Preslia 96: 209–221, 2024
doi: 10.23855/preslia.2024.209

Preslia

Effects of summer desiccation on desmid microflora of ombrogenous pools in central-European mountain peat bogs

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Abstract: Seasonal desiccation of ombrogenous pools caused by high summer temperatures and changing precipitation patterns is a consequence of ongoing climate change in central-European peat bogs. This phenomenon may be a critical stress factor for the microphytobenthos that thrive in these shallow aquatic habitats. One of the abundant groups in the phytobenthos of ombrogenous bog pools are desmids, a lineage of streptophyte algae closely related to vascular plants. In this study, we tested whether the assemblages of these microalgae are affected by differential desiccation of pools in three mountain bogs in the Ore Mountains (Czech Republic). In addition to the dynamics of species composition, the study focused on analysing the desmid-based NCV (nature conservation value) index to assess the conservation value of individual sites. The gradient of studied pools ranged from those found to be dried out in all field surveys during the summer to those constantly flooded. The varying desiccation rate of pools was closely related to their depth. The shallower pools with higher desiccation rates had slightly lower pH and higher concentrations of dissolved organic carbon, total nitrogen and Pb. However, virtually all pools were highly acidic, with a pH below 4.0. The most frequently detected species were *Actinotaenium silvae-nigrae* and *Staurastrum margaritaceum*, which occurred at most sites. Conversely, the more sensitive taxa, such as *Cosmarium pygmaeum*, *C. sphagnicolum* or *S. scabrum*, which have high indication values for the calculation of the NCV index, were also found in several pools. The desiccation rate was significantly related to the species composition. In addition, the NCV index values of pools with higher desiccation rates were lower compared to pools with a more stable hydrological regime. In particular, *Tetmemorus laevis*, *S. hirsutum*, and *S. furcatum* var. *aciculiferum* were more likely to occur at sites that did not dry out completely during the summer season. These species can therefore be considered as indicators of bogs with relatively low rates of seasonal desiccation. Conversely, *Cosmarium obliquum* was the only species that preferred pools with a longer desiccation period. The study showed that hydrological fluctuation represents a key environmental factor for desmid phytobenthos in ombrogenous bog pools. As the frequency of extreme climate fluctuations increases, desiccation events in central-European bogs are likely to occur more frequently and last longer. The study has shown that this environmental disturbance is likely to lead to significant shifts in the peat bog microflora.

Keywords: *Desmidiales*, NCV index, peat bogs, phytobenthos, *Zygnematophyceae*

Received: 10 Mar 2024; Revised: 17 May 2024; Accepted: 18 May 2024; Published: 18 Jun 2024

Introduction

Ombrogenous bogs are among the wetlands that are perhaps most affected by ongoing climate change. This is because their water supply is determined by the dynamics of precipitation and evapotranspiration. Changes in the frequency and amount of precipitation as well as summer temperature extremes that lead to high evaporation can significantly reduce the water level in these ecosystems (Breeuwer et al. 2009). At the same time, fluctuations in water table are a key factor driving the structure of natural communities in ombrogenous bogs (Wheeler & Proctor 2000, Turetsky & Louis 2006).

The aquatic microhabitats in these wetlands typically consist of shallow, highly acidic pools in the central areas of individual bogs. A drop in the water table caused by meteorological fluctuations during the vegetative season can lead to partial or complete desiccation of these localities, considerably altering the ecological conditions for benthic organisms such as microalgae, which form the microphytobenthos of peat bog pools. In addition to the obvious desiccation stress for free-living unicellular organisms, this temporary summer desiccation also leads to relatively abrupt changes in the abiotic characteristics of benthic microhabitats caused by peat mineralization, resulting in higher nutrient availability (Hájková et al. 2011) and facilitation of heavy metals from the sediments (Rothwell et al. 2005, Shuttleworth et al. 2017). In bog areas affected by the pulse of anthropogenic acidification in the second half of the 20th century, increased desiccation can also lead to a temporary amplification of this negative effect due to the mineralization of reduced sulphur compounds deposited in the surface sediment of the peat as a result of past industrial immissions (Van Dam & Meesters 2021). Consequently, these factors tend to accentuate the extreme abiotic conditions of bog microhabitats.

Ombrogenous bogs in central Europe, such as in the Ore Mountains (Krušné hory) of the Czech Republic, represent marginal habitats that are distributed close to their natural environmental limits, especially with regard to the combination of precipitation and evapotranspiration (Čížková et al. 2013). However, aquatic habitats in these bogs are currently subject to significant environmental fluctuations related to ongoing climate change (Breeuwer et al. 2009). Typically, individual pools reach their maximum depth and water volume after the snowmelt in the spring. During the summer season, however, they often dry out completely, as high-temperature peaks and changes in the distribution of precipitation lead to pronounced dry periods (Neustupa et al. 2023). With the drop in temperature and the associated lower evaporation at the end of the vegetative season, they are usually rewetted. However, the occurrence and length of the summer drying period can vary considerably among different pools, even within the same bog system, which is probably related to their varying water column levels.

In addition, these mountainous bogs underwent a period of intense acidification in the second half of the 20th century due to the combustion of sulphur-rich lignite in nearby thermal power plants, which led to increased acidic immissions and a drop in the pH value of the aquatic microhabitats below 4.0. Due to these acidic immissions, organic humic and fulvic acid anions were gradually replaced by inorganic SO_4^{2-} anions in the surface waters (Hruška et al. 1996). Although this acidification pulse has subsided for the most part in the central-European region, the acidity of these sites is still largely driven by sulphate anions, and the pH of aquatic sites remains extremely low (Garmo et al. 2014). In addition, the ongoing acidification of aquatic habitats is also accentuated by their more frequent seasonal desiccation, leading to the mineralization of reduced sulphur compounds in the organosolic sediment and an associated drop in pH (Van Dam & Meesters 2021). All these processes now lead to complex stress effects that can reduce the biotic complexity of these ecosystems, which represent one of the ecological hotspots of ongoing global change. At the same time, it has been shown that microorganisms in wetland ecosystems tend to respond faster to environmental stress than macroorganisms (Hájek et al. 2014). Some important groups of peatland microbenthos, such as desmids, testate amoebae or diatoms, are therefore important bioindicators that illustrate ecological dynamics or disturbance at individual important localities (Neustupa et al. 2013, 2023, Poulíčková et al. 2013, Łuców et al. 2022). Interestingly, it has been shown that changes in the communities of these eukaryotic microorganisms that thrive in the aquatic microhabitats of peat bogs and fens are also related to water table dynamics and substrate moisture in different sites (Mataloni 1999, Poulíčková et al. 2004, Lamentowicz et al. 2010, Hájek et al. 2011). Since differences in seasonal desiccation rates of individual pools in central-European mountainous ombrogenous bogs could be a key factor for understanding their biotic variability, this study focused on their comparison within three bog systems in the Ore Mts in the Czech Republic. The aim was to show the effects of seasonal desiccation on benthic microalgae inhabiting these extreme environments. The study was based on the species composition of desmids, a group of streptophyte green algae that typically form one of the dominant components in the microphytobenthos of bog pools (Coesel 1982). In addition to community structure analyses, the study used the NCV (nature conservation value) index, a desmid-based biotic parameter, to assess differences among individual sites (Coesel 2001, Neustupa et al. 2011, Capmourteres & Anand 2016).

In particular, the study aimed to answer the following questions: (i) Is there a relationship between the species structure of desmid microphytobenthos and the intensity of summer desiccation in individual bog pools? (ii) Which species, if any, can be identified as indicators sensitive to prolonged desiccation? (iii) How does the intensity of seasonal desiccation affect the conservation value of individual pools and, more broadly, of entire bog systems? By addressing these questions, we aimed to detect the impacts of ongoing climate change in mountainous bogs and predict changes in the biotic composition of desmid assemblages as the ecological stability of these ecosystems declines.

Material and methods

Sampling and identification

The sampling sites were selected in three bogs located on a levelled mountainous plateau in the Ore Mts (Czech Republic) at an altitude of 830–895 m a.s.l. (Fig. 1). A total of 30 pools (10 from each bog) were analysed between April and November 2023 (Supplementary Table S1). At each site, a square of 25 × 25 cm was selected in the deepest part of each analysed pool. In April 2023, epipelon was sampled from the uppermost 0.5 cm sediment layer using a 50 ml plastic syringe. In addition, metaphytic microalgae were collected by squeezing submerged mosses and macrophytes.

In the second half of April 2023, about three weeks after the snow cover melted, water depth was measured at each site. The water samples were then taken on May 16–19 for

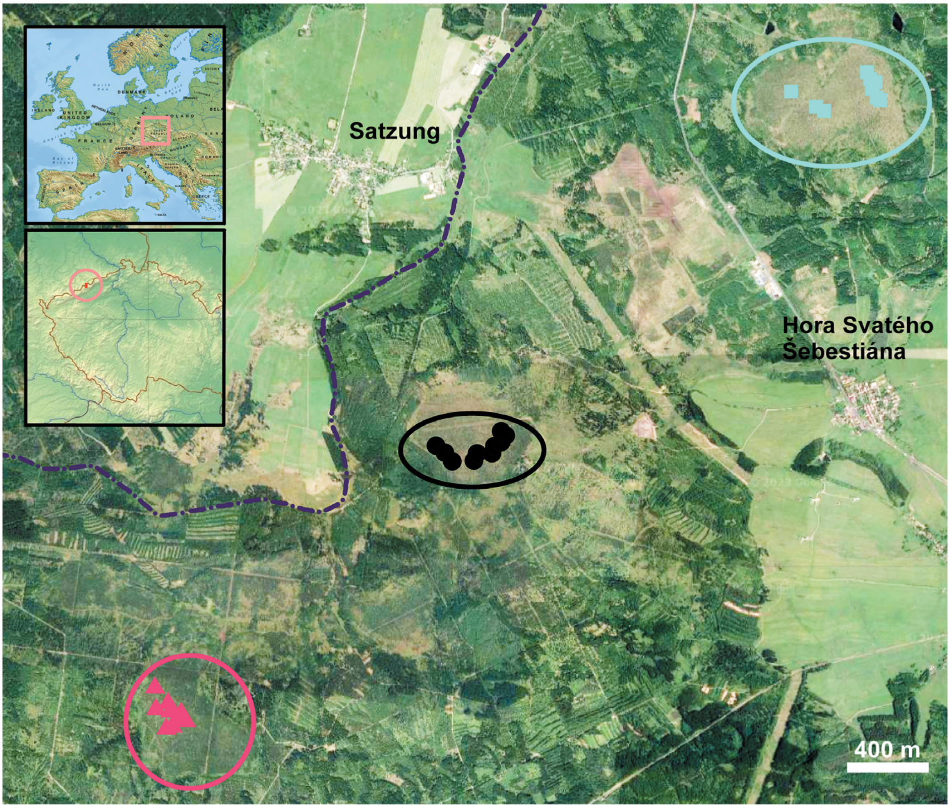

Fig. 1. Location of three investigated bogs in the study area. Maps of Europe and the western part of the Czech Republic show the wider location of the study area. Colors and symbols correspond to the delimitation of individual bogs (A – blue squares, B – black circles, C – red triangles). Scale bar = 400 m.

the analysis of abiotic factors. The height of the water level was recorded four times at each site during the vegetative season (Supplementary Table S1). During the last observation in November 2023, microphytobenthos samples were again collected for species composition analysis. Electrical conductivity and water pH were measured with a WTW 340i pH/conductivity meter (WTW GmbH, Weilheim, Germany) immediately before sampling in the field. Hydrochemistry of the pools was analysed within 24 hours after sampling in the laboratory of the Vltava River Basin State Enterprise from filtered water stored in collection tubes. Dissolved organic carbon (DOC) was measured by thermal decomposition with a platinum cathode, total nitrogen (total N) was measured by thermal oxidation with electrochemical detection, and inductively coupled plasma mass spectrometry (IPC-MS) was used to analyse total phosphorus (total P), magnesium (Mg), calcium (Ca), copper (Cu), zinc (Zn), and lead (Pb).

The desiccation rate of each site was expressed as the number of separate visits to individual sites associated with the measurement of their depth where the locality was found to be dried out during the season. This means that the bottom of the pool was completely dry, with no free water or water-saturated mucilaginous biofilm. The samples of microphytobenthos were processed on the day of sampling. Each sample was examined on five microscopic slides (22 × 22 mm) at 200× magnification under brightfield illumination using a Leica DM2500 light microscope (Leica Microsystems, Wetzlar, Germany). Class-level abundances of individual desmid species were established using a semiquantitative scale: 1 = less than 5 cells (scarce); 2 = 6–50 cells (common); and 3 = more than 51 cells (dominant). Desmids were delimited as members of the monophyletic order *Desmidiales*, which includes the families *Peniaceae*, *Gonatozygaceae*, *Closteriaceae*, *Desmidiaceae*, and the genus *Netrium* (Hess et al. 2022).

Data analysis

Patterns of species composition among sites and their relation to abiotic factors were visualized using 2-D non-metric multidimensional scaling (NMDS) (Clarke 1993). The Manhattan distance measure for the semiquantitative data was used to calculate the distance matrix among sites. Prior to this analysis, abiotic factor values were standardized to zero mean and unit variance. They were then projected as vectors onto the ordination plot showing their correlation with both coordinates produced by the NMDS analysis. In addition, species loadings were also shown by projecting them onto the ordination plot.

The mutual relationships among the standardized values of the abiotic factors were evaluated by a series of linear correlation analyses. Pearson's r-coefficients and the corresponding Bonferroni corrected P-values were illustrated by a correlation plot. The effects of individual abiotic factors on the community structure of sites were quantified by a series of distance-based permutational multivariate analyses of variance (permutational MANOVA; Anderson 2017). The Euclidean distance matrix of sites was based on their scores on individual principal components yielded by the principal component analysis (PCA) of species-in-sites data. The significance of individual effects was assessed by permutation tests on the F-ratio comparing the original value with 9,999 random repetitions. The conventional significance level at $P = 0.05$ was decreased by a Bonferroni correction for multiple comparisons. The combined effects of locality (three different peat bogs) and season (spring and autumn samples) were evaluated by a two-way permutational MANOVA quantifying the seasonal variation and the differences in desmid community structure among samples from individual bogs. The significance of these effects and their interaction was evaluated by permutation tests on F-ratio with 9,999 random repetitions. In addition, these effects were visually represented by a separate 2-D NMDS analysis based on the Manhattan distance matrix of the sites with regard to their species composition.

The calculation of the desmid-based nature conservation value (NCV) index was based on species indicator values for central-European habitats published by Šťastný (2010). For each site, the total species richness and the sum of regional rarity and ecological sensitivity values of the individual taxa were obtained (Coesel 2001). To convert these taxon-specific scores into the final NCV index values for individual samples, modified tables designed for biomonitoring of acidic mountainous peatlands were used (Neustupa et al. 2023). The relationship between NCV index values and desiccation parameters was analysed by linear correlation analysis with Pearson's r-value evaluated by permutation tests with 9,999 repetitions.

The NMDS ordination analyses, PCA, linear correlation analysis and the two-way permutational MANOVA were conducted in PAST, ver. 4.10 (Hammer et al. 2001).

Permutational MANOVA models evaluating relationships between community structure and abiotic factors were performed in R, ver. 4.0.5 (R Core Team 2021), using the function adonis implemented in the vegan package, ver. 2.6–2 (Oksanen et al. 2022).

Results

All the sites investigated proved to be highly acidic aquatic habitats. Their pH varied between 3.3 and 4.1, with a median value of 3.6. The depth of the pools varied from 3 to 21 cm. The individual pool-depth values at the beginning and end of the vegetative season were strongly correlated (Pearson's r = 0.947, Fig. 2). A total of 16 pools were found to be desiccated during all surveys in the summer season (June to September). In contrast, six pools had a non-zero water column on all observations, and four other pools were found to be dried out on only one occasion (Supplementary Table S1). The depth of the pools at the beginning and end of the vegetative season was strongly negatively correlated with their desiccation rate (Fig. 2). Thus, the deeper pools dried out less frequently and for shorter periods of time. In general, shallower pools with higher desiccation rates had lower pH and relatively higher concentrations of DOC, nutrients and heavy metals, such as Pb (Supplementary Table S2, Fig. 2).

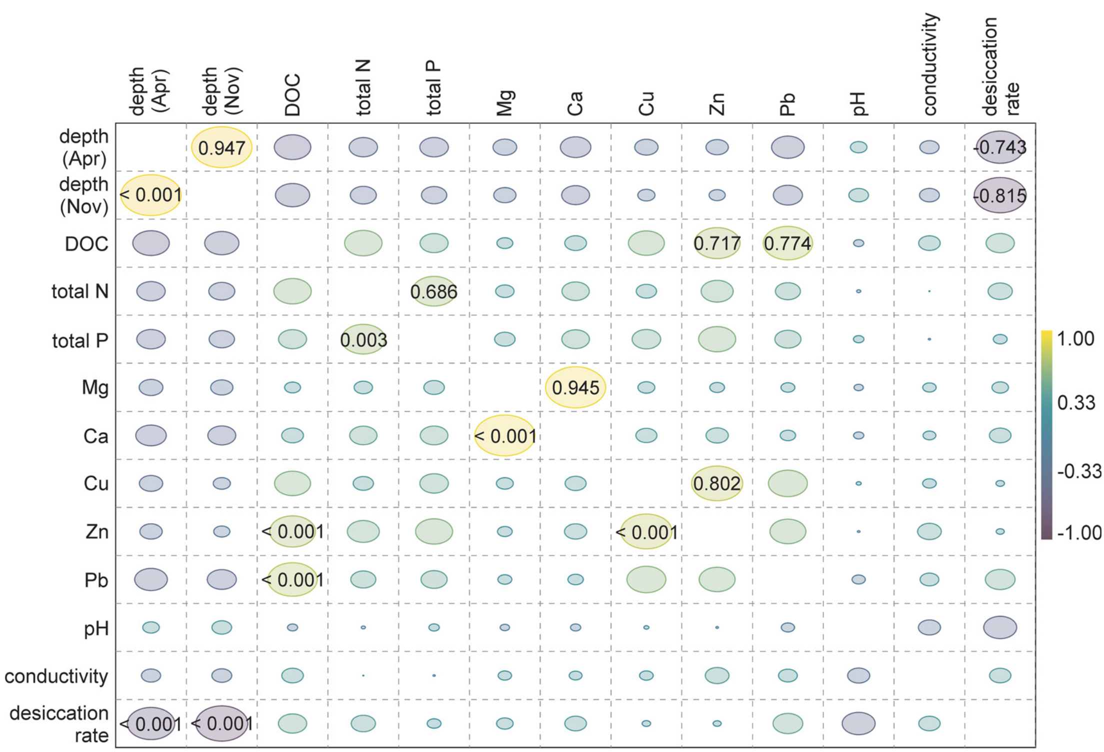

Fig. 2. Correlation plot showing Pearson's r-coefficients among tested independent factors. The size of the ellipses corresponds to the strength of the linear correlation. The positive correlation is shown in light green to yellow, and the negative correlation in blue to purple. Values of Pearson's r-coefficients (upper triangle) and corresponding Bonferroni-corrected P-values (lower triangle) are shown for significant relationships.

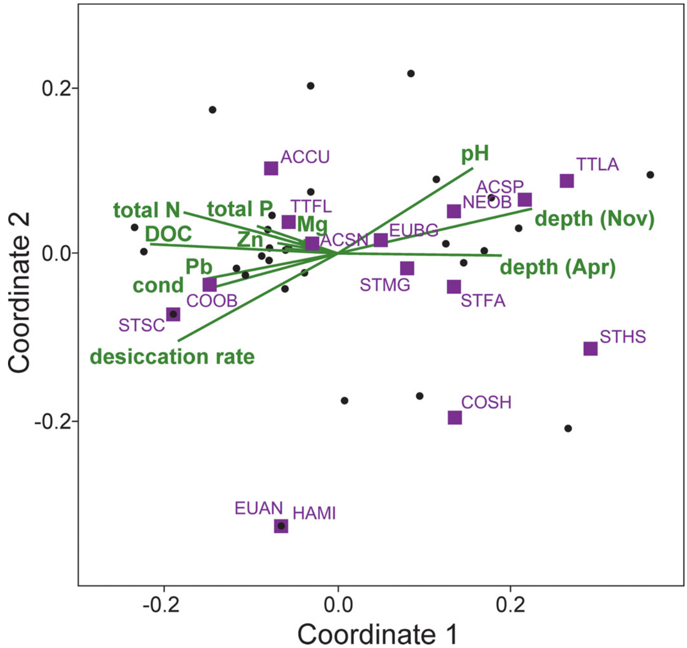

Fig. 3. NMDS ordination plot of the species-in-samples data. Positions of individual pools in the ordination space are illustrated by dots, and positions of taxa by squares. Abbreviations correspond to those included in Supplementary Table S1. Abiotic factors, such as desiccation rate, depth of pools (April and November), pH, total N and P, conductivity, DOC, Pb, Zn, and Mg, are projected as vectors onto the ordination space.

Table 1. Results of a series of multivariate linear models evaluating the effects of the independent factors on desmid community structure in samples. Total df and SS are identical for each of the separate multivariate models. Significant Bonferroni-corrected P-values lower than 0.0038 are indicated by bold font; df – degrees of freedom; SS – sums of squares; R^2 – coefficient of determination; F – ratio of variation explained by the model vs. that explained by the average value; P – probability of the null hypothesis.

Source of variation	df	SS	R^2	F	P
pH	1	22.216	0.099	2.961	0.0121
conductivity	1	13.781	0.061	1.763	0.0995
total N	1	28.524	0.127	3.923	**0.0025**
total P	1	10.077	0.045	1.267	0.2528
Pb	1	34.028	0.151	4.815	**0.0011**
Zn	1	11.262	0.050	1.424	0.1919
Cu	1	14.819	0.066	1.905	0.0850
Ca	1	7.040	0.031	0.873	0.5145
Mg	1	6.708	0.029	0.830	0.5316
DOC	1	42.022	0.187	6.207	**0.0002**
depth (Nov)	1	37.017	0.165	5.322	**0.0005**
depth (Apr)	1	33.764	0.150	4.771	**0.0009**
desiccation rate	1	31.715	0.141	4.434	**0.0013**
Total	28	224.828			

Table 2. Results of two-way permutational multivariate analysis of variance (PerMANOVA) evaluating the effects of locality and seasonal variation on desmid community structure in samples; df – degrees of freedom; SS – sums of squares; MS – mean squares; η^2 – coefficient of determination; F – ratio of variation explained by the model vs. that explained by the average value; P – probability of the null hypothesis. Significant P-values lower than 0.05 are indicated by bold font.

Sources of variation	df	SS	MS	η^2	F	P
Locality area	2	0.326	0.163	21.997	7.815	**0.0001**
Season	1	0.016	0.016	1.080	0.784	0.5179
Locality × Season	2	0.014	0.007	0.945	0.328	0.9346
Residuals	54	1.126	0.021	75.978		
Total	59	1.482				

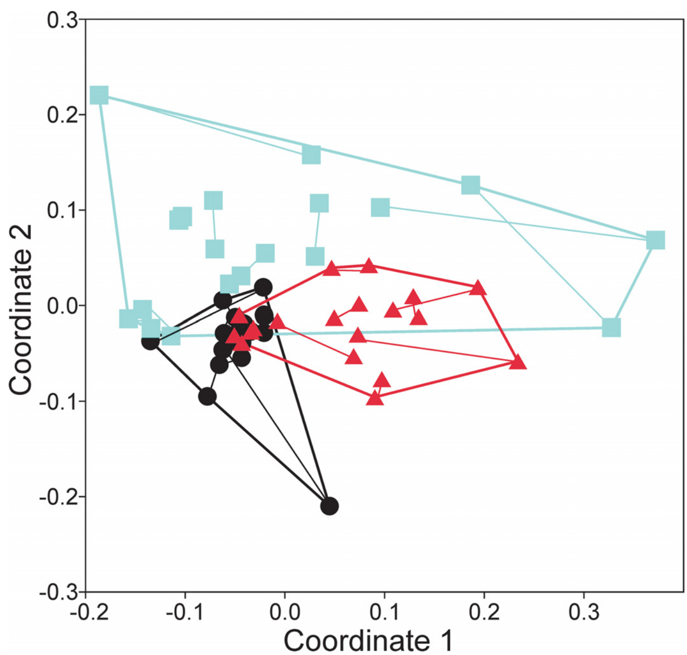

Fig. 4. NMDS ordination plot of the species-in-samples data showing data both from April and November surveys. Colors and symbols correspond to the delimitation of individual bogs (A – blue squares, B – black circles, C – red triangles). The line segments connect samples from the same pools taken in April and November.

The desmid biota of the pools consisted of 16 species (Supplementary Table S1). The most frequently detected species were *Actinotaenium silvae-nigrae* and *Staurastrum margaritaceum*, which were present in 91.7% and 75.0% of the samples, respectively. Conversely, *Euastrum ansatum*, *Haplotaenium minutum*, and *Staurastrum scabrum* were only present in one of the studied pools. The NMDS ordination analysis of the individual sites based on their species composition showed that projections of the abiotic factors were correlated mainly with the first ordination axis (Fig. 3). The directions of the individual vectors representing the abiotic factors were largely consistent with previous bivariate correlation analyses. The deeper pools had a slightly higher pH and typically contained the species *Tetmemorus laevis*, *Staurastrum hirsutum*, *S. furcatum* var. *aciculiferum,* and *Netrium oblongum*. The opposite part of the ordination area contained shallower sites with higher desiccation rates and relatively higher concentrations of DOC, nutrients and Pb. Besides *Staurastrum scabrum*, which was only found in one sample, *Cosmarium obliquum* was the only species that preferred these sites. In addition, species such as *Actinotaenium silvae-nigrae*, *A. cucurbita*, *Tetmemorus flensburgii* and *Staurastrum margaritaceum* were also typically present but were found in most of the studied pools regardless of their desiccation rate.

Six separate abiotic factors were found to be significantly related to the community structure of the sites in the multivariate linear models (Table 1). In particular, the depth of the pools in spring (April) and in autumn (November) and the closely correlated desiccation rate of pools proved to be relatively strong predictors of species composition, explaining 14.1–16.5% of their total variation. Total nitrogen, Pb, and DOC concentrations were also significantly linked to changes in desmid community structure among sites. The pools in each of the three peat bogs studied were considerably more similar to each other than expected by chance (Table 2, Fig. 4). However, the two-way permutational MANOVA did not detect any consistent seasonal variation between the April and November samples (Table 2).

The NCV index varied between 2.5 and 6.4 (Supplementary Table S2). The values were significantly related to the depth and desiccation rates of the pools. In particular, the depth of individual pools in April correlated positively with their NCV (Pearson's $r = 0.46$, $R^2 = 0.21$, $P = 0.011$). Similarly, a higher desiccation rate was related to a decrease in NCV values of the sites (Pearson's $r = -0.38$, $R^2 = 0.14$, $P = 0.039$). However, the strongest relationship between the NCV index and an abiotic factor was the negative correlation of Pb and NCV (Pearson's $r = -0.60$, $R^2 = 0.36$, $P = 0.0005$). In addition, there were significant, albeit slightly less tight, negative correlations between NCV and other heavy metals, such as Cu and Zn.

Discussion

All 16 desmid taxa found in the studied ombrogenous pools have been classified in the literature as distinctly acidophilic organisms (Coesel & Meesters 2007, Štěpánková et al. 2012). This is consistent with the extremely low pH values below 4.0 in almost all the pools surveyed. Under such conditions, free-living cells have to cope with a constant significant imbalance between the concentration of H^+ ions in the cytoplasm and the external environment (Gross 2000). In addition, the low pH at these sites means that inorganic carbon is present in the surrounding aquatic environment almost exclusively in the form of CO_2 molecules and not as HCO_3^- or CO_3^{2-} anions (Spijkerman et al. 2005, Van Dam & Meesters 2021). In almost all cases, these acidophilic species are found exclusively in this specific, extreme type of freshwater environment. At the same time, however, their occurrence in the central-European landscape is essentially linked to viable ombrogenous peatlands, where extremely low pH is maintained by physico-chemical processes during the anaerobic formation of organosols.

As shown by NMDS, correlation analyses and subsequent multivariate linear models, the dominant abiotic gradient that ordinated the natural communities of desmid phytobenthos was a differentiation between deeper pools that were less desiccated during the summer season and those with higher desiccation rates and thus positively correlated concentrations of DOC, Pb and total nitrogen. Likely, the longer duration of complete desiccation of the pools was causally related to the relatively higher concentrations of these compounds. When the peat surface becomes dry, its weathering facilitates the release of ions that were bound in the peat sediment (Hájková et al. 2011, Van Dam & Meesters 2021), and therefore their concentration may increase after the rewetting of previously desiccated pools. There was one outlier from this gradient (pool A1), where *Euastrum ansatum* and *Haplotaenium minutum* were found, which did not occur at any other site within the surveyed localities. These are rather minerotrophic species with a relatively broad ecological valence, also reported from less acidic habitats (Coesel & Meesters 2007, Neustupa et al. 2013). It is therefore likely that this particular pool, which is otherwise relatively close to the edge of its peat bog, is occasionally connected with the surrounding ditches created in the 19th and 20th centuries by peat extraction and reforestation of nearby mining areas. Comparison of the desmid communities in time and space showed that spatial differentiation among sites played a key role in their variation within the studied area. The pools within each of the three peat bogs were significantly more similar in their species composition than would have been the case with a random distribution. However, this is consistent with previous studies showing that desmid communities in the phytobenthos of acidic wetlands generally lack pronounced seasonal patterns, and their variability is mainly determined by ecological and spatial factors (Gray et al. 2022). This can most likely be explained by their environmental niches, which include extreme values of key abiotic factors such as pH and nutrients that remain relatively constant throughout the year, resulting in reduced interspecific competition and thus leading to higher temporal stability of these communities.

The extent of environmental desiccation of individual pools appeared to be a key environmental factor that was relatively closely related to changes in the species structure of the desmid microphytobenthos. In addition to the widely distributed species such as *Actinotaenium silvae-nigrae*, *Euastrum binale* var. *gutwinskii* and *Staurastrum margaritaceum*, which occurred virtually across the observed ecological gradient, several species were detected that clearly avoided prolonged desiccation of pools. These were, for example, *Staurastrum hirsutum*, *S. furcatum* var. *aciculiferum* and *Netrium oblongum*. Thus, in a one-time survey of ombrogenous bog sites, these taxa can be regarded as indicators of a relatively stable water column during the season. On the other hand, *Cosmarium obliquum* was the only species that consistently preferred sites with a prolonged dry-out period. This species, which is characterized by its unique cell symmetry that differs from all other representatives of the *Zygnematophyceae* (Van Westen & Coesel 2010), thus also represents a unique strategy within acidophilic desmids inhabiting ombrogenous bogs. It should be noted that there are no molecular phylogenetic data for this distinctive species and it is therefore possible that its unique morphological and ecological characteristics reflect the separate phylogenetic position of this taxon.

In summary, our study has shown that a prolonged desiccation period significantly affects the species composition of desmid phytobenthos in ombrogenous bog pools. Relatively shallower pools that dried out for longer periods during the summer season also typically had reduced NCV values, indicating a lower conservation value due to shifts in the species composition of the desmid microflora. These data suggest that ongoing climate change leading to changes in the water regime in central-European ombrogenous bogs may, in the future, substantially affect the biotic structure of these unique habitats comprising highly specialized acidophilic organisms that are largely restricted to this environment.

Supplementary materials

Table S1. List of species in the samples, the abiotic data of the sites and the NCV index parameters.
Table S2. Linear correlation among abiotic factors and the NCV index values of the sites.

Supplementary materials are available at www.preslia.cz

Acknowledgements

The study was funded by the Czech Science Foundation (Project No. 22-20989S). The authors thank Jan Rothanzl for his assistance in obtaining permission for the field research, which was granted by the Regional Authority of the Ústecký Region (No. KUUK/073894/21).

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Vliv letního vysychání na krásivkovou mikroflóru ombrogenních tůní ve středoevropských horských rašeliništích

V důsledku probíhajících klimatických změn dochází ve středoevropských rašeliništích k častějšímu sezónnímu vysychání ombrogenních tůní, způsobenému vysokými letními teplotami a změnami srážkových poměrů. Tento jev může představovat kritický stresový faktor pro mikrofytobentos obývající tyto mělké vodní lokality. Jednou z častých skupin fytobentosu těchto rašelinných tůní jsou desmídie (krásivky), které tvoří linii streptofytních zelených řas blízce příbuznou cévnatým rostlinám. Naše studie zjišťovala, zda jsou desmidiální společenstva v horských rašeliništích v Krušných horách ovlivněna rozdílným vysycháním jednotlivých ombrogenních tůní. Vedle dynamiky druhového složení se studie zaměřila také na analýzu tzv. NCV indexu založeného na struktuře společenstev krásivek, aby bylo možné posoudit ochranářskou hodnotu jednotlivých lokalit. Gradient studovaných tůní pokrýval škálu od těch, které byly při všech terénních průzkumech v letním období zjištěny jako vyschlé, až po ty, které byly trvale zavodněné. Různá míra vysychání úzce souvisela s hloubkou jednotlivých tůní. Mělčí tůně s vyšší mírou vysychání měly mírně nižší pH a vyšší koncentrace rozpuštěného organického uhlíku, celkového dusíku a olova. Prakticky všechny tůně však byly silně kyselé s hodnotami pH nižšími než 4,0. Nejčastěji zjištěnými druhy byly *Actinotaenium silvae-nigrae* a *Staurastrum margaritaceum*, které se vyskytovaly na většině sledovaných lokalit. Naopak citlivější taxony, jako *Cosmarium pygmaeum*, *C. sphagnicolum* či *S. scabrum* s vysokými indikačními hodnotami pro výpočet indexu NCV, byly také nalezeny v několika tůních. Míra vysychání se ukázala jako významně související s druhovým složením. Hodnoty NCV indexu tůní s vyšší mírou vysychání byly nižší ve srovnání s tůněmi se stabilnějším hydrologickým režimem. Zejména druhy *Tetmemorus laevis*, *S. hirsutum* a *S. furcatum var. aciculiferum* se častěji vyskytovaly na lokalitách, jež během letní sezóny zcela nevyschly. Tyto druhy lze tedy považovat za indikátory rašelinišť s relativně nízkou mírou sezónního vysychání. Naopak *Cosmarium obliquum* bylo jediným druhem, který zřejmě preferoval tůně s delší dobou vysychání. Studie tedy ukázala, že hydrologické výkyvy představují klíčový faktor pro fytobentos v ombrogenních rašelinných tůních. S rostoucí frekvencí extrémních klimatických výkyvů se vysychání na středoevropských rašeliništích bude pravděpodobně vyskytovat častěji a bude trvat déle. Tato environmentální změna pravděpodobně povede k významným posunům v rašeliništní mikroflóře.

How to cite: Neustupa J., Woodard K., Kulichová J. & Němcová Y. (2024) Effects of summer desiccation on desmid microflora of ombrogenous pools in central-European mountain peat bogs. – Preslia 96: 209–221.

Preslia, a journal of the Czech Botanical Society

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