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Vegetation composition, main gradient and subatlantic elements in spring fens of the northwestern Carpathian borders

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ABSTRACT: The vegetation composition and the physical-chemical properties of waters were recorded on spring fens in the northwestern Carpathians (the Moravskoslezské Beskydy Mts., the Turzovská vrchovina Mts., the Kysucké Beskydy Mts., the Kysucká vrchovina Mts. and the Bieskid Żywiecki Mts.; Czech Republic, Slovakia, Poland). Combinations of species groups, which indicate mineral ion concentration levels in the water, have been used in delimitation of plant communities. The poor-rich trophic gradient controls the major vegetation gradient. Five widely distributed communities were distinguished along this gradient: the *Valeriano-Caricetum flavae* association (rich alkaline spring fens depositing peat, moderate slopes), the *Sphagno warnstorfii-Eriophoretum latifolii* ass. (moderately rich, neutral spring fens or alkaline sources of poor water or advanced succession stages), the *Caricetum goodenowii* ass. (moderately poor, neutral sites with low organic content in the soil), the *Carici echinatae-Sphagnetum sphagnetosum flexuosi* subass. (poor spring fens with a stable water regime and moderately acid pH) and the *Carici echinatae-Sphagnetum sphagnetosum fallacis* subass. (strongly acid poor fens, especially sites with lowered water tables). Two other rich fen communities, the *Eleocharitetum pauciflorae* and the *Carici flavae-Cratoneuretum*, were found only occasionally in the study area. The vegetation composition correlates best with the pH and conductivity of the water. Both the water redox-potential and the altitude also increase towards the poor end of the gradient. There is an important group of subatlantic species occurring in the study area, generally rare in the Western Carpathians. These species grow mainly in the central part of the major vegetation gradient, on moderately acid and moderately poor fens (*Caricetum goodenowii*, *Carici echinatae-Sphagnetum sphagnetosum flexuosi*).

KEYWORDS: Czech Republic, mires, ordination, phytosociology, Poland, Slovakia, water properties

Introduction

Mire ecosystems can be divided into two major groups according to nutrient input type, namely the ombrotrophic bogs and minerotrophic fens (GORE 1983, WHEELER & PROCTOR 2000). Floristic composition of mires, especially fens, changes from mineral-poor to mineral-rich sites along the poor-rich trophic gradient (see e. g. MALMER 1986, GERDOL 1995). A continuous gradient of vegetation composition controlled by the continuous increase of metallic element (Ca, Mg, Na, K) concentrations in water and soil (WAUGHMANN 1980, MALMER 1986, VITT 2000, GERDOL & BRAGAZZA 2001, HÁJEK & al. 2002) causes fens that are rich in transitional vegetation types. The majority of fen species overlap between several related vegetation types distinguished along the poor-rich gradient. It causes problems in phytosociological classification. The classification system used in some of the Central European countries (RYBNÍČEK & al. 1984, RYBNÍČEK 1985, KONRÁD 1998, HÁJEK & HÁBEROVÁ 2001) respects the Scandinavian tradition (DU RIETZ 1949, 1954, SJÖRS 1952, RUUHIJÄRVI 1960, FRANSSON 1972, HEIKKILÄ 1987) and delimits associations according to their position on the poor-rich gradient. The second classification approach based just on diagnostic plant species (see, for example, DIERSSEN 1982, STEINER 1992) reflects the poor-rich gradient in delimitation of subassociations.

The poor-rich gradient also controls the major vegetation gradient in Carpathian spring fens. There it strongly correlates with water calcium and magnesium concentrations, pH and conductivity of spring waters. In previous papers (POULÍČKOVÁ & al. 2001, HÁJEK & al. 2002), the plant species distribution along the poor-rich gradient has been presented for 70 analysed springs for which the complete water chemistry was known. These studies, performed in the western part of the Carpathian flysch zone, analysed the long gradient from extremely rich spring fens with tufa formation to poor *Sphagnum*-fens. The *Sphagnum* fens show wider floristic and habitat variance than extremely rich brown moss fens in the study area (HÁJEK & al. 2002). They prevail in the phytogeographically noteworthy northern part of the study area. Several subatlantic species of vascular plants and mosses reach their distribution limits here.

This study, utilising a data set enlarged from that in the previous paper (Hájek & al. 2002), is aimed at (a) improving knowledge of vegetation composition and species distribution along the major trophic gradient in northwestern Carpathian fen vegetation; (b) verifying that the main vegetation gradient correlates with the poor-rich trophic gradient; (c) utilising the gradient analysis in phytosociological classification on a local scale; (d) describing the presence of subatlantic elements in fen vegetation. Since the study area covers territory in three states (Czech Republic, Slovakia, Poland), the results improve the knowledge about the distribution of particular plant communities in these countries.

Material and methods

The study area

This study concerns the northern part of the crossborder area between the Czech and Slovak Republics and part of the adjacent region of Poland on the northwestern margin of the Western Carpathians (Fig. 1). The study area forms part of the Carpathian flysch zone. The bedrock is composed of a group of flysch beds belonging to the Rača, Bystrica and Silesian Units. The groundwater chemical composition reflects the bedrock chemistry (RAPANT & al. 1997). The study area belongs to the following orographic units: the Moravskoslezské Beskydy Mts. (Czech Republic, Slovakia; prevailing non-calcified iron-cemented sandstone); the Turzovská vrchovina Mts. (Slovakia; prevailing calcified sandstone and claystone); the Kysucké Beskydy Mts. and the Kysucká vrchovina Mts. (prevailing calcified iron-cemented sandstone) and the western part of the Polish Bieskid Żywiecki Mts. (Poland; prevailing calcified sandstone). A large part of the study area belongs to the following Protected Landscape Areas: Beskydy, Kysuce and Żywiecki Park Krajobrazowy. The climate is cold and humid (the typical example, station Bílá-Salajka in the Moravskoslezské Beskydy Mts.: average annual temperature 5.4°C; average annual precipitation 1144 mm). The studied fens occur at a range of altitudes between 495 m (Lány Nature Reserve in the Kysucká vrchovina Mts., Slovakia) and 970 m (Uherská hill in the Moravskoslezské Beskydy Mts., Slovakia). Most open spring fens are young; they developed from forest springs following settlement and deforestation in 17^{th} - 18^{th} centuries (RYBNÍČEK & RYBNÍČKOVÁ 1995).

Field data sampling

Only relevés of fen vegetation (*Scheuchzerio-Caricetea fuscae*) were studied. All of them (76) are presented in this paper. Wet meadow communities with a prevalence of meadow species (the *Molinio-Arrhenateretea* class) are not included. For an estimate of abundance and dominance of plant species (bryophytes, vascular plants) the nine-grade scale (BARKMAN & al. 1964, VAN DEN MAAREL 1979) was used. Vegetation relevés were subjectively taken from central, well-hydrated and well-developed parts of spring fens. A small hole was dug in a well-hydrated part of the site near the headspring. The water conductivity (at 20 °C), pH (at 20 °C) and redox potential were measured in situ here using portable instruments (CM 101 and PH 119, Snail Instruments). Water redox potential was measured with a platinum electrode with silver chloride reference in a 3M KCl solution. The measurements were repeated at 38 separate sites in August 1998, May 2000 and September 2000. These sites were selected because they are not distant from roads and tracks and thus we were able to measure water properties at all sites during a short time. The mean values were calculated for each site. Conductivity caused by H^+ ions in acid waters was subtracted (SJÖRS 1952).

Fig. 1. The position of the study area

Data analysis

The following aggregate species were used in numerical analyses. *Drepanocladus revolvens* includes *D. cossonii*, *Chiloscyphus polyanthos* includes var. *pallescens* and *Campylium stellatum* includes var. *protensum*.

The CANOCO 4 package (TER BRAAK & ŠMILAUER 1998) was used for gradient analyses. The species-by-sample matrix was subjected to detrended correspondence analysis (DCA), using default options with downweighting of rare species. Ordination site scores were correlated with environmental factors using Pearsson´s correlation coefficient. The Monte Carlo test of significance of the first ordination axis for cannonical correspondence analysis (CCA) with a single variable was used for testing the importance of each environmental variable.

The following species considered to be subatlantic elements in Western Carpathian flora (see PILOUS 1971, CHRTEK & KŘÍSA 1984, GRULICH 1997, DOBOŠOVÁ 1998, SLAVÍK 1998, VALACHOVIČ & HÁJEK 2000, HÁJKOVÁ & HÁJEK 2001, DÍTĚ & al. 2001) were selected to demonstrate subatlantic species occurrence in spring fens: *Carex demissa*, *Hydrocotyle vulgaris*, *Juncus bulbosus*, *J. squarrosus*, *Lotus uliginosus*, *Lycopodiella innundata*, *Lysimachia nemorum*, *Montia fontana*, *Pedicularis sylvatica*, *Sphagnum auriculatum*, *Sphagnum inundatum*. These species were counted in and closely near the all of relevé areas. A chart showing the number of these species in five vegetation types distinguished along the major vegetation gradient was constructed. The Kruskal-Wallis test was used for comparing the number of subatlantic elements among the five major vegetation types.

The nomenclature of plant species is according to DANIELS & EDDY (1990) for *Sphagnum* species and MARHOLD & HINDÁK (1998) for other species. The nomenclature of syntaxa is according to VALACHOVIČ (2001).

Abbreviations: Ch = the character species; D = the differential species; ass. = association; all. = alliance; ord. = order; MB = the Moravskoslezské Beskydy Mts.; TV = the Turzovská vrchovina Mts.; KB = the Kysucké Beskydy Mts.; KV = the Kysucká vrchovina Mts.; BZ = the Bieskid Żywiecki Mts.

Results

Vegetation composition and species distribution along the major gradient is shown in Tab. 1. The syntaxa and the majority of relevés are arranged according to their site score on the first DCA axis (see Fig. 2), from calcium-rich spring fens on the left to calcium-poor fens on the right. Five common and two rare plant communities were distinguished. Each fen community is well differentiated by a combination of several diagnostic species groups (see Tab. 1). The most widely distributed communities are:

1. ***Valeriano-Caricetum flavae*** (Tab. 1, rel. 5-30)
Syntaxonomy: the *Caricetalia davallianae* order, the *Caricion davallianae* alliance
Species combination: Ch *Caricetalia davallianae* + Ch *Caricion davallianae* + Ch *Caricetalia fuscae* + regional character species (*Valeriana simplicifolia, Philonotis fontana, Alchemilla glabra, Calliergon giganteum, Dicranum bonjeanii, Palustriella decipiens*) + *Hypnum pratense*
Distribution: KB, KV, TV, BZ
Ecology: calcium- and iron- rich spring fens depositing peat, moderate slopes
Variability: *Palustriella commutata* can be found on slopes with running water (Tab. 1, rel. 5). The *Valeriano-Caricetum flavae* is however clearly separated from the *Carici flavae-Cratoneuretum* in the western flysch Carpathians (see HÁJKOVÁ & HÁJEK 2000). Small-scale patches dominated by *Eleocharis quinqueflora* occur on disturbed sites. *Menyanthes trifoliata* dominates on the Lány site (Kysucká vrchovina), where other tall sedges of the *Caricion rostratae* all. (*Carex rostrata, C. diandra*) also grow.

2. ***Sphagno warnstorfii-Eriophoretum latifolii*** (Tab. 1, rel. 31-39)
Syntaxonomy: the *Caricetalia davallianae* order, the *Sphagno-Tomenthypnion* alliance
Species combination: Ch *Caricetalia davallianae* + Ch *Caricetalia fuscae* (in comparison with *Valeriano-Caricetum flavae* mostly *Sphagnum subsecundum, Viola palustris, Calliergon stramineum*) + *Hypnum pratense* + regional alliance character species (*Sphagnum warnstorfii, S. teres, S. contortum, S. squarrosum*)
Distribution: MB, TV, BZ
Ecology: calcium moderately rich fens, surrounding of mineral-poor sources, advanced succession stages in rich fens
Variability: *Sphagnum* sect. *Subsecunda* occurs in early succession stages. On some sites poor in organic carbon, the rich group of *Molinietalia* species occurs.

3. ***Caricetum fuscae*** (Tab. 1, rel. 40-50)
Syntaxonomy: the *Caricetalia fuscae* order, the *Caricion fuscae* alliance
Species combination: Ch *Caricetalia fuscae* + regional alliance character species (*Ranunculus flammula, Carex demissa, Juncus bulbosus, Pedicularis sylvatica, Drepanocladus exannulatus*)

Distribution: MB, TV
Ecology: calcium moderately poor sites with low organic content in the soil
Variability: The *Caricion fuscae* alliance is the most heterogenous fen vegetation in the study area, due to the common occurrence of transitional types with the *Calthion* wet meadows, the *Sphagno-Tomenthypnion* rich fens and the *Sphagno recurvi-Caricion canescentis* poor fens.
Types dominated by *Amblystegiaceae* (subas. typicum; Tab. 1, rel. 40-47) and by *Sphagnum subsecundum* (subas. *sphagnetosum subsecundi*; Tab. 1, rel. 48-50) can be distinguished.

4. *Carici echinatae-Sphagnetum* (Tab. 1, rel. 51-77)
Syntaxonomy: the *Caricetalia fuscae* order, the *Sphagno recurvi-Caricion* alliance
Species combination: Ch *Caricetalia fuscae* + regional alliance character species (*Sphagnum flexuosum, S. fallax, S. palustre, Drosera rotundifolia, Carex canescens, Polytrichum commune, P. strictum*)
Distribution: MB
Ecology: Fens poor in all mineral cations, but rich in organic matter
Variability: Due to precise identification of *Sphagnum* species, the poor fens of this association can be divided into two main types. The occurrence of differential vascular plant and bryophyte species as well as pH-values of water support this classification:
subas. *sphagnetosum flexuosi*, subass. nova hoc loco (Tab. 1, rel. 51-65; nomenclature type: rel. 52) is differentiated from the second subasociation by *Sphagnum flexuosum, Carex demissa, Pedicularis sylvatica, Crepis paludosa, Briza media, Equisetum palustre, E. fluviatile* and *Lysimachia vulgaris*. It occurs in poor spring fens with stable water regimes and moderately acid pH. It was recorded also on calcium moderately rich sites eutrophicated by phosphates (HÁJEK & al. 2002).
subas. *sphagnetosum fallacis*, subass. nova hoc loco (Tab. 1, rel. 66-76; nomenclature type: rel. 73) is differentiated by *Sphagnum fallax, S. magellanicum, S. papillosum, S. auriculatum* and *Vaccinium vitis-idaea*. It occupies poor fen hummocks or other sites with a lowered water table and with low pH. *Sphagnum papillosum* dominates in several sites.

Two rare rich fen communities were recorded in the study area. The *Carici flavae-Cratoneuretum* ass. grows on tufa-forming, Ca-extremely rich springs with very low organic matter content. It has been reported at one small spring near Bílá (Tab. 1, rel. 4). The second rare association, the *Eleocharitetum pauciflorae*, is characterised by the dominance of *Eleocharis quinqueflora* and a sparse herb layer (RYBNÍČEK & al. 1984, HÁBEROVÁ & HÁJEK 2001).

Several *Sphagnum*-dominated communities, reported by DUDA (1950) from the Šance bog, are no longer found in the study area. They were bog communities of the *Eriophoro vaginati-Sphagnetum recurvi* association, a bog community with *Carex pauciflora* and the poor fen communities of the *Carici* *rostratae-Sphagnetum* association. These associations disappeared after the flooding of the Ostravice valley by a reservoir.

The site position on the major vegetation gradient, expressed as the site score for the first DCA axis (Fig. 2), correlates strongly with pH and conductivity (Tab. 2). CCA with a single variable gives similar results: pH and conductivity are more important than altitude and redox, the degrees of the slope has no sigificant impact on vegetation composition. When pH is eliminated as a covariable factor, conductivity and altitude still explain significant share of floristic variation (see Tab. 2). The conductivity is the most important factor for explaining vegetation composition when pH is above 6 (see Fig. 2).

The *Carici echinatae-Sphagnetum sphagnetosum fallacis* subass. grows on acidic fens (pH < 5.3) with low water mineral content (conductivity < 50 μS/cm), the *C.e. - S. sphagnetosum flexuosi* subass. needs higher pH-values (5.2-6.1; see Fig. 3). The *Caricetum goodenowii* and the *Sphagno warnstorfii-Eriophoretum latifolii* ass. occupy slightly acid or neutral fens having water conductivity below 150 μS/cm. The rich fen vegetation of the *Valeriano-Caricetum flavae* ass. occurs at water conductivity values from 170 to 410 μS/cm. The annual mean pH is above 6.8, with the exception of one site on mineral soil (pH 6.3; see Fig. 3). The water redox potential correlates slightly with the main vegetation gradient (Tab. 2), with pH and conductivity and strongly (P< 0.001) with altitude.

Both extreme ends of the major trophic gradient are poor in subatlantic plant species (Fig. 4). The vegetation types in the central part of the gradient (moderately rich fens with slightly acidic reaction) have 1-4 of these species.

Discussion

The phytosociological classification based on species combinations of both bryophytes and vascular plants which have varying mineral concentration requirements produces a system which reflects the poor-rich trophic gradient at a higher hierarchical level than does a system, based on one or two diagnostic, widely-distributed species. The most of our relevés correspond to the broad association *Caricetum nigrae* (see DIERSSEN 1982, MATUSZKIEWITZ 1982, STEINER 1993, MARTINČIČ 1995, STEINBUCH 1996, ZECHMEISTER & STEINER 1995). These two different systems are related at several points. The *Caricetum nigrae sphagnetosum subsecundi* subass., described by STEINER (1992), has the same content in both systems.

The system used here takes into account species which cannot be regarded as character species. The occurrence of some species (e.g. *Hypnum pratense, Sphagnum subsecundum, S. teres, Viola palustris, Calliergon stramineum, C. giganteum, Aulacomnium palustre*: see Tab. 1) can indicate the position on the poor-rich gradient. These species have no significant link to phytosociological units when data from the entire Western Carpathians are analysed (HÁJEK 2002).

Tab. 2. Pearsson´s correlation coefficients between environmental factors (physical-chemical properties of water, altitude and slope degrees) and site scores on the first two DCA axes (major vegetation gradients). The results of a Monte Carlo test performed in CCA with a single variable: a) without covariable and b) with pH as a covariable. Significance values are presented; n.s. = not significant.

			water pH	water cond.	water redox	altitude	slope degrees
Pearsson´s correlation	DCA: 1st axis	r P	-0.90 $<1.10^{-15}$	-0.85 $<1.10^{-14}$	0.34 =0.038	0.36 =0.024	n.s.
	DCA: 2nd axis	r P	-0.47 =0.003	-0.57 <0.001	n.s.	n.s.	n.s.
CCA: Monte Carlo test	single variable	F P	6.34 <0.005	5.6 <0.005	1.68 =0.045	1.89 =0.015	n.s.
	single variable, covariable: pH	F P	---	1.86 <0.005	n.s.	1.40 =0.025	n.s.

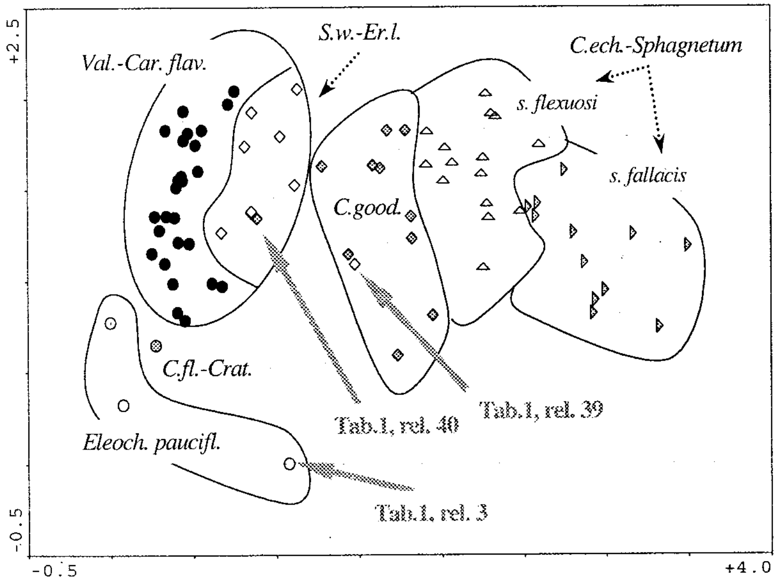

Fig. 2. The DCA ordination diagram of the relevés. The sites belonging to the same vegetation types, as they are classified in Tab. 1, are differentiated with various symbols and bordered by lines. Relevés for which the ordination score does not correspond with the phytosociological classification, are indicated by arrows and labelled by relevé number (see Tab. 1).

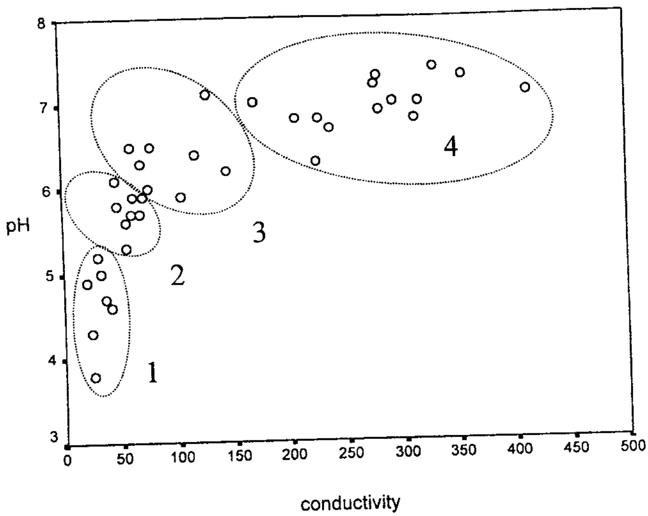

Fig. 3. Variation of pH and water conductivity (µS/cm/20°C) in relation to vegetation types distinguished in the northwestern Carpathians (1 = *Carici echinatae-Sphagnetum sphagnetosum fallacis*; 2 = *Carici echinatae-Sphagnetum sphagnetosum flexuosi*; 3 = *Sphagno warnstorfii-Eriophoretum* & *Caricetum goodenowii*; 4 = *Valeriano-Caricetum flavae.*

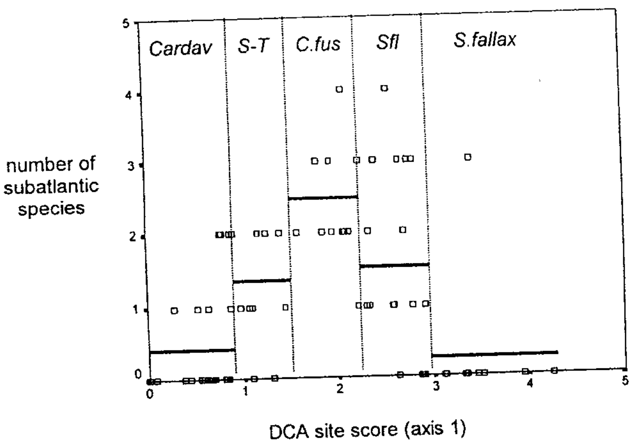

Fig. 4. Distribution of subatlantic species along the poor-rich gradient expressed as dependence of the number of subatlantic species in the relevé upon the DCA site score. The horizontal stripes show the arithmetic means in each group. The Kruskal-Wallis test is significant ($P< 0.001$). Vegetation types: *Cardav* = the *Caricion davallianae*; *S-T* = *Sphagno -Tomenthypnion*; *C.fus* = *Caricion fuscae*; *Sfl* = *Carici echinatae-Sphagnetum sphagnetosum flexuosi*; *S.fallax* = *Carici echinatae-Sphagnetum sphagnetosum fallacis.*

The species combinations used in the study area are not, in some cases, transferable to other regions. The *Valeriano-Caricetum flavae* ass. is differentiated not only by joint occurrence of *Caricetalia davallianae* and *Caricetalia fuscae* species (HÁJEK & HÁBEROVÁ 2001), but also by the distinct species group of *Valeriana simplicifolia, Equisetum fluviatile, Philonotis fontana* and *Calliergon giganteum*. These species also occur similarly in poor *Sphagnum*-fens of the Horehron basin (see HÁBEROVÁ 1976).

The *Eleocharitetum pauciflorae* is well characterised in its physiognomy, but is badly differentiated according to floristic composition. HÁJEK & HÁBEROVÁ (2001) do not report any diagnostic species of this association in Slovakia. This association is, from the floristic point of view, identical to the *Carici flavae-Cratoneuretum* ass. in the Strážovské vrchy Mts. (HÁJKOVÁ & al. 2001). The situation is similar in the study area, where two relevés of *Eleocharitetum pauciflorae* are floristically identical with *Valeriano-Caricetum flavae* (Tab. 1, rel. 1-2). These two relevés come from calcium-rich sites. The third one, with a mixture of rich and poor fen species, was recorded on a calcium-poor spring fen with neutral pH. Its position in the table does not correspond with its position on the first DCA axis. The DCA site score (1^{st} axis) of this site corresponds to the *Sphagno-Tomenthypnion* communities instead (Fig. 2).

The *Sphagno-Tomenthypnion* alliance is generally a succesionally more advanced type of vegetation than the *Caricion davallianae* fens (RYBNÍČEK 1974, RYBNÍČEK & al. 1984, HÁJEK 1999). This concerns mainly the eastern part of the study area (the Kysucká vrchovina Mts., the Bieskid Żywiecki Mts.), where the first rare patches of *Sphagnum subsecundum* have been found in *Valeriano-Caricetum flavae* outside the sample plots. On the contrary, *Sphagno-Tomenthypnion* communities cannot be connected with the *Caricion davallianae* fens in the western part of the region. Here there is extremely low organic matter content in the soil (HÁJEK & al. 2002), lower water conductivity (as compared to *Caricion davallianae* fens) and the stands occur directly on spring outflows. Transitional types among the *Sphagno-Tomenthypnion*, *Caricion fuscae* and *Calthion* communities have also been found. These facts explain the overlap of water pH and conductivity values between *Sphagno-Tomenthypnion* and *Caricion fuscae* stands (Fig. 3).

Two vegetation types, distinguished within the *Carici echinatae-Sphagnetum* association, cannot be verified using a data set from whole Slovakia (see HÁJEK & HÁBEROVÁ 2001). One of the reasons is disagreement among various authors concerning identification of small species of the *Sphagnum recurvum* complex; the other reasons bear upon regional peculiarities in water chemistry and in plant species distribution. This findings confirms that regional and national vegetation classifications are not generally comparable as a whole (CHYTRÝ 2000), especially in the case of the lowest syntaxa.

The pH and conductivity of water have a strong correlation with the major vegetation gradient (first DCA axis), as described from other areas in Europe and

North America (e. g. SJÖRS 1952, MALMER 1963, SLACK & al. 1980, WAUGHMANN 1980, CHARMAN 1993, GERDOL 1995, BRAGAZZA & GERDOL 1996, GERDOL & BRAGAZZA 2001). The exact values of water pH and water conductivity correlated with the major vegetation types (Fig. 3) are identical with those reported from southern Scandinavia (see MALMER 1986: Fig. 5). Not only total floristic composition, but also the species richness of both vascular plants and bryophytes is influenced by these factors in our study area. The species richness is, however, a strongly scale-dependent variable (HÁJKOVÁ & HÁJEK *in prep.*).

The correlation between the poor-rich gradient and water redox-potential seems to be an important ecological feature. In the previous paper (HÁJEK & al. 2002) no correlation was found between these characteristics. Both the small number of Ca-extremely rich tufa-forming springs in the analysed data and redox- measurement performed repeatedly helped reveal this relationship. The increasing mean values of water redox-potential towards poor *Sphagnum* fens are connected with the influence of rain water, which has high redox-potential (DE MARS & WASSEN 1999). There is no correlation between the poor-rich gradient and slope degrees in the presented data. Such correlation has been found in the data set from a wider area including the southern and western parts of the Carpathian flysch margin (HÁJEK & al. 2002).

The subatlantic migrants are important components of moderately acid and moderately poor fens in the Moravskoslezské Beskydy Mts. and the adjacent regions. Two suboceanic species (*Hydrocotyle vulgaris, Lotus uliginosus*) were surprisingly found on a rich brown moss fen near the Hrubý Buk village. The occurrence of non-freezing flushes is typical for the poor spring fen near the Zajacovci village, which hosts the rare subatlantic moss *Sphagnum auriculatum*. Generally, subatlantic species are not typical components of the Carpathian poor *Sphagnum*-fens. Some of these species grow in Slovakia in the Borská nížina lowland (south-west), where there are regional diagnostic species of the *Rhynchosporion* alliance (*Hydrocotyle vulgaris, Juncus bulbosus, Sphagnum inundatum* - see RYBNÍČEK 1970, HÁJEK & HÁBEROVÁ 2001). Some other subatlantic species are confined to the poor fens of the study area and adjoining regions in northern Slovakia (see e. g. VALACHOVIČ & HÁJEK 2000, DÍTĚ & al. 2001, ŠOLTÉS 2001).

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