Comparison of the algal flora in subalpine and montane mires in the Krkonoše Mts (the Giant Mts; Czech Republic)

Srovnání algoflóry subalpínských a montánních rašelinišť Krkonoš

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Abstract

The subalpine mires in the Krkonoše Mts are unique among the Central European mountain mires due to their microtopography and phytosociology. The research was carried out to find out whether there is a difference between the subalpine and montane peatbogs in the algal flora as well. Samples from two subalpine mires (Pančavské rašeliniště, Úpské rašeliniště) and one montane bog (Černohorské rašeliniště) were examined. The algal flora of Pančavské rašeliniště peatbog diverged from the other two mires more than they differed each other. Local environmental conditions (e.g. physical and chemical variables, diversity of microbiotopes) seem to be more directive for the algal flora diversity than the altitudinal zonation.

Introduction

The subalpine mires in the Krkonoše Mts have been objects of numerous investigations because of their unique microtopography and phytosociology. RUDOLPH & FIRBAS (1927) were the first ones who referred to the similarity between these mires and the peatlands in Scandinavia. JENÍK & SOUKUPOVÁ (1992) pointed out the exceptionality of subalpine mires in the Krkonoše Mts among the Central European mountain mires. Recently, a great attention has been paid to them, as the components of the intensively examined arcto-alpine tundra (e.g. SOUKUPOVÁ at al. 1995, VANĚK 2004).

The montane peatbogs have been studied less. The largest and the only one explored in detail (PACLTOVÁ 1957) is the peatbog at Černá hora Mt (Černohorské rašeliniště). Its vegetation and topography resembles more the mires of the Šumava Mts and the Jizerské Mts than the subalpine mires of the Krkonoše Mts (HADAČ & VÁŇA 1968).

The aim of the presented research was to find out whether there is a difference in the algal flora between the subalpine and montane peatbogs.

More than 60 mires are known in the Krkonoše Mts (OČADLÍK & FUKSA 1968) but some of them dry out during the summer and small or shallow peatbogs are often influenced by the surrounding environment (transport of nutrients and organisms) or by human impact. Moreover, only a few mires were studied in detail. Three bogs selected for this preliminary study are comparable as for their area and the amount of water biotopes suitable for algae. They also belong to the most explored mires in the Krkonoše Mts, and so the comparison could be based on the results from different branches of science.

Localities

Two subalpine mires and one montane mire were examined.

The Úpské rašeliniště peatbog lies at a plateau under Sněžka Mt in the eastern part of the Krkonoše Mts, in the spring area of the White Elbe and the Úpa rivers. With the altitude of 1420 m a.s.l., it is the highest mire in the Czech Republic. The Pančavské rašeliniště peatbog (cca 1340 m a.s.l.) is situated at a similar summit plateau in the western part of the Krkonoše Mts, in the spring area of the Elbe and the Mumlava rivers. Both peatbogs belong to patterned mires due to their microrelief (JENÍK & SOUKUPOVÁ 1992) and separate raised bogs due to their topography (DOHNAL 1965). Their vegetation consists of oligotrophic communities belonging to the *Oxycocco-Sphagnetea*, and of minerotrophic fen communities of the class *Scheuchzerio-Caricetea fuscae* (JENÍK & SOUKUPOVÁ 1992).

The Černohorské rašeliniště peatbog (60 ha, cca 1180 m a.s.l.) is the largest mire in the Krkonoše Mts. It developed from several smaller peat deposits and so some parts have the character of a saddle mire and some of a sloping mire (PACLTOVÁ 1957). In the central part of the bog lies an open mossy and grassy area (the German name for the peatbog comes from it: Mooswiese = moss meadow), girdled by a broad belt of the dwarf-pine (in this area not dwarfish at all, but about 2 m tall). Large marginal parts of the peatbog are overgrown with spruce forests. There is a number of small water-filled hollows in the forested part of the peatbog. In the open mossy area one larger pool (about 1m deep and 1m in diameter) is situated, a residue of the terrestrialized lake (PACLTOVÁ 1957).

Table 1 presents other geographical and geological characteristics of the investigated mires .

Table 1: Geographical and geological characteristics of the mires according to OČADLÍK & FUKSA (1968). (PR = Pančavské rašeliniště, UR = Úpské rašeliniště; CR = Černohorské rašeliniště. * Although the chemical variables varied in different parts of mires, each peatbog was represented by single sampling in OČADLÍK & FUKSA (1968). The examined bogs belong to different peatland complexes. The range of the pH values for the whole complex is given in brackets.)

	UR	PR	CR
Altitude (m a.s.l.)	1420-1430	1310-1371	1165-1190
Area (ha)	10	26	60
Average depth of the peat layer (m)	0.5	1	0.7
Maximum depth of the peat layer (m)	1.7	2.8	2
pH of the peat *	3.9 (3.9-4.5)	4.4 (4-5.7)	4.5 (4-4.6)
Bedrock	biotite gneiss	biotite gneiss	phyllite

Material and methods

Water samples were taken from various microhabitats in three peatbogs in the summer and autumn 2004. The water temperature, pH and conductivity were measured at the time of sampling using the WTW pH-meter 330 with the combined electrode SenTix 41, and WTW conductometer LF 315.

Most taxa were identified directly from fresh samples. Diatom slides were prepared following standard methods: the samples were treated with H_2O_2 and $K_2Cr_2O_7$ in order to remove organic material. After several rinsing and centrifugation, cleaned diatom valves were mounted in Naphrax resin.

The relationship between the floristic and environmental data was analysed by multivariate statistical methods using the programme Canoco for Windows (TER BRAAK & ŠMILAUER 1998). Detrended correspondence analysis (DCA) was performed to reveal the structure of data. Canonical correspondence analysis (CCA) with locations of samples in the particular mires as independent variables was accomplished to reveal how much the mires differ. CCA with microhabitat and basic chemical parameters as environmental variables and the locations in the particular mire as covariables was performed to eliminate the effect of the individuality of the mires.

The differences of chemical variables between the mires were tested using ANOVA and the relationship between the environmental variables and the number of species within the mires was tested using regression.

Results and discussion

Table 2 summarises the measured environmental data and species diversity data.

Table 2: Environmental variables of water and numbers of taxa. (CR = Černohorské rašeliniště, UR = Úpské rašeliniště, PR = Pančavské rašeliniště. Values: mean ± standard deviation.)

	CR	UR	PR
pH	3.75 ± 0.12	4.2 ± 0.22	4.8 ± 0.33
Conductivity (µS . cm^{-1})	52.4 ± 25.7	24.4 ± 6.0	20.8 ± 9.8
Total number of taxa	58	74	112
Number of taxa per sample	12.3 ± 6.0	26 ± 8.5	33.6 ± 11.6
Sørensen's indices of similarity between samples within the mire	29.04 ± 12.85	44.57 ± 9.81	35.06 ± 12.60

The poorest algal assemblages were found in the forested part of the Černohorské rašeliniště peatbog. Filamentous algae (*Microspora pachyderma, M. tumidula*) and euglenophytes (*Rhabdomonas costata, Euglena adhaerens*) were the most frequent dominants. Other abundant species were *Cylindrocystis brebissonii, Staurastrum hirsutum* var. *muricatum, Pinnularia rupestris* and *P. subcapitata*. The most frequent bog diatom *Frustulia rhomboides* did not occur here. Mesotaenioid desmids *Penium polymorphum* and *Mesotaenium* cf. *chlamydosporum* were the most prominent species in the "lawn" sites at the open area of the bog. The underground water was reaching the surface in the expanse of the Černohorské rašeliniště and, even though no water-filled hollows were present, a slight pressure on the waterlogged ground was enough to obtain the samples of water. *Oocystis solitaria, Bambusina brebissonii, Staurodesmus omearii* and *Eunotia denticulata* were abundant species in the central lakelet.

The algal flora of Úpské rašeliniště partially resembled the unforested part of Černohorské rašeliniště, but it was more uniform. *Chroococcus subnudus, C. turgidus, Frustulia rhomboides, Pinnularia rupestris, Eunotia paludosa, Oocystis solitaria* and *Bambusina brebissonii* occurred in most of the examined pools. Other frequent taxa were *Oedogonium* sp., *Binuclearia tectorum, Microspora* sp. div., *Phacomyxa sphagnicola, Actinotaenium cucurbita, Netrium digitus, Staurastrum aciculiferum, S. hirsutum* var. *muricatum, S. margaritaceum, Staurodesmus extensus,* and *S. omearii*.

The richest algal flora was found in the Pančavské rašeliniště peatbog. In particular, the diversity of diatoms and desmids was significantly higher than in the two previous mires. Nevertheless, many taxa found only in Pančavské rašeliniště during this study have been reported also from Úpské rašeliniště or the pools in its vicinity (NOVÁKOVÁ 2002, NOVÁKOVÁ in prep.). However, *Cyanothece aeruginosa, Rhabdogloea linearis, Anomoeoneis serians, Closterium nilssonii, Cosmarium pseudopyramidatum, C. ralfsii, Staurastrum orbiculare,* and *Teilingia granulata* seem to occur exclusively in the Pančavské rašeliniště mire.

Of 116 taxa of cyanobacteria and algae found during this research, 44 taxa were observed in all the investigated bogs. *Cylindrocystis brebissonii, Frustulia rhomboides, Pinnularia rupestris, Cryptomonas* sp. div., *Mougeotia* sp. div. steril., *Staurastrum hirsutum* var. *muricatum,* and *Chroococcus subnudus* occurred most frequently.

Many species occurring in both subalpine mires were not observed in samples from the Černohorské rašeliniště peatbog. As they were found only in the pools with higher pH in Úpské rašeliniště, it was not the location in montane zone but the low pH values what may have prevented their occurrence in Černohorské rašeliniště. On the contrary, acidophilic species *Staurastrum aciculiferum* was found only in Úpské rašeliniště and Černohorské rašeliniště. The occurrence of *Tetmemorus laevis* and *Pinnularia subcapitata* in Pančavské rašeliniště and Černohorské rašeliniště, and their absence in Úpské rašeliniště still cannot be explained. Previous records of *P. subcapitata* from the Úpské rašeliniště peatbog (NOVÁKOVÁ 2002) were recently re-determined according to KRAMMER (2000) as *P.* cf. *subinterrupta*.

DCA (Fig. 1) displayed the distribution of samples along the first ordination axis, following the gradient: Černohorské rašeliniště – Úpské rašeliniště – Pančavské rašeliniště, but the composition of the algal flora seemed to change fluently along this gradient, the samples from Úpské rašeliniště being scattered in between the samples from two outer peat bogs. However, in CCA (Fig. 2) the first ordination axis separated samples from Pančavské rašeliniště and the second axis split Černohorské rašeliniště and Úpské rašeliniště, which means the algal flora of the Pančavské rašeliniště peatbog diverged from the other two mires more than they differed each other.

The first ordination axis in the DCA diagram apparently correlated with pH. Nevertheless, as only three peatbogs were sampled, it cannot be simply concluded that pH was most the important factor influencing the algal flora. The measured chemical variables differed significantly between the mires (for pH $F_{2,32} = 63.95$, $p < 0.0001$; for conductivity $F_{2,32} = 11.77$, $p = 0.00015$), and there could have been also other variables differentiating the examined mires. Therefore, the distinctness of the mires was eliminated and the effects on the algal flora were studied only within a mire in the following analyses.

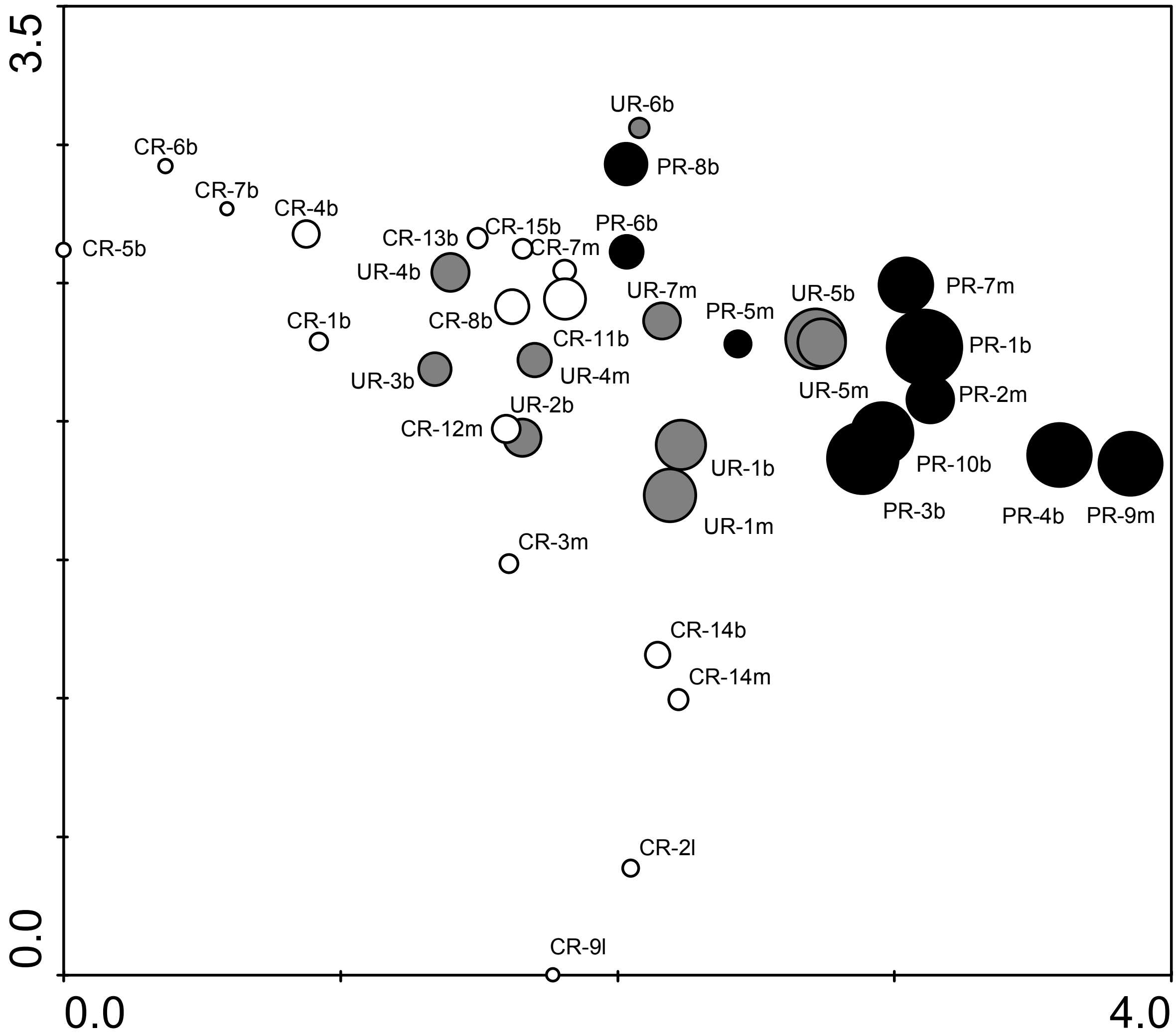

Fig. 1: The results of DCA in ordination space of first two axes. (The size of symbols correlates with the species richness in the samples. White = Černohorské rašeliniště, grey = Úpské rašeliniště, black = Pančavské rašeliniště.)

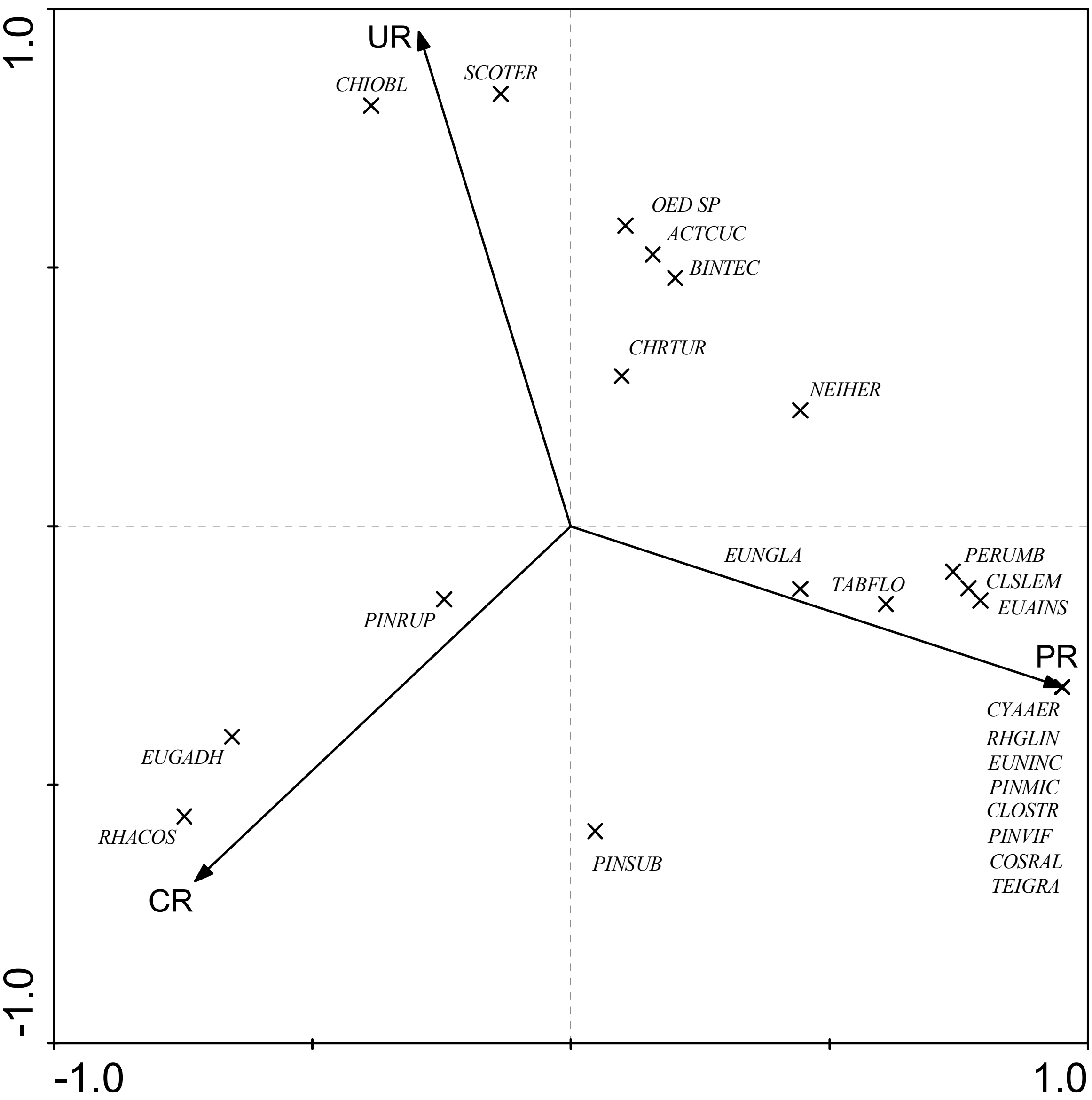

Fig. 2: CCA based on the location of samples in the particular mire. (Only well-fitting species depicted. ACTCUC - *Actinotaenium cucurbita,* BINTEC - *Binuclearia tectorum,* CLOSTR - *Closterium striolatum,* CLSLEM - *Closteriospira lemanensis,* COSRAL - *Cosmarium ralfsii,* CYAAER - *Cyanothece aeruginosa,* EUAINS - *Euastrum insigne,* EUGADH - *Euglena adhaerens,* EUNGLA - *Eunotia glacialis,* EUNINC - *E. incisa,* CHIOBL - *Chilomonas oblonga,* CHRTUR - *Chroococcus turgidus,* NEIHER - *Neidium hercynicum,* OED SP - *Oedogonium* sp., PERUMB - *Peridinium umbonatum,* PINMIC - *Pinnularia microstauron,* PINRUP - *P. rupestris,* PINSUB - *P. subcapitata,* PINVIF - *P. viridiformis,* RHACOS - *Rhabdomonas costata,* RHGLIN - *Rhabdogloea linearis,* SCOTER - *Scotiellopsis terrestris,* TABFLO - *Tabellaria flocculosa,* TEIGRA - *Teilingia granulata.*)

Although the dependence of the species richness on physico-chemical variables is significant for all samples, in individual mires only the results for pH in Pančavské rašeliniště and for conductivity in Úpské rašeliniště were significant at α level = 0.05 (Fig. 3, Table 3).

In partial CCA (unfigured) the highest variation was, surprisingly, caused by the remoteness of two "lawn" samples from Černohorské rašeliniště. Their algal flora was too distinct to be compared with other samples; therefore, they were excluded from the following analysis.

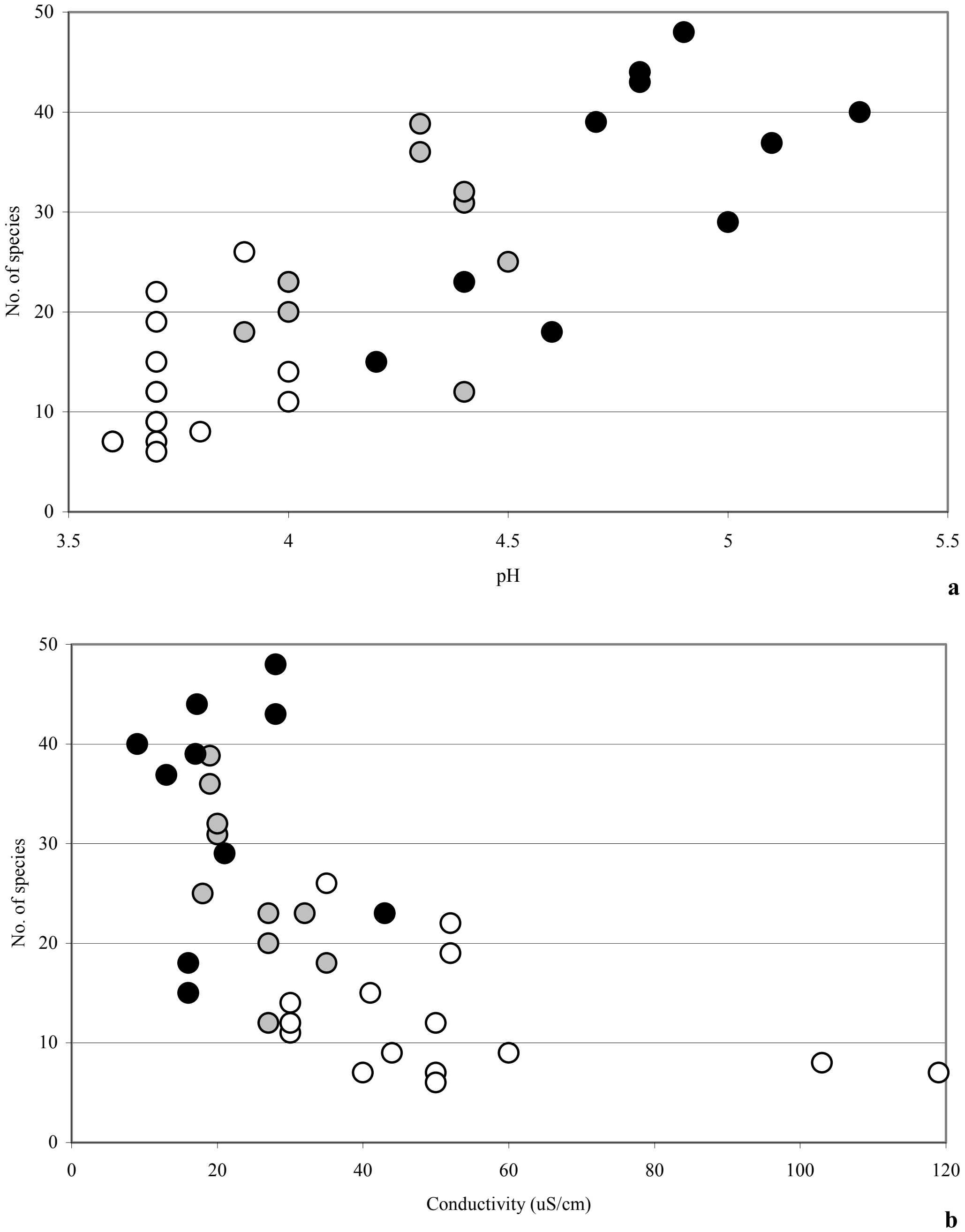

Fig. 3: Correlation of the numbers of species per sample and the measured environmental variables: a – pH, b – conductivity. (Symbols of localities : white = CR, grey = UR, black = PR.)

Table 3: The results of regression for the number of species and the measured environmental variables.

	pH		Conductivity	
	R^2	p	R^2	p
Total	0.811	< 0.0001	0.589	0.0002
CR	0.336	0.221	0.349	0.203
UR	0.371	0.291	0.725	0.018
PR	0.669	0.035	0.061	0.867

In contrast to the species richness, the species composition was proved to be in relation with pH even after the suppression of the effect of differences between the mires (Fig. 4). Correlation between scores of the samples along the first ordination axis and pH was statistically significant ($R^2 = 0.151$, $p = 0.026$). Further, CCA well differentiated the samples according to the type of microbiotope. Only the metaphytic sample PR-5m was placed among the benthic samples. *Warnstorfia fluitans* was squeezed in this sample while other metaphytic samples were obtained by squeezing *Sphagnum*, which seems to provide more preferable environment for many species (HINGLEY 1999).

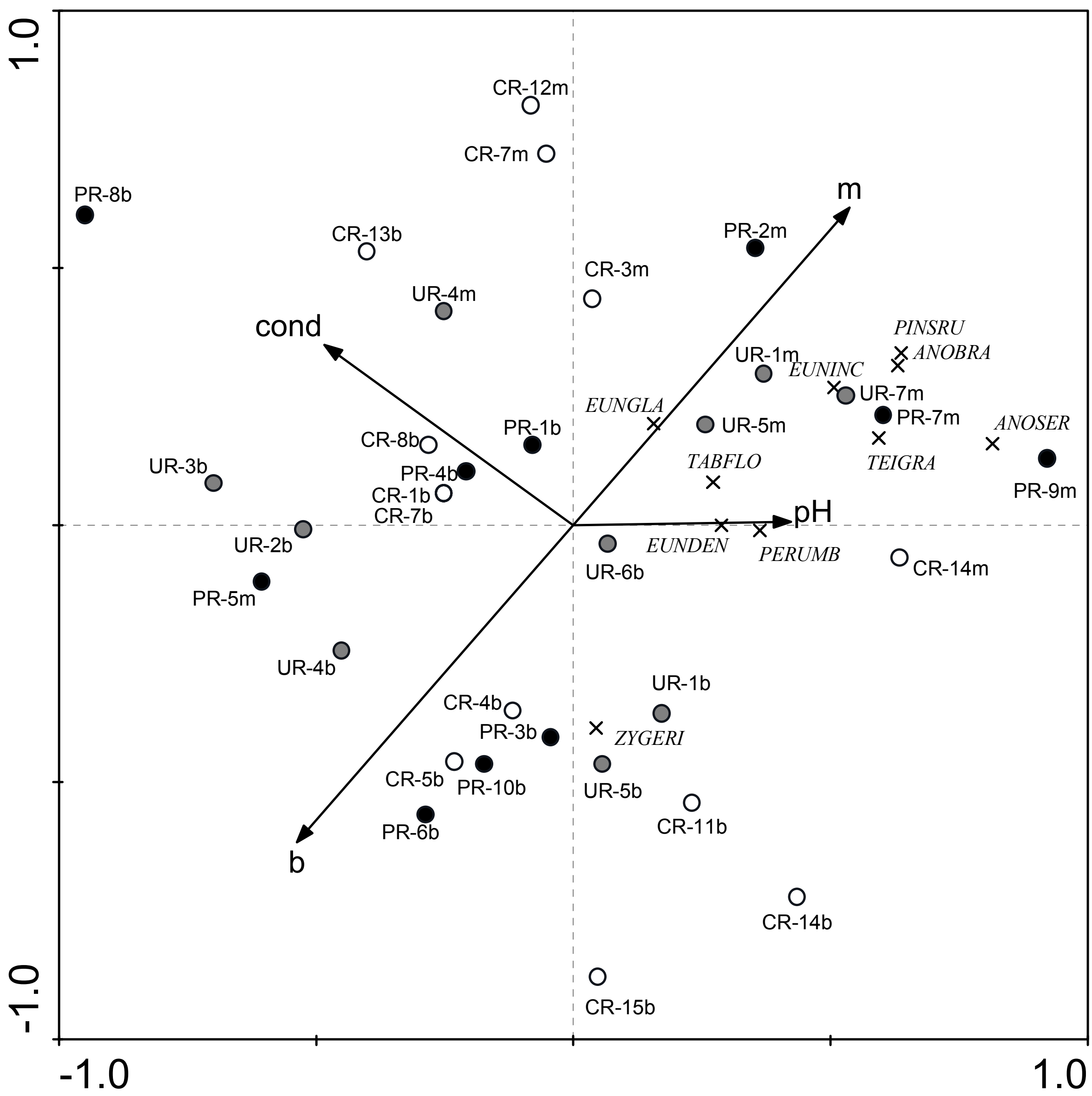

Fig. 4: Partial CCA based on microhabitat and chemical environmental variables, with location in the particular mire as covariable. (Localities: white = CR, grey = UR, black = PR. Environmental variables: pH, cond = conductivity, b = benthos, m = metaphyton. Only well-fitting species depicted. ANOBRA - *Anomoeoneis brachysira,* ANOSER - *Anomoeoneis serians,* EUNDEN - *Eunotia denticulata,* EUNGLA - *E. glacialis,* EUNINC - *E. incisa,* PERUMB - *Peridinium umbonatum,* PINSRU - *Pinnularia subrupestris,* TABFLO - *Tabellaria flocculosa,* TEIGRA - *Teilingia granulata*, ZYGERI - *Zygogonium ericetorum.*)

HADAČ & VÁŇA (1968) stated that the vegetation of vascular plants and mosses in Černohorské rašelniště was poorer than in the mires in higher altitudes due to less diversified microrelief without erosion structures, such as flarks and strings. Although the algal flora of Černohorské rašeliniště was poorer in comparison with two subalpine mires as well, the variation between the sites was the highest one (the lowest values of Sørensen's indices of similarity in Tab. 2). This variation was partially caused by small numbers of taxa in samples, but it was also influenced by the diversity of water microbiotopes. The lawn sites and shaded pools under the canopy of trees were not observed in the other two mires during this study.

The last statement leads to the speculation whether shading can be considered a feature characteristic for montane mires. Nevertheless, shaded pools, hidden underneath dwarf-pine shrubs, were occasionally found in the subalpine zone during the previous research and they had similar, poor algal flora consisting of cryptophytes, euglenophytes, diatoms, and chlorophytes (NOVÁKOVÁ 2002).

With regard to the presented results, the hypothesis of the exceptionality of algal flora in the subalpine mires and their distinctness from the montane mires is to be rejected. The algal flora is influenced rather by local environmental conditions than by altitude. More diversified sets of samples from more peatbogs are necessary to get a sufficient reply, which environmental variables are responsible for the diversity of algae in the mires and among them.

Acknowledgement

This study was supported by the Czech Ministry of Education research project No. J13/98113100004 and by the Czech Ministry of Environment grant No. 610/3/00.

I am grateful to RNDr. Jiří Neustupa, Ph.D. and the students participating in the phycological excursion to the Krkonoše Mts for their help in the field, and to RNDr. Zuzana Münzbergová, Ph.D. for her help with statistical methods.

References

DOHNAL, Z. (ed.) (1965): Československá rašeliniště a slatiniště. – 336pp., Naklad. ČSAV, Praha.

HADAČ, E. & VÁŇA, J. (1968): Příspěvek k poznání rašelinných rostlinných společenstev Východních Krkonoš. – Opera Corcontica 5: 157-173.

HINGLEY, M. (1999): Microscopic life in *Sphagnum*, with an exploration of associated epiphytes and endophytes. – Quekett J. Microsc. 38: 275-284.

JENÍK, J. & SOUKUPOVÁ, L. (1992): Microtopography of subalpine mires in the Krkonoše Mountains, the Sudets. – Preslia 64: 313-326.

KRAMMER, K. (2000): The genus *Pinnularia*. – 703 pp., in: LANGE-BERTALOT H. (ed.): Diatoms of Europe, A.R.G. Gantner Verlag, Ruggell.

NOVÁKOVÁ, S. (2002): Algal flora of subalpine peat bog pools in the Krkonoše Mts. – Preslia 74: 45-56.

NOVÁKOVÁ, S. (in prep.): Structure and dynamics of the algal flora in subalpine mires in the Krkonoše Mts (Giant Mountains; Czech Republic).

OČADLÍK, J. & FUKSA, V. (1968): Topografie rašelinišť krkonošského národního parku.-Opera Corcontica 5: 53-81.

PACLTOVÁ, B. (1957): Rašeliny na Černé hoře a dějiny lesa ve východních Krkonoších. – Ochrana přírody 12: 65-83.

RUDOLPH, K. & FIRBAS, F. (1927): Paläofloristische und stratigrafische Untersuchung böhmischer Moore. III. Die Moore des Riesengebirges. – Beih. bot. Zbl. 43: 69-114.

SOUKUPOVÁ, L., KOCIÁNOVÁ, M., JENÍK, J. & SEKYRA, J. (eds.) (1995): Arctic-alpine tundra in the Krkonoše, the Sudetes. – Opera Corcontica 32: 5-88.

TER BRAAK, C. J. F. & ŠMILAUER, P. (1998): CANOCO references manual and user's guide to Canoco for Windows. Software for Canonical Community Ordination (version 4). – 352 pp., CPRO-DLO, Wageningen.

VANĚK, J. (ed.) (2004): Komplexní analýza dlouhodobých změn krkonošské tundry. Ms.: Zpráva projektu MŽP VaV/610/3/00, depon. in MŽP Praha and Správa KRNAP, Vrchlabí.