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Formal definitions of Slovakian mire plant associations and their application in regional research

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Abstract: We applied the Cocktail method to a large data set of 4 117 relevés of all Slovak vegetation types with the aim to create formalised definitions of all Slovakian mire plant associations. We defined 21 groups of species with the statistical tendency of joint occurrences in vegetation. These groups differed substantially in their position along the pH/calcium gradient. We further defined 24 plant associations according to presence and/or absence of certain groups and/or strong dominance of some species. Only six traditional plant associations were not possible to be reproduced this way. We applied our formalised definitions to the regional data set of mires from the surrounding of the Vysoké Tatry Mts. Combined with frequency-positive fidelity index this method has led to the classification of the majority of vegetation plots into ten associations. When the vegetation types obtained from Cocktail-based classification and from cluster analysis were compared with respect to measured pH and conductivity in the study region, 82% of pairs differed significantly either in pH or in water conductivity in the former classification and 69% in the latter one.

Key words: Braun-Blanquet approach; Cocktail; fen; peatland; species group; vegetation survey; Slovakia

Introduction

The Central and West European phytosociology approach recently deals with the critique about subjectivism and inconsistency by an effort to standardise and formalise the classification process and by an effort towards unifying national classification systems (e.g. Rodwell et al. 1997; Bruelheide & Chytrý 2000; Botta-Dukát et al. 2005; Knollová et al. 2006). In order to obtain transparent results, two types of formalised classification are applied: the most widespread are agglomerative or divisive classification algorithms such as cluster analysis or Twinspan. In this method, the classification criteria are clear and results are easily repeatable. However, the results are unique only for certain data set, which was used in the analysis, and they are strongly dependent on the geographical or ecological extent and stratification of the data sets (Bruelheide & Chytrý 2000). A change in data structure, e.g. in the number of the relevés in the analysis, results in a change in the obtained classification. The cluster analysis can also reflect some local peculiarities rather than ecological differences. Additionally, there are several other constraints to correctly apply cluster analysis to phytosociological data (Podani 2005). An alternative to the commonly used numerical classification algorithms is the Cocktail method proposed by Bruelheide (1995, 2000). This method produces formalized definitions of vegetation units by providing unequivocal criteria, most often species group combinations, for assignment of relevés to the plant associations. The resulting classification system produces classifications that are compatible among different regions as opposed to the former method (Bruelheide & Chytrý 2000). This method can be described as supervised and it differs in that a classifier is developed from a training data set (Ejrnæs et al. 2004) and it can reproduce the expert-based classification and assure a stability of classification systems of large areas (Kočí et al. 2003; Chytrý 2007). By analogy with numerical classification algorithms this method provides repeatable results and it has statistical background in (Chytrý et al. 2002). Besides Germany (Bruelheide 1995, 2000), the method was applied in vegetation survey of Czech Republic (Kočí et al. 2003; Lososová 2004, Chytrý 2007; Havlová 2006; Roleček 2007), and in classification of Bulgarian high mountains (Hájková et al. 2006) and Slovakian wet meadows (Hájková & Hájek 2005). The latter study showed that formal definitions obtained from national data set can be successfully applied in regional classification.

Slovakian mire vegetation has been synthesised five years ago using conventional phytosociological methods (Valachovič et al. 2001). The consistency of species groups diagnostic for particular associations was then tested by phi-coefficient calculating (Hájek 2002). Now we have the opportunity to create formal definitions of Slovakian mire associations, because the first author collected much new data, and because a national vegetation database comprising data from all Slovakian habitats was completed. The aims of this study are: (i) to create the groups of co-occurring mire species in the improved data set from throughout all Slovakian habitats and to show ecological differences among these species groups; (ii) to find out if it is possible to define the traditional associations unequivocally by the species group combinations; (iii) to apply national formal definitions to the regional data set of mire vegetation plots from the surrounding of the Vysoké Tatry Mts; (iv) to compare the results of supervised and unsupervised classification in terms of ecological differences among associations.

Methods

Field data sampling

All relevés from the study area (surroundings of the Vysoké Tatry Mts) were collected in the vegetation seasons 2001–2004. For an estimate of abundance and dominance of plant species (vascular plants, bryophytes) the nine-grade scale (van der Maarel, 1979) was used. Most of the relevés have been taken from a plot size of 16 m^2, which is the recommended size for the sampling of grassland and mire vegetation (Chytrý & Otýpková 2003).

Water pH and conductivity were measured directly in free spring water circumfluent the moss layer. When the water level was several centimetres below the surface, a small shallow pit was dug and spring water was allowed to clarify before measurement. Whenever spatial variation of water pH or conductivity was observed, several replications were conducted and arithmetic means were calculated. Conductivity caused by H^+ ions was subtracted in acidic waters with pH < 5.5 (Sjörs 1952). Corrected conductivity was used as a proxy of total mineral richness of the water sample correlating the most strongly with a sum of calcium and magnesium concentrations (Sjörs & Gunnarsson 2002; Horsák 2006).

Data analysis

The 4117 phytosociological treeless relevés from the West Carpathians stored in Central Phytosociological Database of Slovakia (www.ibot.sav.sk/cdf) and in private databases of authors were exported into JUICE software (Tichý 2002). Next we defined vegetation types of mires, which are reported from Slovakia (Valachovič et al. 2001). We characterised these vegetation types by the formal definitions using the combination of defined groups of species with the statistical tendency of joint occurrences in vegetation. Using a large database that covers a broad spectrum of different habitats and a large geographical area is important for obtaining species groups of more general validity. Species of the same group usually have similar habitat requirements and phytogeographical affinities (Kočí et al. 2003). The species groups were created by the Cocktail method (Bruelheide 2000), using the phi-coefficient (Chytrý et al. 2002). The species group is present in the relevé if at least one half of its members are present. The resulting groups were combined by logical operators AND, OR and AND NOT; the strong dominance of some species was also used as a character in some cases. The goal was to obtain definitions whose application to the data set led to selection of relevés which (i) can be identified with certain association, (ii) do not overlap substantially with another association, (iii) can be characterised by their own diagnostic species, i.e. the species that reach high fidelity to the group of relevés.

For the classification of the regional data set from the surrounding of the Vysoké Tatry Mts, we applied national formal definitions, and relevés that remained unclassified were subsequently assigned to the associations by calculating similarity to relevé groups that had already been assigned to the associations using the Positive fidelity-Frequency index (Tichý 2005) and by the number of diagnostic species. Finally, the diagnostic species were recalculated. Only species with positive fidelity and simultaneously with a probability of non-random occurrence yielded by Fischer's exact test lower than 0.01 (Chytrý et al. 2002) were included to the synoptic table.

To compare ecological interpretability of supervised and unsupervised classification, the regional data set was further classified by the cluster analysis in the program PC-ORD 4, using relative Euclidean (chord) distance as a resemblance measure and flexible beta group linkage method with parameter beta = -0.25. In this classification, 10 clusters at the highest level of classification hierarchy were accepted because this number corresponded to the number of associations recognized by supervised classification. Multiple comparison (Tukey post-hoc test following one-way ANOVA) was applied to test the differences in pH and conductivity among associations obtained by supervised method and among groups obtained from cluster analysis.

For each species belonging to some of species groups we calculated species response curve to single environmental factors (pH and conductivity) by Huisman, Olff & Fresco (HOF) model of type 5 (Huisman et al. 1993) based on logistic regression and following the algorithm of Oksanen & Minchin (2002). The medians of response optima yielded by this method were calculated for each group.

Nomenclature follows Marhold & Hindák (1998) for both vascular plants and bryophytes.

Results

We created 21 species groups (Table 1). The species groups cover the entire pH/calcium gradient (Fig. 1). According to presence and/or absence of certain groups and/or strong dominance of some species, we were able to define 24 associations from the Valachovič et al. (2001) and two associations not reported by this source (Table 2). Eight mire associations were not possible to be defined this way: *Seslerietum uliginosae, Schoenetum ferruginei, Juncetum subnodulosi, Sphagno-Caricetum appropinquatae, Scorpidio-Caricetum diandrae, Carici limosae-Sphagnetum contorti, Carici rostratae-Sphagnetum cuspidati, Carici chordorrhizae-Sphagnetum apiculati.*

The application of national definitions to the regional data set from the Vysoké Tatry Mts, combined with frequency-positive fidelity index, has led to the classification of the mires in this region into ten associations (Table 3). Cluster analysis with ten accepted groups formed two difficult-to-interpret clusters of local occurrence, which were too small to be included into

Table 1. The sociological species groups created by the Cocktail method. The data set involving all relevés of treeless vegetation of the West Carpathians was used. These species groups were used for the formal definition of particular associations.

Carex echinata **group**
Agrostis canina, Carex echinata, C. canescens, Epilobium palustre, Viola palustris
Carex lasiocarpa **group**
Carex lasiocarpa, Drepanocladus vernicosus, Meesia triquetra
Carex rostrata **group**
Calliergon giganteum, Carex diandra, C. rostrata, Equisetum fluviatile, Galium palustre, Menyanthes trifoliata
Sphagnum warnstorfii **group**
Carex dioica, Paludella squarrosa, Sphagnum contortum, S. teres, S. subnitens, S. warnstorfii
Sphagnum fallax **group**
Drosera rotundifolia, Eriophorum vaginatum, Polytrichum commune, Sphagnum fallax, S. palustre, Oxycoccus palustre
Sphagnum flexuosum **group**
Calliergon stramineum, Carex demissa, Lotus uliginosus, Juncus bulbosus, Pedicularis sylvatica, Sphagnum flexuosum
Sphagnum cuspidatum **group**
Carex limosa, Drepanocladus fluitans, Scheuchzeria palustris, Sphagnum cuspidatum
Calliergon sarmentosum **group**
Calliergon sarmentosum, Carex lachenalii, Drepanocladus exannulatus, Scapania irrigua
Sphagnum fuscum **group**
Andromeda polifolia, Empetrum sp. (nigrum + hermaphroditum), Jungermannia sphaerocarpa, Sphagnum fuscum, Vaccinium uliginosum
Sphagnum magellanicum **group**
Carex pauciflora, Polytrichum strictum, Sphagnum magellanicum, S. rubellum
Triglochin maritima **group**
Centaurium litoralle subsp. uliginosum, Glaux maritima, Plantago maritima, Schoenoplectus tabernaemontani, Triglochin maritima, Trichophorum pumilum
Cratoneuron commutatum **group**
Carex flacca, Cratoneuron commutatum, Eupatorium cannabinum, Juncus inflexus, Tussilago farfara
Eleocharis quinqueflora **group**
Eleocharis quinqueflora, Chara sp., Philonotis calcarea, Triglochin palustre
Rhynchospora alba **group**
Hydrocotyle vulgaris, Rhynchospora alba, Sphagnum inundatum
Primula farinosa **group**
Carex davalliana, C. hostiana, C. lepidocarpa, Pinguicula vulgaris, Primula farinosa
Eriophorum latifolium **group**
Campylium stellatum, Drepanocladus cossonii, Epipactis palustris, Eriophorum latifolium, Tomenthypnum nitens
Valeriana simplicifolia **group**
Cirsium rivulare, Crepis paludosa, Dactylorhiza majalis, Equisetum palustre, Geum rivale, Plagiomnium affine agg.
Lychnis flos-cuculi **group**
Alopecurus pratensis, Cardamine pratensis, Festuca pratensis agg., Lathyrus pratensis, Lychnis flos-cuculi, Ranunculus acris, R. auricomus agg.
Carex acutiformis **group**
Carex acutiformis, C. elata, Lycopus europaeus, Lythrum salicaria, Mentha aquatica, Thelyptheris palustris
Scorpidium scorpioides **group**
Carex chordorrhiza, Drosera anglica, Utricularia minor, Scorpidium scorpioides
Carex nigra **group**
Caliergonella cuspidata, Carex flava, C. nigra, C. panicea, Eriophorum angustifolium

multiple comparisons. When the vegetation types obtained from COCKTAIL analysis and from cluster analysis were compared with respect to measured pH and conductivity, 82% of pairs differed significantly either in pH or in water conductivity in COCKTAIL classification and 69% in classification based on cluster analysis.

Discussion

The supervised formalised classification based on combination of Cocktail groups and similarity index satisfactorily reproduced the expert-based classification of mire vegetation of Slovakia (Valachovič et al. 2001) at the level of associations. We formulated unequivocal assignment criteria for a majority of the associations. The same results were obtained by Kočí et al. (2003) using data-set from Czech subalpine tall-forb vegetation. The remaining associations of the original classification were abandoned as they lacked positive differentiation or were highly similar or overlapping to some other associations in terms of total species composition.

Proposed changes in the classification of fens

In this paper, we also propose to simplify the classification system of fens and bog hollows (*Scheuchzerio-Caricetea fuscae*) at the level of alliances. Five major and ecologically well-defined fen types are distinguished in ecological literature throughout the word, which should be unified with phytosociological classification system in order to facilitate international communication: (1) poor *Sphagnum*- fens (*Sphagno recurvi-Caricion canescentis*); (2) Moderately rich *Sphagnum*-fens (*Caricion fuscae*); (3) Rich *Sphagnum*-fens (*Sphagno warnstorfii-Tomenthypnion*); (4) Extremely rich peat-forming or tufa-forming fens (*Caricion davallianae*) and (5) bog hollows (*Sphagnion cuspidati*). The phytosociological alliances that overlap between several of these types or that are highly ambiguous with respect

Table 2. Associations recognised in the Cocktail classification and their formal definitions in terms of occurrence of species groups and dominance species. In the Cocktail definitions, species groups are printed in bold and dominant species in normal letters. The associations are hierarchically ordered according to simplified system of higher-rank sytaxa proposed in this paper. Associations which are not mentioned in Valachovič (2001) are indicated by asterisk.

Association	Cocktail definition
Scheuchzerio-Caricetea fuscae ***Caricetalia davallianae*** ***Caricion davallianae***	
1. ***Caricetum davallianae***	{***Primula farinosa* group** NOT (***Sphagnum warnstorfii* group** OR *Carex limosa* cover > 5%))} NOT ({***Lychnis flos-cuculi* group** OR ***Valeriana simplicifolia* group**} OR *Sphagnum contortum* cover > 5%)
2. ***Eleocharitetum pauciflorae***	*Eleocharis quinqueflora* cover > 5% NOT{(***Primula farinosa* group** OR ***Eriophorum latifolium* group**) OR ***Cratoneuron commutatum* group**}
3. ***Carici flavae-Cratoneuretum filicini***	(***Cratoneuron commutatum* group** AND ***Eriophorum latifolium* group**) NOT ***Lychnis flos-cuculi* group**
4. ***Carici flavae-Eriophoretum latifolii***	(***Eriophorum latifolium* group** OR *Eriophorum latifolium* cover > 5%) AND ***Carex acutiformis* group**
5. ***Valeriano simplicifoliae-Caricetum flavae***	{(***Valeriana simplicifolia* group** AND ***Eriophorum latifolium* group**) NOT (***Primula farinosa* group** OR ***Lychnis flos-cuculi* group**)}NOT{(*Sphagnum warnstorfii* cover > 5% OR ***Sphagnum warnstorfii* group**) OR *Sphagnum fallax* cover > 5%}
6. ***Amblystegio scorpioidis-Caricetum limosae***	{(*Scorpidium scorpioides* cover > 5% OR *Drepanocladus cossonii* cover > 5%) AND Carex limosa cover > 5%} NOT (***Scorpidium scorpioides* group** OR *Carex chordorrhiza* cover > 5%)
7. ***Drepanoclado revolventis-Caricetum lasiocarpae***	(***Eriophorum latifolium* group** AND *Carex lasiocarpa* cover > 5%) NOT *Sphagnum warnstorfii* cover > 5%
8. ***Glauco-Trichophoretum pumili****	***Triglochin maritima* group**
Sphagno warnstorfiani-Tomenthypnion	
9. ***Sphagno-Caricetum lasiocarpae***	(***Sphagnum warnstorfii* group** OR *Sphagnum warnstorfii* cover > 5%) AND (***Carex lasiocarpa* group** OR *Carex lasiocarpa* cover > 5%)
10. ***Sphagno warnstorfiani-Caricetum davallianae***	(***Sphagnum warnstorfii* group** OR *Sphagnum warnstorfii* cover > 5%) AND ***Primula farinosa* group**
11. ***Sphagno warnstorfiani-Eriophoretum latifolii***	(***Sphagnum warnstorfii* group** OR *Sphagnum warnstorfii* cover > 5%) AND (***Eriophorum latifolium* group** NOT ***Primula farinosa* group**)
12. ***Amblystegio scorpioidis-Caricetum chordorrhizae***	(***Scorpidium scorpioides* group** OR *Drepanocladus cossonii* cover > 5%) AND *Carex chordorrhiza* cover > 5%
Caricetalia fuscae ***Caricion fuscae***	
13. ***Sphagno subsecundi-Rhynchosporetum albae***	***Rhynchospora alba* group**
14. ***Caricetum goodenowii***	[{(***Carex echinata* group** AND ***Carex nigra* group**) NOT (***Carex lasiocarpa* group** OR ***Lychnis flos-cuculi* group**)} NOT (***Eriophorum latifolium* group** OR ***Rhynchospora alba* group**)] NOT [{(***Sphagnum fallax* group** OR *Sphagnum fallax* cover > 5%) OR ***Sphagnum warnstorfii* group**} OR *Sphagnum flexuosum* cover > 5%]
Sphagno recurvi-Caricion canescentis	
15. ***Carici echinatae-Sphagnetum***	(***Carex echinata* group** NOT ***Sphagnum warnstorfii* group**) AND [{(***Sphagnum flexuosum* group** OR ***Sphagnum fallax* group**) OR *Sphagnum flexuosum* cover > 25%} OR *Sphagnum fallax* cover > 25%]
16. ***Carici rostratae-Sphagnetum apiculati***	[***Carex rostrata* group** AND {(*Sphagnum fallax* cover > 5% OR *Sphagnum flexuosum* cover > 5%) OR *Sphagnum teres* cover > 5%}] NOT ***Sphagnum warnstorfii* group**
17. ***Carici filiformis-Sphagnetum apiculati****	{(***Sphagnum fallax* group** OR *Sphagnum fallax* cover > 5%) AND *Carex lasiocarpa* cover > 5%} NOT ***Sphagnum warnstorfii* group**
Drepanocladion exannulati	
18. ***Drepanocladetum exannulati***	***Calliergon sarmentosum* group** NOT ***Carex echinata* group**
Scheuchzerietalia palustris ***Sphagnion cuspidati***	

Table 2. (continued)

Association	Cocktail definition
19. ***Sphagno cuspidati-Caricetum limosae***	(***Sphagnum cuspidatum*** **group** AND *Carex limosa* cover > 5%) NOT (***Carex nigra*** **group** OR *Sphagnum subsecundum* cover > 5%)
20. ***Sphagno tenelli-Rhynchosporetum albae***	(***Sphagnum cuspidatum*** **group** OR *Sphagnum tenellum* cover > 5%) AND *Rhynchospora alba* cover > 5%
Oxycocco-Sphagnetea ***Sphagnetalia medii*** ***Oxycocco-Empetrion hermaphroditi***	
1. ***Carici lachenalii-Eriophoretum vaginati***	***Calliergon sarmentosum*** **group** AND *Eriophorum vaginatum* cover > 5%
2. ***Scirpetum austriaci***	*Trichophorum cespitosum* cover > 5%
3. ***Empetro hermaphroditi-Sphagnetum fusci***	***Sphagnum fuscum*** **group** NOT *Pinus mugo* cover > 25%
Sphagnion medii	
4. ***Eriophoro vaginati-Sphagnetum recurvi***	[{(***Sphagnum fallax*** **group** NOT ***Carex nigra*** **group**) NOT (***Sphagnum fuscum*** **group** OR ***Sphagnum cuspidatum*** **group**)} NOT (*Carex lasiocarpa* cover > 5% OR ***Carex rostrata*** **group**)] NOT ***Sphagnum magellanicum*** **group**
5. ***Sphagnetum medii***	(***Sphagnum magellanicum*** **group** AND ***Sphagnum fallax*** **group**) NOT (***Carex nigra*** **group** OR *Pinus mugo* cover > 25%)
6. ***Pino mugo-Sphagnetum***	{(***Sphagnum fuscum*** **group** OR ***Sphagnum magellanicum*** **group**) OR *Sphagnum fallax* cover > 50%} AND *Pinus mugo* cover > 25%

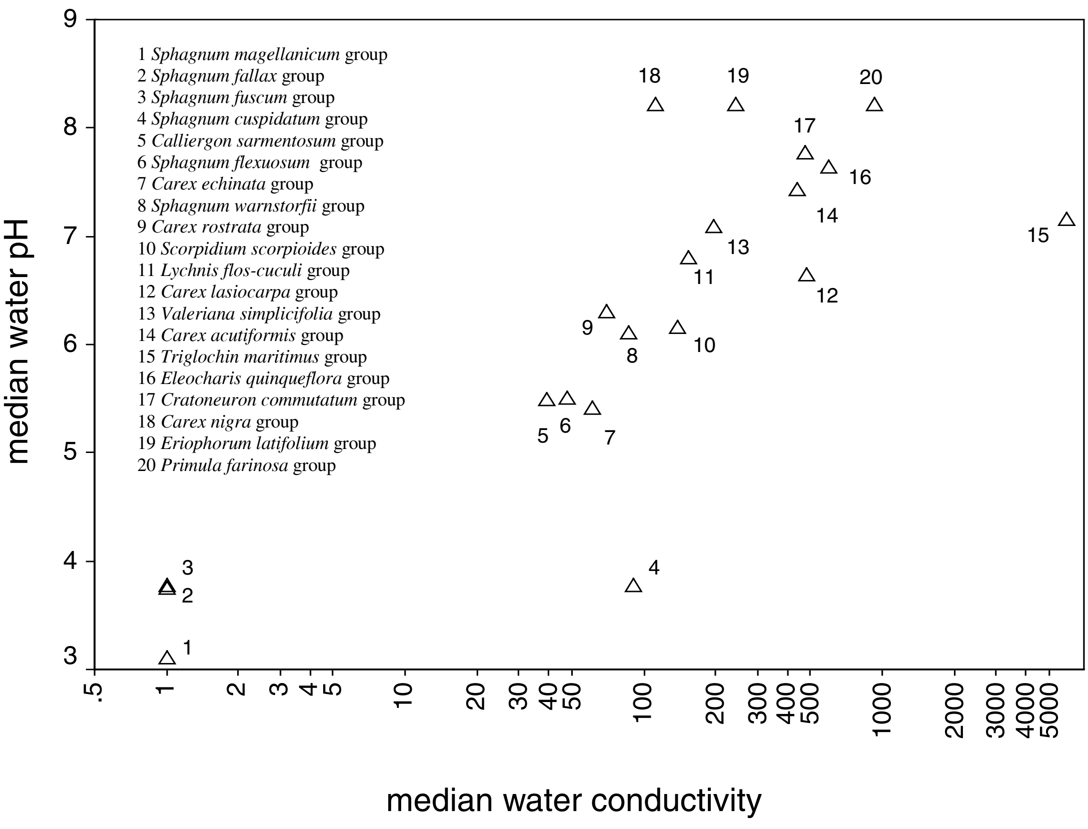

Fig. 1. The medians of response optima for the species forming particular species groups. Species response curves to pH and conductivity were created by logistic regression and HOF model. Note that x-axis is in a log-scale.

to their interpretation should be abandoned. This is especially applicable for *Caricion lasiocarpae* and *Rhynchosporion albae* (Hájek et al. 2006). Therefore, the associations defined as vegetation lacking any *Sphagnum* species and dominated by so called brown mosses (*Bryidae*) were all assigned to the *Caricion davallianae* alliance; the associations defined by the join occurrence of rich-fen calcicole species and calcitolerant *Sphagna* were

Table 3. Synoptic table of mire associations found in the regional data set from the surrounding of the Vysoké Tatry Mts. Diagnostic species are ranked by decreasing phi-coefficient. Phi-coefficient is standardised to equal size of all groups. Only species with positive fidelity to any of the columns with a probability of non-random occurrence yielded by Fischer's exact test < 0.01 were included to the synoptic table.

Group No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No. of relevés	**12**	**11**	**26**	**8**	**5**	**5**	**10**	**45**	**8**	**9**
Scheuchzerio-Caricetea fuscae										
Caricetalia davallianae										
Caricion davallianae										
Caricetum davallianae										
Pedicularis sceptrum-carolinum	**48.7**	–	–	–	–	–	–	–	–	–
Gymnadenia conopsea (agg.)	**41.1**	–	–	–	–	–	–	–	–	–
Pinguicula vulgaris	**38.3**	–	–	29.9	24.8	–	–	–	–	–
Eriophorum latifolium	**31.1**	–	–	28.3	–	–	–	–	–	–
Galium verum	**30.8**	–	–	–	–	–	–	–	–	–
Parnassia palustris	**40.3**	–	–	28.6	–	–	32.1	–	–	–
Primula farinosa	**50.4**	–	–	50.4	–	–	35.9	–	–	–
Eleocharitetum pauciflorae										
Utricularia australis	–	**61.5**	–	–	–	–	–	–	–	–
Chara vulgaris	–	**51.4**	–	–	–	–	–	–	–	–
Triglochin palustre	25.8	**43.0**	–	–	–	–	–	–	–	–
Eleocharis uniglumis	–	**38.1**	–	–	–	–	–	–	–	–
Eleocharis quinqueflora	18.3	**35.6**	–	–	–	–	–	–	–	–
Typha angustifolia	–	**32.2**	–	–	–	–	–	–	–	–
Drepanocladus cossonii	25.3	**30.9**	–	30.9	–	–	–	–	–	–
Valeriano simplicifoliae-Caricetum flavae										
Carex davalliana	30.7	–	**31.2**	–	–	–	29.6	–	–	–
Equisetum variegatum	–	–	**52.8**	–	–	–	–	–	–	–
Climacium dendroides	–	–	**51.0**	–	–	–	–	–	–	–
Cirsium rivulare	–	–	**43.1**	–	–	–	–	–	–	–
Lathyrus pratensis	–	–	**42.9**	–	–	–	–	–	–	–
Cruciata glabra	–	–	**39.1**	–	–	–	–	22.0	–	–
Ranunculus acris	–	–	**38.0**	–	–	–	–	21.6	–	–
Chaerophyllum hirsutum	–	–	**33.1**	–	–	–	–	–	–	–
Plagiomnium affine (agg.)	–	–	**32.5**	–	–	–	–	–	–	–
Thuidium recognitum	–	–	**32.4**	–	–	–	–	–	–	–
Centaurea phrygia	–	–	**32.4**	–	–	–	–	–	–	–
Juncus inflexus	–	–	**32.4**	–	–	–	–	–	–	–
Primula elatior	–	–	**30.8**	–	–	–	–	25.8	–	–
Dactylorhiza majalis	–	–	**30.5**	–	–	–	–	16.8	–	–
Amblystegio scorpioidis-Caricetum limosae										
Carex limosa	–	–	–	**100.0**	–	–	–	–	–	–
Carex lepidocarpa	19.2	–	–	**68.7**	–	–	–	–	–	–
Calliergon trifarium	–	–	–	**48.0**	–	–	–	–	–	–
Polygala amara	–	–	–	**47.4**	–	–	–	–	–	–
Salix repens ssp. *rosmarinifolia*	18.1	–	–	**45.8**	–	–	–	–	–	–
Carex flacca	–	–	–	**43.9**	–	–	–	–	–	–
Frangula alnus	–	–	–	**43.0**	–	–	–	–	–	–
Dactylorhiza incarnata	–	–	–	**40.6**	–	–	–	–	–	–
Peucedanum palustre	–	–	–	**36.7**	–	–	–	–	–	–
Drepanoclado revolventis-Caricetum lasiocarpae										
Menyanthes trifoliata	–	–	–	**43.6**	**38.1**	23.3	–	–	–	–
Pedicularis palustris	–	–	–	–	**62.6**	24.5	–	–	–	–
Silene pusilla	–	–	–	–	**61.2**	–	–	–	–	–
Hamatocaulis vernicosus	–	–	–	–	**55.5**	–	–	–	–	–
Riccardia multifida	–	–	–	–	**52.8**	–	–	–	–	–
Calliergon giganteum	–	–	–	–	**42.6**	–	23.8	–	–	–
Philonotis calcarea	–	–	–	–	**40.2**	–	–	–	–	–
Epipactis palustris	14.3	–	–	–	**36.1**	–	21.6	–	–	–
Carex rostrata	13.3	17.8	–	–	**30.0**	–	–	–	–	–
Sphagno warnstorfiani-Tomenthypnion										
Sphagno-Caricetum lasiocarpae										
Carex lasiocarpa	–	–	–	–	**63.4**	**44.2**	–	–	–	–
Persicaria bistorta	–	–	–	–	–	**71.3**	–	–	–	–
Lychnis flos-cuculi	–	–	–	–	–	**46.0**	–	–	–	–
Sphagnum flexuosum	–	–	–	–	–	**46.0**	–	–	–	19.7
Dactylorhiza maculata	–	–	–	–	–	**42.9**	–	–	–	–
Senecio sp. = *Tephroseris crispa*	–	–	–	–	–	**42.9**	–	–	–	–
Geum rivale	–	–	21.6	–	–	**41.6**	–	–	–	–
Sphagnum fallax	–	–	–	–	–	**70.8**	–	–	–	32.4
Oxycoccus palustris	–	–	–	–	–	**50.7**	–	–	–	34.6

Table 3. (continued)

Group No. No. of relevés	1 12	2 11	3 26	4 8	5 5	6 5	7 10	8 45	9 8	10 9
Sphagno warnstorfiani-Caricetum davallianae										
Paludella squarrosa	–	–	–	–	–	–	**63.5**	–	–	–
Drosera rotundifolia	–	–	–	–	–	–	**61.0**	18.2	–	–
Succisa pratensis	–	–	–	–	–	–	**50.6**	–	–	–
Calluna vulgaris	–	–	–	–	–	–	**47.0**	–	–	27.8
Luzula multiflora	–	–	–	–	–	–	**46.6**	–	–	–
Juniperus communis	–	–	–	–	–	–	**45.5**	–	–	–
Lotus corniculatus	–	–	16.6	–	–	–	**39.5**	–	–	–
Angelica sylvestris	–	–	–	–	–	–	**38.5**	12.6	–	–
Sphagnum teres	–	–	–	–	–	–	**37.9**	9.8	–	–
Blysmus compressus	29.8	–	–	–	–	–	**37.8**	–	–	–
Sphagnum capillifolium	–	–	–	–	–	–	**37.5**	–	–	–
Carex flava	–	–	–	–	–	–	**37.5**	13.0	–	–
Cirsium palustre	–	–	–	–	–	–	**36.6**	8.2	–	–
Prunella vulgaris	–	–	20.8	–	–	–	**35.9**	–	–	–
Briza media	–	–	–	–	–	–	**35.1**	20.7	–	–
Carex hostiana	26.9	–	–	–	–	–	**33.9**	–	–	–
Selinum carvifolia	–	–	–	–	–	–	**33.3**	–	–	–
Danthonia decumbens	–	–	–	–	–	–	**31.9**	–	–	–
Sphagno warnstorfiani-Eriophoretum latifolii										
Sphagnum warnstorfii	–	–	–	–	–	–	**44.7**	**51.8**	–	–
Leontodon hispidus	–	–	–	–	–	–	–	**32.7**	–	–
Carex chordorrhiza	–	–	–	–	–	–	–	**31.8**	–	–
Caricetalia fuscae										
Caricion fuscae										
Caricetum goodenowii										
Carex echinata	–	–	–	–	–	–	–	**33.0**	**39.4**	–
Sphagnum squarrosum	–	–	–	–	–	–	–	–	**53.0**	–
Rhytidiadelphus triquetrus	–	–	–	–	–	–	–	–	**49.9**	–
Senecio subalpinus	–	–	–	–	–	–	–	–	**49.2**	–
Chiloscyphus polyanthos	–	–	–	–	–	–	–	–	**48.5**	–
Epilobium palustre	–	–	–	–	–	–	–	–	**47.8**	–
Viola palustris	–	–	–	–	–	–	–	–	**42.8**	–
Agrostis stolonifera	–	–	–	–	–	–	–	–	**41.4**	–
Agrostis canina	–	–	–	–	–	–	28.6	15.0	**38.9**	–
Pseudobryum cinclidioides	–	–	–	–	–	–	–	–	**38.2**	–
Comarum palustre	–	–	–	–	–	–	–	–	**36.7**	–
Carex canescens	–	–	–	–	–	–	–	–	**36.7**	20.2
Sphagnum contortum	–	–	–	–	–	–	–	19.5	**35.3**	–
Philonotis fontana	–	–	–	–	–	–	–	–	**34.8**	–
Lysimachia vulgaris	–	–	–	–	–	–	–	–	**33.3**	–
Calliergon stramineum	–	–	–	–	–	–	–	–	**33.1**	27.9
Galium palustre	–	–	–	–	–	–	–	–	**32.8**	–
Polytrichum commune	–	–	–	–	–	–	–	–	**31.9**	–
Sphagno recurvi-Caricion canescentis										
Carici echinatae-Sphagnetum										
Calamagrostis villosa	–	–	–	–	–	–	–	–	–	**55.7**
Carex pauciflora	–	–	–	–	–	–	–	–	–	**55.7**
Melampyrum pratense	–	–	–	–	–	–	–	–	–	**51.7**
Sphagnum magellanicum	–	–	–	–	–	–	–	–	–	**45.2**
Sphagnum rubellum	–	–	–	–	–	–	–	–	–	**45.2**
Calliergon cordifolium	–	–	–	–	–	–	–	–	–	**34.2**
Drepanocladus exannulatus	–	–	–	–	–	–	–	–	–	**34.1**
Calamagrostis canescens	–	–	–	–	–	–	–	–	–	**32.7**

all assigned to the *Sphagno warnstorfii-Tomenthypnion* alliance; the associations of fens lacking both rich-fen calcicole species and strongly acidophilous species and not dominated by *Sphagnum* sect. *Cuspidata* were assigned to the *Caricion fuscae* alliance and, finally, the species-poor minerotrophic mires strongly dominated by *Sphagnum* species were assigned to the *Sphagno recurvi-Caricion canescentis* alliance.

New data collected in northern Slovakia made the formal defining of the association *Carici filiformis-Sphagnetum apiculati* (= *Carici lasiocarpae-Sphagnetum fallacis*) possible. This association is characterised by the dominance of both the species from *Sphagnum recurvum* group and *Carex lasiocarpa* and by the absence of any calcicole or calcium-tolerant species (see also Rybníček et al., 1984; Dítě & Hájek 2005). This association is not mentioned in Valachovič (2001), because at that time, northern Slovakian mires with *Carex* *lasiocarpa* were not studied in detail. The association *Glauco-Trichophoretum pumili* is proposed to be assigned to the *Caricion davallianae* alliance due to a high floristic similarity of the association with this unit. Vicherek (1973) described this association within separate salt-marsh alliance *Halo-Trichophorion pumili* Vicherek 1973.

Why to distinguish or not distinguish some associations?
We should note that no exact method exists for determining if formal definition of a plant association is really impossible. Some associations, which cannot be defined by the combinations of the species groups, can be defined by the dominance of certain species. Kočí et al. (2003) and Chytrý (2007) accepted only associations with diagnostic species, but arbitrary threshold of phi-coefficient value was used to regard species to be diagnostic. We must decide whether several rich-fen associations, which could be defined primarily as based on the dominance, will be defined and accepted. On the one hand, *Eleocharitetum pauciflorae* (= *quinqueflorae*) has been accepted, as its definition selected many relevés, which did not match with definitions of other rich-fen associations. Moreover, further arguments why this association should be distinguished are given in Dítě et al. (2006). On the other hand, *Schoenetum ferruginei* were not defined because all relevés, which were selected by the dominance of *Schoenus ferrugineus*, either overlapped with *Caricetum davallianae* or represented dry stages of former *Schoenus*–fens without rich-fen species. *Seslerietum uliginosae* cannot be defined merely based on the dominance because *Sesleria uliginosa* can dominate in dry grasslands and mesophilous meadows as well; the combination of *S. uliginosa* dominance and some rich-fen species group however led to a large overlap with *Caricetum davallianae*. Further field research could be focused on the communities dominated by *Schoenus ferrugineus* and *Sesleria uliginosa* in order to confirm or reject our conclusion. Further associations were rejected for similar reasons.

The advantages of supervised classification
This study showed that species groups obtained by the Cocktail method have a clear ecological explanation (Fig. 1). The fact that the species groups which were created by the Cocktail method differ substantially in their position along the pH/calcium gradient accords well with the fact that pH and calcium are generally the most important determinants of floristic variation in mires (e.g. Hájková & Hájek, 2004; Tahvananinen 2004; Navrátilová & Navrátil 2005). Our results suggest that the supervised classification reflects this major compositional gradient somewhat better than the unsupervised classification based on cluster analysis, but further studies are needed. We improved the expert-based system of Valachovič et al. (2001) in such way that now we have 24 mire associations clearly defined and confirmed by the formalised method. These formal definitions are tools for potential users to assign vegetation relevés to the existing plant associations, as the case study from the surroundings of the Vysoké Tatry Mts showed. Nevertheless, certain simplifications of the formalised definitions are possible in such an application. A negative member of the definition may be deleted if certain species group is completely missing in the study region or if only data from mire vegetation are analysed. In the latter case, negative member of the definition might be omitted if it differentiates the association from other than mire habitats which are not included into regional data set.

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