their natural occurence, however, peatlands contain a complete gradient of habitats, from alkaline fens to ombrotrophic bogs (Hájek & Hájková 2007).

Fens in the Western Carpathians cover only small areas, but are still relatively well-preserved, with the occurence of numerous typical fen species (Grootjans et al. 2005). However, they have faced many threats and their area has been significantly reduced (Stanová 2000). Calcareous fens host a very specific type of fen vegetation, containing species that are well-adapted to extreme environmental conditions: a high content of calcium in the groundwater and a strong nutrient (mostly phosphorus) limitation (Hájek et al. 2006). In the Western Carpathians, they are closely associated with mineral-rich springs.

Rapid changes in the landscape and the abandonment of wet grasslands in central Europe have led to significant changes in the species composition of wet grasslands (Halada et al. 2008). One of the common effects is the expansion of high grasses into fens (e.g., *Phragmites communis*, *Molinia sp. div.*) (Hájek et al. 2008). This might be connected with the eutrophication of fen habitats and might have a negative impact on fen vegetation (Güsewell & Klötzli 1998). The control of such competitive grasses is rather complicated, but mowing twice a year might be one suitable method to suppress their spread (Hájková et al. 2009). The removal of biomass is usual after mowing and thus, nutrients are removed from the soil. However, this is not the only effect of the mowing; mowing is especially harmful to taller expansive grasses, which lose a relatively high proportion of their biomass by mowing (Klimeš & Klimešová 2002), which controls their spread in fen grasslands.

Experience from the restoration efforts on fens throughout Europe has shown controversial results. Sites where fen grasslands are heavily degraded have to be restored by costly methods such as top-soil removal or diaspore transfer (Klimkowska et al. 2007). If the main problem of the locality is the absence of regular management, the simple re-introduction of mowing might be sufficient for restoration (e.g., Vinther & Hald

2000; Billeter et al. 2007). However, a necessary prerequisite is still a viable source of fen species diaspores and an unchanged nutrient and water regime (Billeter et al. 2007).

The evaluation of restoration success on fen grasslands is not easy, because an increased species richness of fen grasslands might not indicate an improved quality of the habitat, and in contrast, might be an indicator of fen degradation (Hájková & Hájek 2003). Therefore, it is appropriate to use only selected indicator species as representatives of habitat quality. In central Europe, several extensive studies have been performed to define target (indicator) species of fen grasslands (Valachovič 2001; Dítě et al. 2007; Jarolímek & Šibík 2008), whose occurence might indicate the success of restoration. However, these species represent various traits that determine their relative success in restoration (Pywell et al. 2003). The response of vascular plants and bryophytes might also differ significantly (Mälson et al. 2008; Hájek et al. 2008).

The aims of this study are the following: (1) to analyse the response of vegetation following restoration measures in the locality, (2) to investigate, whether indicator fen species react positively to restoration mowing, (3) to compare the response of vascular plants and bryophytes to restoration.

Material and methods

Site description

The experiment was established in the Sliačske travertíny Nature Reserve (49°03′ N, 19°25′ E), which is located in central Slovakia on the north-western edge of the Nízke Tatry National Park. The nature reserve is saturated by highly-mineralised water, which springs on the edge of the reserve and the water flows inside the area. Due to a high content of minerals, the environment is alkaline, with a high pH (about 7) and conductivity (2,300–3,300 μS/cm). The travertine crusts occur in several places and are also present in the soil.

Most of the locality is covered by calcareous fen vegetation of the *Caricion davallianae* alliance, with the occurence of several sub-halophytic species (e.g., *Triglochin maritima, Eleocharis uniglumis, Blysmus compressus*).

Although the reserve was established in 1951, the regular management of the locality was not ensured. Traditional mowing was subsequently abandoned and the reserve started to degrade. Some parts of the fen were colonised by shrubs (mostly willows) and some parts were nearly totally covered by the reed, *Phragmites australis.* Since 2004, the national park administration started to organise restoration measures in the locality (mowing, removal of shrubs) and this study was designed to evaluate these activities.

Experimental design and sampling

The development of the vegetation within the locality was observed in six permanent plots. Three plots were established in the part of the locality overgrown by willows (plots 1-3) and three plots were in the part dominated by reeds (plots 4-6).

The only restoration measure applied in the willow area was the removal of shrubs in 2004. No other management measures were subsequently applied in this area.

Mowing once a year in September was performed in the reed area annually since 2005 (the second year of observation), only in 2008, two cuts were performed (the first cut at the beginning of July and the second cut in September).

Each plot was 2 × 2 m and the corners were fixed by metal pipes. The relevé method was used for each plot annually, and the percentage cover of vascular plants species and bryophyte species was recorded. The presence/absence data were sampled in sixteen squares (0.25 × 0.25 m) located in the corners of each plot (four squares per corner). Sampling was performed in the first half of June each year, in the period 2004–2009. The first sampling in 2004 was carried out before the application of restoration measures. Plot 4 was not sampled in 2005.

Data analysis

Changes in species composition were analysed by the methods of indirect and direct gradient analysis. The frequency data from 16 subsquares (0.25 × 0.25 m) were used as a source for the matrix imported into ordination software. The CANOCO for Windows 4.5 programme (ter Braak & Šmilauer 2002) was used to compute and to plot ordination results. The method of principal component analysis (PCA) was applied for indirect gradient analysis and redundancy analysis (RDA) was used for direct gradient analysis. The data were standardised by the sample norm, because the change in the relative proportion of species was of the highest ecological priority in our analysis. Monte Carlo permutation test with 499 permutations was applied.

The data concerning the number of vascular plants and bryophytes were analysed by General Linear Models (GLM). The factor TIME as consecutive time from the beginning of data recording was used as a continuous predictor and was correlated with the factors representing the numbers of vascular plants and bryophytes. These values were calculated for three scales (0.25 × 0.25 m, 0.5 × 0.5 m and 2 × 2 m), separately for the area dominated by willows and those dominated by reeds. Since the data were recorded for permanent plots, the factor PLOT that identified the sampling plot was also considered in the analysis as a categorical factor.

Results

Floristic difference between willow and reed areas.

Changes in species composition were analysed by PCA. The ordination graph (Fig. 1) shows first and second ordination axes representing the main gradients that determine the species composition on the permanent plots. We consider that the main gradient on the x axis represents the difference between plots (1–3) in the area overgrown by willows and the plots (4–6) in the area invaded by reeds. The series of records from plots 4–6 are located in the right part of the ordination diagram. These are characterised by a much greater presence of fen indicator species, which are mostly located in the right part of the diagram. On the opposite side, in plots 1–3 located in the area overgrown by willows, there are much fewer fen indicator species present. The gradient on axis y is more difficult to interpret, but we consider it as a gradient of species richness. Relatively species-rich records are located in the upper part of the graph and the species-poor ones are located in the bottom part of the graph.

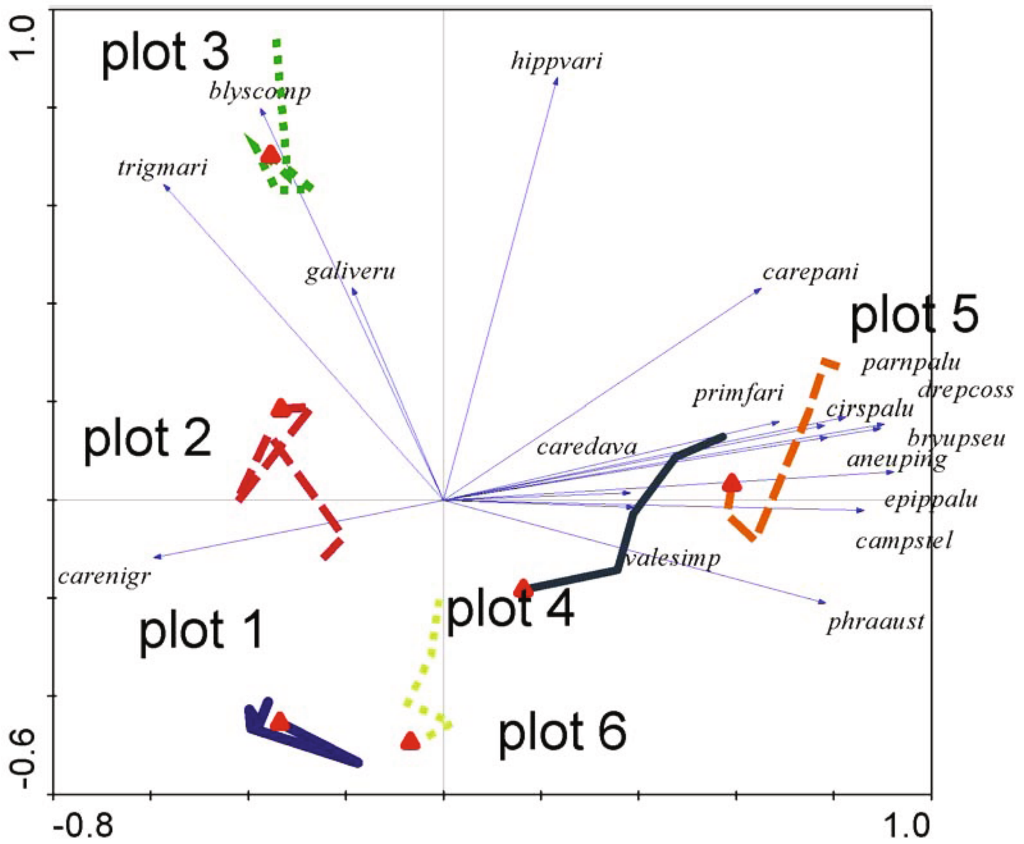

Fig. 1. The ordination diagram is a result of Principal Component Analysis (PCA). The centroids of the records from the same plot are connected by the time series. Fen indicator species (Hájek & Háberová 2001) are plotted on the graph by arrows plus the invasive species *Phragmites australis* = *phraaust. aneuping* = *Aneura pinguis, blyscomp* = *Blysmus compressus, bryupseu* = *Bryum pseudotriquetrum, campstel* = *Campylium stellatum, caredava* = *Carex davalliana, carenigr* = *Carex nigra, carepani* = *Carex panicea, cirspalu* = *Cirsium palustre, drepcoss* = *Drepanocladus cossonii, epippalu* = *Epipactis palustris, galiveru* = *Galium verum, hippvari* = *Hippochaete variegata, parnpalu* = *Parnassia palustris, primfari* = *Primula farinosa, trigmari* = *Triglochin maritima, valesimp* = *Valeriana simpliciifolia.*

Changes in species composition on permanent plots

If we follow the dynamics of the vegetation in particular plots described by the ordination graph of the PCA, we observe that no clear direction is recognisable in plots 1–3, which have not been mown (Fig. 1). The observed pattern of temporal changes might be the result of year-to-year fluctuations. A different situation is observed in plots 4–6, which were mown. There is a trend for all plots to a movement on the second axis towards records with a higher species richness. Movement to the right, indicating records with a greater presence of fen indicator species is visible only in plot 4. In plots 5–6, the interpretation is not so clear.

The testing of changes in temporal species composition (RDA analysis) showed that both areas of the site faced significant temporal changes ($P = 0.012$, 8.4% of the explained variability in the willow area and $P = 0.018$, 7.4% of the explained variability in the reed area). However, the direction of the changes differed between these two areas.

Wetland generalists such as *Lysimachia nummularia, Cirsium palustre, Carex acuta* and grass species such as *Agrostis capillaris, Dactylis glomerata* and *Arrhenatherum elatius* are positively correlated with the factor TIME in the willow area. However, the frequency of some typical species of calcareous fens e.g., *Campylium stellatum, Caliergonella cuspidata, Cratoneuron fillicinum* and *Cirsium rivulare* was lower (Fig. 2a).

A different pattern was found in the mown reed area; species that were positively correlated with TIME were not only calcareous fen species such as *Primula farinosa, Hippochaete variegata* and *Drepanocladus cossonii*, but also some wetland generalists, e.g., *Agrostis stolonifera, Solanum dulcamara* and *Salix purpurea. The* abundance of dominant reeds decreased only slightly and still dominated in the canopy. Few species showed a negative response to TIME, e.g., the mosses *Calliergonella cuspidata* and *Hypnum lindbergii* and the plants *Cirsium rivulare* and *Eupatorium cannabinum* (Fig. 2b).

Changes in species richnes and the establishment of target species groups

In general, we observed a different pattern of species richness in both areas with different management regimes. In the area dominated by willows, the number of vascular plants increased slightly, but the effect was significant only on the scale 2 × 2 m ($P = 0.02$) (Fig. 3, Table 1). However, the number of recorded bryophyte

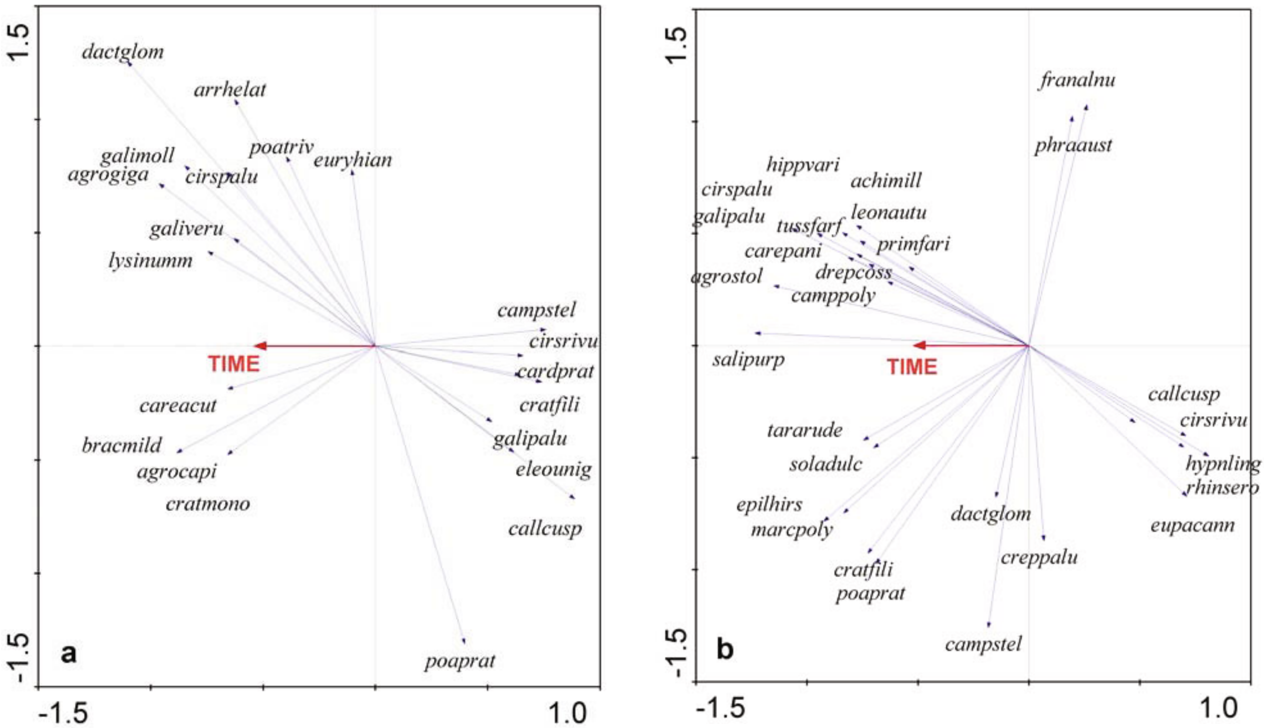

Fig. 2. Biplots from redundancy analysis (RDA) for a; area dominated by willows and b; area dominated by reeds. Permutations were restricted by blocks defined by covariables representing sampling plots and by repeated measurements. TIME – consecutive time from the beginning of the survey, *achimill = Achillea millefolium, agrocapi = Agrostis capillaris, agrogiga = Agrostis gigantea, agrostol = Agrostis stolonifera, arrhelat = Arrhenatherum elatius, bracmild = Brachythecium mildeanum, callcusp = Calliergonella cuspidata, camppoly = Campylium polygamum, campstel = Campylium stellatum, cardprat = Cardamine pratensis, careacut = Carex acuta, carepani = Carex panicea, cirspalu = Cirsium palustre, cirsrivu = Cirsium rivulare, cratmono = Crataegus monogyna, cratfili = Cratoneuron filicinum, creppalu = Crepis paludosa, dactglom = Dactylis glomerata, drepcoss = Drepanocladus cossonii, eleounig = Eleocharis uniglumis, epilhirs = Epilobium hirsutum, eupacann = Eupatorium cannabinum, euryhian = Eurynchium hians, franalnu = Frangula alnus, galimoll = Galium mollugo agg., galipalu = Galium palustre, galiveru = Galium verum, hippvari = Hippochaete variegata, hypnling = Hypnum lindbergii, leonautu = Leontodon autumnalis, lysinumm = Lysimachia nummularia, marcpoly = Marchantia polymorpha, phraaust = Phragmites australis, poaprat = Poa pratensis, poatriv = Poa trivialis,primfari = Primula farinosa, rhinsero = Rhinanthus serotinus, salipurp = Salix purpurea, soladulc = Solanum dulcamara, tararude = Taraxacum sect. Ruderalia, tussfarf = Tussilago farfara.*

Table 1. The results of GLM analysis on species richness and the number of fen indicator species on different scales.

	Vascular plants F	Vascular plants *P*	Bryophytes F	Bryophytes *P*	Number of fen indicator vascular plants F	Number of fen indicator vascular plants *P*	Number of fen indicator bryophytes F	Number of fen indicator bryophytes *P*
Willows (2 × 2 m)								
Time	6.938	0.02	0.003	0.956	0.215	0.650	0.939	0.349
Plot	61.059	<0.001	0.710	0.509	154.135	<0.001	1.449	0.268
Willows (0.5 × 0.5 m)								
Time	0.676	0.425	8.688	0.011	0.803	0.385	2.246	0.156
Plot	66.954	<0.001	0.461	0.640	147.089	<0.001	0.029	0.971
Willows (0.25 × 0.25 m)								
Time	1.426	0.252	5.842	0.030	0.009	0.924	2.381	0.145
Plot	38.662	<0.001	2.603	0.109	322.781	<0.001	0.313	0.736
Reeds (2 × 2 m)								
Time	26.177	<0.001	2.087	0.172	7.311	0.018	3.118	0.101
Plot	60.196	<0.001	8.474	0.004	133.616	0.018	62.991	<0.001
Reeds (0.5 × 0.5 m)								
Time	8.658	0.011	1.176	0.298	5.757	0.032	4.431	0.055
Plot	64.177	<0.001	11.594	0.001	59.802	<0.001	55.628	<0.001
Reeds (0.25 × 0.25 m)								
Time	68.09	<0.001	16.363	0.001	19.592	0.001	15.097	0.002
Plot	97.391	<0.001	25.280	<0.001	49.722	<0.001	140.564	<0.001

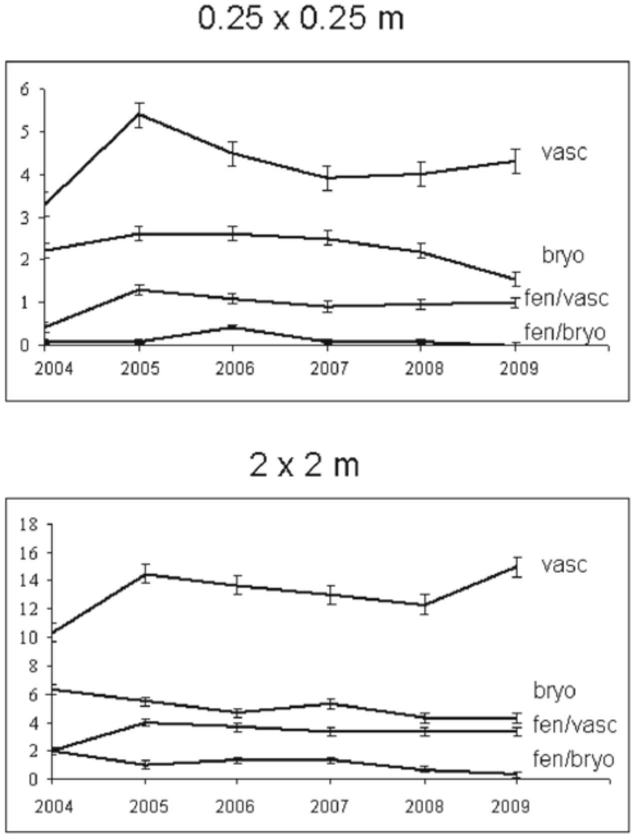

Fig. 3. Changes in the number of vascular plants (vasc), the number of bryophytes (bryo), the number of fen indicator species of vascular plants (fen/vasc) and the number of fen indicator bryophyte species (fen/bryo) on two scales (0.25 × 0.25 m, 2 × 2 m) in the area dominated by willows.

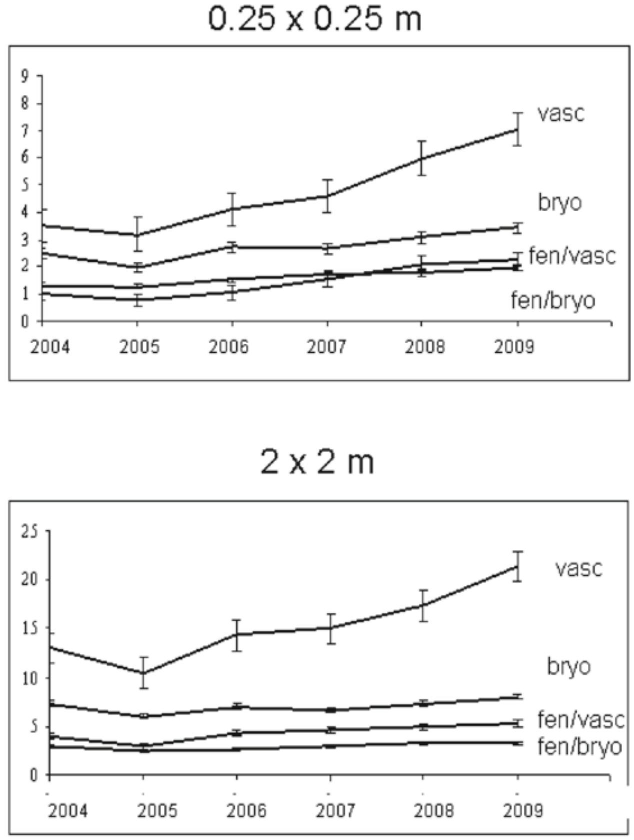

Fig. 4. Changes in the number of vascular plants (vasc), the number of bryophytes (bryo), the number of fen indicator species of vascular plants (fen/vasc) and the number of fen indicator bryophyte species (fen/bryo) on two scales (0.25 × 0.25 m, 2 × 2 m) in the area dominated by reeds.

species decreased, with the most pronounced decrease on the finest scale (0.25 × 0.25 m, or 0.5 × 0.5 m; P = 0.011 or 0.030, respectively). The number of fen indicator species remained roughly stable during the period of observation, with no significant changes (Fig. 3, Table 1).

An increasing trend in the number of vascular plants was observed in the area dominated by reeds and the trend was more pronounced on the finest scale (0.25 × 0.25 m). Notably, the number of indicator vascular plants also increased significantly on all scales, even though the effect was less pronounced than for the total number of vascular plants. A different pattern was observed for bryophytes, where a significant increase was detected only on the scale 0.25 × 0.25 m for all bryophytes (P = 0.001) as well as indicator fen bryophytes (P = 0.002). No significant effects were found on other scales, but for fen indicator species of bryophytes, the values of P were closer to the significance level (e.g. P = 0.055 for the scale 0.5 × 0.5 m) (Fig. 4, Table 1).

Discussion

Manipulated field experiments are the best approach to test the effect of particular treatments on vegetation (Lepš & Šmilauer 2003; Underwood 1997). However, their establishment and organisation usually require considerable effort and funding. In addition, their establishment might be constrained by various technical reasons. Therefore, simple obervations on permanent plots are often used in a conservation approach, to survey whether applied restoration treatments affect target vegetation. Such data have many intepretational constraints, but are of some value, because they describe vegetational changes in particular permanent plots, as was the case here.

Mowing is considered a very efficient tool for the restoration of fen vegetation that is degraded due to abandonment and usually leads to a relatively rapid recovery of fen plant communities (Vinther & Hald 2000; Billeter et al. 2007; Hájková et al. 2009), which was also partly confirmed by our survey. Our mown plots showed evidence of an increase in the number of fen indicator species (Fig. 4) and the entire species composition was much closer to that of alkaline fens at the end of the survey (Fig. 1), although unmown plots showed a more or less stabile species composition (Fig. 1).

The efficiency of mowing as a technique of fen restoration might be limited and depends strongly on the initial situation (Klimkowska et al. 2007). Dispersal and microsite limitations might particularly play a very important role in wet meadows (Poschlod & Biewer 2005; Vítová & Lepš 2011), which we also observed at our site, where the development of particular plots was very individual. Several fen indicator species were present in mown plots 4 and 5, which prior to restoration mowing, were more similar to well-preserved alkaline fens than plot 6, where the fen vegetation was very degraded due to a strong accumulation of litter from the expansive reeds.

The fact that species richness is not a good indicator of fen grassland quality and that more attention should be paid to the occurence of typical fen species (Hájek et al. 2008), was confirmed by our results. The species richness of vascular plants increased in both areas (willow and reed), but the number of fen-indicating vascular plants only increased in the reed area (Fig. 4). An increase in richness in the unmown area with willows was probably connected with secondary succession changes and with the expansion of some high grasses into the fen.

Changes in the richness of bryophyte species showed a different pattern, where the number of bryophytes, including indicator species, increased in the reed area, but decreased in the willow area (Figs 3, 4). Bryophytes have a negative relationship to increased vascular plant cover (Bergamini et al. 2001), which might limit light reaching the surface of the soil. This was probably the case in the willow area, where some vascular plants, including grasses and shrubs, spread and thus suppressed the bryophyte layer. However, the reaction of bryophytes to changes in the management regime might be very individual and depend on the traits of different bryophyte species (Hájková et al. 2009).

The number of bryophytes and indicator bryophyte species increased significantly in the reed area, but only on the detailed scale 0.25 × 0.25 m (Fig. 4, Table 1). A similar pattern was also found for indicator vascular plants in the reed area, where the increase was significant at all scales, but was most pronounced at the most detailed scale of 0.25 × 0.25 m (Fig. 4, Table 1). When restoration mowing is applied to mesic mountain grasslands with rather extensive species pools, species richness tends to increase firstly at a larger scale (Galvánek & Lepš 2008). However, calcareous fens have a very limited species pool, with a high proportion of fen specialists (Hájek et al. 2006), therefore, restoration mowing does not favour the colonisation of new species from the surroundings, but rather suppresses dominant reeds and thus, enables existing populations of fen indicator species to increase in population density. Nevertheless, indicator species must be present at the locality. If the locality is heavily degraded, re-colonisation by fen indicator species might be limited by seed dispersal (Mälson et al. 2008; Klimkowska et al. 2010).

This confirms our expectation that degradation occurs in unmown willow areas and secondary succession leads to the step-by-step elimination of habitat specialists. In contrast, mowing of the reed area promoted the improvement of conditions for habitat specialists, which were suppressed by dominant reeds.

One of the possibillities to suppress expansive reeds on fen grasslands is to increase the intensity of mowing. If two cuts are applied, the restoration process appears to occur more rapidly (Güsewell 2003; Hájek et al. 2008). However, it appears that the total removal of reeds from fens only via intensive mowing is not realistic and our results show that it might not be necessary, since some fen species are able to survive and spread even in dense reed stands.

The results of our survey showed that mowing might promote the re-colonisation of typical species of calcareous fens, even though the dominance of reeds is not substantially suppressed by mowing. However, the speed of the process is strongly dependent on the level of degradation (mostly on the amount of accumulated litter) and the presence of viable diaspores of target species at the restored sites or in their close surroundings.

We presume that restoration mowing can be successfully implemented on calcareous fens invaded by reeds, but it cannot be expected that reeds would be completely removed from the site. If the locality is overgrown by shrubs (e.g. willows), the removal of shrubs as the only applied management is not sufficient for long-term survival of fen vegetation and regular mowing should be applied after shrub removal.

Acknowledgements

We would like to thank J. Janoviak and A. Devečka for help with sampling and we are also grateful to M. Jasík and P. Turis for their assistance with the establishment of monitoring plots. We thank Petra Hájková for comments on a previous version of the manuscript. The study was partly financed by the State Nature Conservancy of the Slovak Republic and was supported by VEGA project 2/0999/13. The preparation of the manuscript was partly financed by the grant SK0115 through the European Economic Area Financial Mechanism and the Norwegian Financial Mechanism and from the state budget of the Slovak Republic.

References

Bergamini A., Pauli D., Peintinger M. & Schmid B. 2001. Relationships between productivity, number of shoots and number of species in bryophytes and vascular plants. J. Ecol. **89:** 920–929.

Billeter R., Peintinger M. & Diemer M. 2007. Restoration of montane fen meadows by mowing remains possible after 4-35 years of abandonment. Bot. Helv. **117:** 1–13.

Dítě D., Hájek M. & Hájková P. 2007. Formal definitions of Slovakian mire plant associations and their application in regional research. Biologia **62:** 400–408.

Galvánek D. & Lepš J. 2008. Changes of species richness pattern in mountain grasslands: Abandonment vs. Restoration. Biodivers. Conserv. **17:** 3241–3253.

Grootjans A., Alserda A., Bekker R., Janáková M., Kemmers R., Madaras M., Stanová V., Ripka J., Van Delft B. & Wolejko L. 2005. Calcareous spring mires in Slovakia: Jewels in the Crown of the Mire Kingdom, pp. 97–115. In: Steiner G.M. (ed.), Moore von Sibirien bis Feuerland/Mires from Siberia to Tierra del Fuego. Stapfia 85, Zugleich Kataloge der Oberösterreichischen Landesmuseen, N.S. 35.

Güsewell S. 2003. Management of *Phragmites australis* in Swiss fen meadows by mowing in early summer. Wetl. Ecol. Manag. **11:** 433–445.

Güsewell S. & Klötzli F. 1998. Abundance of common reed (*Phragmites australis*), site conditions and conservation value of fen meadows in Switzerland. Acta Bot. Nederl. **47:** 113–129.

Hájek M. & Háberová I. 2001. *Scheuzerio-Caricetea fuscae*, pp. 185–273. In: Valachovič M. (ed.), Rastlinné spoločenstvá 3. Vegetácia mokradí, Veda, Bratislava.

Hájek M. & Hájková P. 2007. Hlavní typy rašelinišť ve střední Evropě z botanického hlediska. Zprávy Čes. Bot. Společn. **22:** 19–28.

Hájek M., Hájková P. & Rozbrojová Z. 2008. Impact of changes in mowing regime on species composition of wet grasslands, pp. 338–345. In: Jongepierrová I. (ed.), Grasslands of the White Carpathians Mountains) ZO ČSOP Bílé Karpaty, Veselí nad Moravou.

Hájek M., Horsák M., Hájková P. & Dítě D. 2006. Habitat diversity of central European fens in relation to environmental gradients and an effort to standardise fen terminology in ecological studies. Perspect. Plant Ecol. **8:** 97–114.

Hájková P. & Hájek M. 2003. Species richness and above-ground biomass of poor and calcareous spring fens in the flysch West Carpathians and their relationships to water and soil chemistry. Preslia **75:** 271–287.

Hájková P., Hájek M. & Kintrová K. 2009. How can we effectively restore species richness and natural composition of a *Molinia*-invaded fen? J. Appl. Ecol. **46:** 417–425.

Halada Ľ., Ružičková H., David S. & Halabuk A. 2008. Seminatural grasslands under impact of changing land use during last 30 years: Trollio-Cirsietum community in the Liptov region (N Slovakia). Community Ecol. **9:** 115–123.

Jarolímek I. & Šibík J. (eds.) 2008. Diagnostic, constant and dominant species of the higher vegetation units of Slovakia. Veda, Bratislava, 332 pp.

Klimeš L. & Klimešová J. 2002. The effects of mowing and fertilization on carbohydrate reserves and regrowth of grasses: do they promote plant coexistence in species-rich meadows? Evol. Ecol. **15:** 363–382.

Klimkowska A., van Diggelen R., Bakker J.P. & Grootjans A.P. 2007. Wet meadow restoration in Western Europe: A quantitative assessment of the effectiveness of several techniques. Biol. Conserv. **140:** 318–328.

Klimkowska A., van Diggelen R., Grootjans A.P. & Kotowski W. 2010. Prospects for fen meadow restoration on severely degraded fens. Perspect. Plant Ecol. **12:** 245–255.

Lepš J. & Šmilauer P. 2003: Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, Cambridge, 269 pp.

Mälson K., Backéus I. & Rydin H. 2008. Long-term effects of drainage and initial effects of hydrological restoration on rich fen vegetation. Appl. Veg. Sci. **11:** 99–106.

Poschlod P. & Biewer H. 2005. Diaspore and gap availability are limiting species richness in wet meadows. Folia Geobot. **40:** 13–34.

Pywell R.F., Bullock J.M., Roy D.B., Warman L., Walker K.J. & Rothery P. 2003. Plant traits as predictors of performance in ecological restoration. J. Appl. Ecol. **40:** 65–77.

Stanová V. 2000. Súčasný výskyt rašelinísk na Slovensku a faktory ich ohrozenia, pp. 3-9. In: Stanová V. (ed.), Rašeliniská Slovenska. DAPHNE – Inštitút aplikovanej ekológie, Bratislava.

ter Braak C. J. F. & Šmilauer P. 2002. CANOCO reference manual and CanoDraw for Windows user's guide. Software for Canonical Community Ordination (version 4.5). Biometris, Wageningen & České Budějovice, 500 pp.

Underwood A.J. 1997: Experiments in Ecology: Their logical Design and Interpretation using Analysis of Variance. Cambridge University Press, Cambridge, 504 pp.

Valachovič M. (ed.) 2001. Rastlinné spoločenstvá Slovenska. 3. Vegetácia mokradí. Veda, Bratislava, 435 pp.

Vinther E. & Hald A.B. 2000. Restoration of an abandoned species-rich fen-meadow in Denmark: changes in species richness and dynamics of plant groups during 12 years. Nord. J. Bot. **5:** 573–584.

Vítová A. & Lepš J. 2011. Experimental assessment of dispersal and habitat limitation in an oligotrophic wet meadow. Plant Ecol. **212:** 1231–1242.

Received February 6, 2014
Accepted December 19, 2014