Benthic algal communities and their ecology in sandstone periodically desiccated brook in National Park Bohemian Switzerland (Czech Republic)

Společenstva bentických řas a jejich ekologie v pískovcovém periodicky vysychajícím potoce v Národním parku České Švýcarsko

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Abstract

Investigated pristine forest brook with silica sandstone bedrock periodically dry out during the year. Attached algae from four different habitats (stones, stream bottom, wood and bryophytes) were collected at two sites of the brook. A total number of 48 algal taxa are identified from 24 samples. Most of the identified species are classified as flora of springs and mountain streams, oligotrophic and electrolyt poor waters, aero-terrestric habitats and sandstone or silica rich substrates. Environmental parameters and identified algal taxa with their abundancies in each sample were analysed using the linear multivariate analysis methods. The greatest variability in data set was explained by different distance of the sampling sites from the spring.

Introduction

The area of the National Park Bohemian Switzerland (NPBS) is geologically composed of nutrient poor silica sandstones with acid reaction and sparsely of volcanic rocks. Species diversity of the area is enriched with streams, but most of the stream water is absorbed by sandstone bedrock, so the most of the running waters periodically dry out during the year (HÄRTEL 2001). The algal flora of the NPBS and neighbouring areas (Elbsandsteingebirge) was investigated in peat bogs (NOVÁKOVÁ 2003), in some running waters (SKÁCELOVÁ 1998; HETEŠA et al. 2000) and on sandstone walls (SCHORLER 1914; SCHADE 1923).

Streams are different ecosystems from other surface waters. Publications of HINDÁK (1978), ETTL (1980) and LELLÁK & KUBÍČEK (1992) concentrate generally on algae in running waters. Studies of algal assemblages in lotic ecosystems, including quantitative assessments, are focused on temporal and spatial variation in species composition (DILLARD 1969; STEVENSON & HASHIM 1989; VAVILOVA & LEWIS 1999; LINDSTRØM et al. 2004), biodiversity of algae (HOLOPAINEN et al. 1988; PIIRSOO 2003), ecology of selected algal groups (ALLES et al. 1991), succesion during colonization (MÜLLER-HAECKEL & HÅKANSSON 1978; STEVENSON & PETERSON 1989), monitoring of running waters (VILBASTE 2001, WUNSAM et al. 2002) and on metabolism of periphyton communities (PRINGLE 1990; STEVENSON et al. 1996; SABATER et al. 1998).

Prezent sutdy on benthic algal communities in periodic stream focuses on question: is species composition affected more by distance from the spring, seasonal variations and/or substráte quality?

Locality

Pristine forest brook Suchá Bělá, approximately 3 km long, is situated in the western part of the National park Bohemian Switzerland. Riparian canopy is predominantly composed of beech (*Fagus sylvatica*) and spruce (*Picea abies*). Suchá Bělá rises from the foot of the basalt hill Großer Winterberg and the rest of the stream flows on the sandstone bedrock in a gorge. Brook is dependent on precipitation and therefore periodically dries out during the year.

Materials and methods

On the Suchá Bělá watercourse were selected two approximately 20 m long transects, which included pools and riffles. One near the spring (SB1; 50°53.65'N, 14°16.15'E; 450 m a.s.l.) and second at lower reaches of the stream (SB2; 50°53.34'N, 14°16.04'E; 270 m a.s.l). Distance between the sampling sites as the crow flies is 610m. Samples were taken in spring 2004 and in winter 2005, when the brook bottom was not desiccated. Stream water measurements of pH, electric conductivity and temperature are in Table 1. Attached algae were randomly collected from four different habitats: stones, stream bottom, wood and bryophytes. The level of current velocity on each habitat is expressed by means of semiquantitative scale: 0 – still water, 1 – flowing water, 2 – waterfall.

The live samples were examined within two days after sampling using the light microscope Olympus CX 31. Two samples from wood and from stream bottom (no. 7 and 14 in Table 2) were cultivated on BBM (Bold's basal medium) agar plates according to KALINA (1994). Diatoms were cleaned with hydrogen peroxide solution (KRAMMER & LANGE-BERTALOT 1986) and mounted in Naphrax.

Species were identified according to following publications: ALLES et al. (1991), ETTL & GÄRTNER (1995), HINDÁK (1996), KRAMMER (2000), KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, 1991b), LANGE-BERTALOT (1996, 2001), LENZENWEGER (1996), LOKHORST (1996), STARMACH (1972).

Algal taxa were documented by LM microphotographs using Olympus BX 51 with digital camera Olympus Camedia Digital Camera C-5050 Zoom. Diatom images in figs. 3 and 4 were taken using methods published by HOUK (2003).

The taxa frequency were estimated by a semiquantitative scale: 3 – frequent, at most two taxons; 2 – common; 1 – rare, one or two cells per slide or only specimen obtained from cultures.

Species abundances together with environmental variables (year, sampling site, temperature, pH, conductivity, habitat, current velocity) were analysed by the multivariate analysis methods in program Canoco for Windows 4.5 (TER BRAAK & ŠMILAUER 1998). Indirect and direct linear ordinations were performed - the lenght of gradient was 1.7. Principal components analysis (PCA) with species data were used for classification of samples (Fig. 1) - centered by species, not transformed. PCA only with environmental variables data show correlations of environmental parameters (Fig. 2) - centered and standardize by species, not transformed. Manual selection with the Monte Carlo permutation test assess which environmental variables have important effect on species composition – RDA, unrestricted 499 permutations under reduced model. Another redundancy analyses were not performed due to results from manual selection and insufficient amount of data.

Results

Environmental variables are presented in Table 1.

A total number of 48 algal taxa (37 Bacillariophyceae, 9 Chlorophyceae, 1 Euglenophyceae, 1 Zygnematophyceae) were identified from 24 samples (Table 2). After examination of colonies on agar plates were recorded two green algal taxa which were not found in natural samples: *Desmococcus* sp. and *Koliella* cf. *corcontica*.

Only six of the identified diatom taxa, *Caloneis bacillum* (Fig. 3/g), *Diadesmis laevissima*, *Eunotia exigua* (Fig. 4/a,b), *E. paludosa* var. *trinacria* (Fig. 4/f,g), *E. praerupta* var. *bigibba* and *Gomphonema parvulum*, were not listed as indicators of oligotrophy in the publication of LANGE-BERTALOT (1996). More than half of the diatoms with abundance values 2 or 3 (a total of 25 taxa) were found in spring or mountain streams and electrolyt poor waters (FOTT 1967; ETTL 1980; KRAMMER & LANGE-BERTALOT 1986, 1988, 1991; POULÍČKOVÁ 1998) and 36% of those taxa - *Diadesmis contenta* (3/h), *Eunotia exigua* (Fig. 4/a,b), *E. minor* (Fig. 4/d), *E. paludosa* var. *tridentula* (Fig. 4/h), *E. praerupta* var. *bigibba*, *Fragilaria virescens* (Fig. 3/d), *Navicula soehrensis*

(Fig. 3/f), *Pinnularia silvatica* (Fig. 3/a) and *Tabellaria flocculosa* - are known from sandstone or silica-rich substrates (SCHORLER 1914; KRAMMER & LANGE-BERTALOT 1986, 1988, 1991). Most of the identified algae were also found in aero-terrestric habitats (ETTL & GÄRTNER 1995).

First four ordination axes of the principal components analysis with species data explained 60.5% of variability in species composition. The first two axes in PCA ordination diagram (Fig. 1) clearly separated upstream samples from downstream samples independently on the year of sampling. In the PCA plot (Fig. 2) are evident the close correlations between environmental variables temperature, pH and year.

According to the Monte Carlo test following environmental variables were detected as significant: sampling site - variability 18%, p-value 0.002; temperature – variability 8.1%, p-value 0.012, and current – variability 6.3%, p-value 0.320.

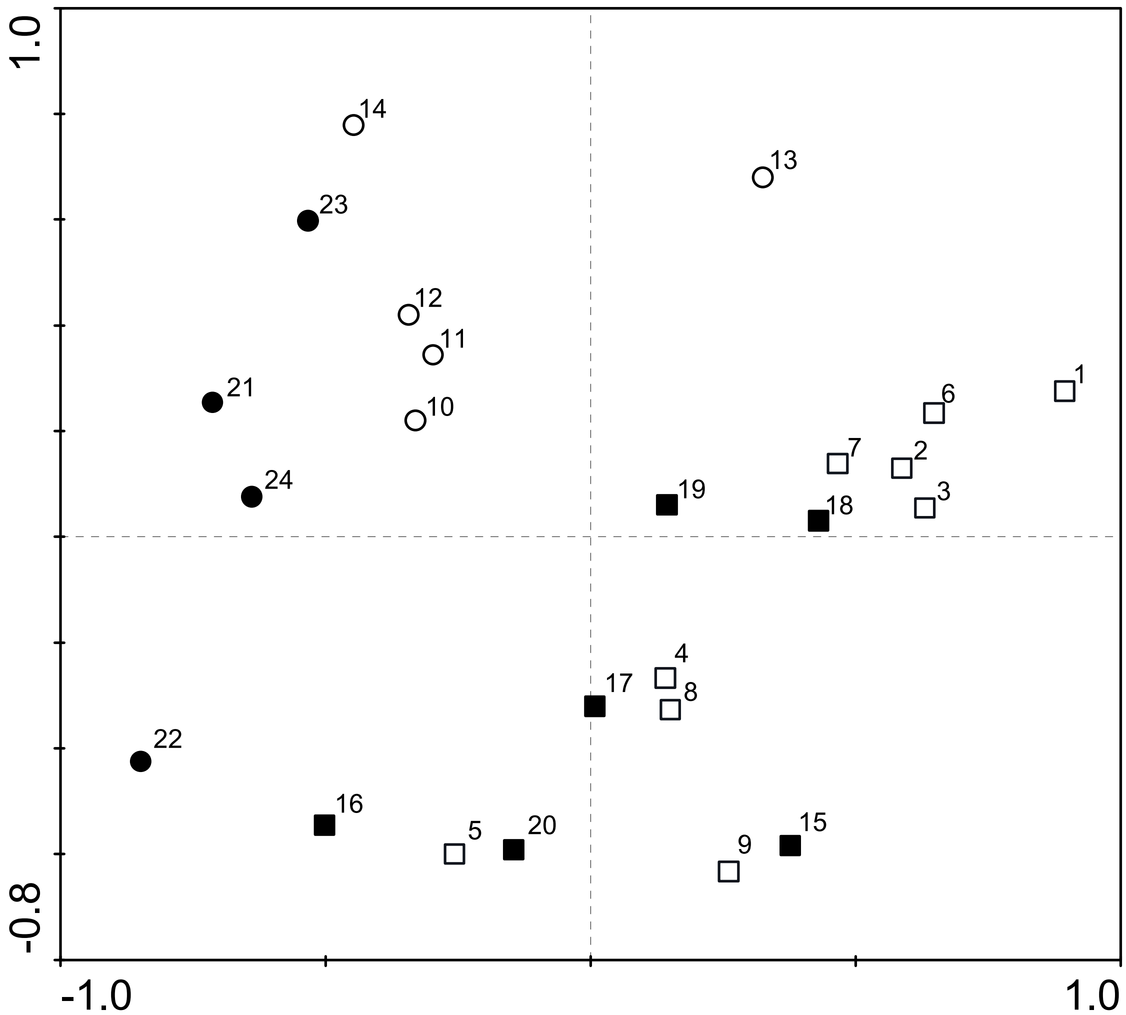

Fig. 1: PCA ordination plot of samples (species data; first axis 23%, second axis 17.6%). Open square SB1 2004, open circle SB2 2004, filled square SB1 2005, filled circle SB2 2005. sample – habitat: 1, 2, 3, 4, 10, 11, 18, 19, 23 – stone; 5, 13, 14, 15, 16, 21, 24 - stream bedrock; 6, 7, 17 – wood; 8, 9, 12, 20, 22 – bryophyte

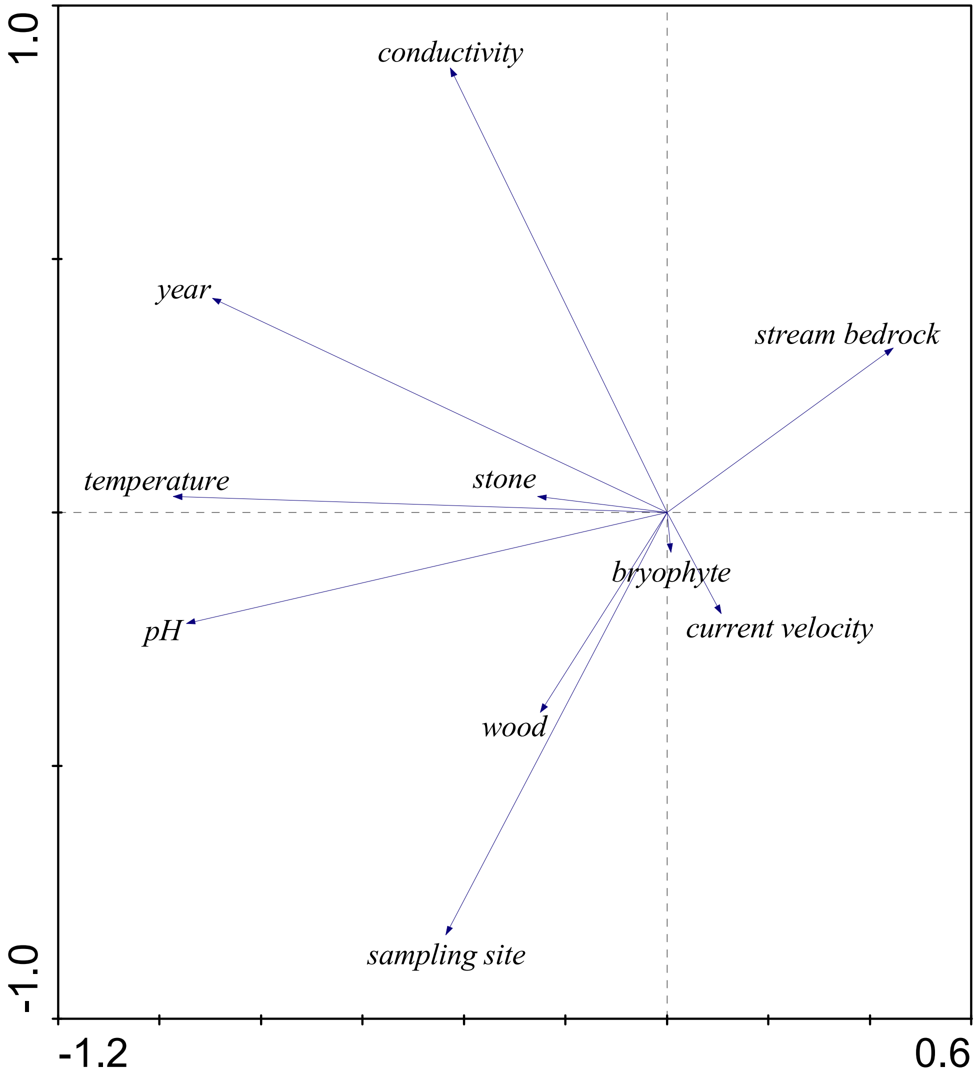

Fig. 2: PCA ordination diagram of environmental variables (environmental data).

Table 1: Measured physical-chemical parameters of stream water at sampling sites.

Sampling site	***Date***	***Temperature (°C)***	***pH***	***Conductivity ($\mu \cdot Scm^{-1}$)***
SB1	8.4.2004	5.4	5.3	80
SB1	14.1.2005	3.7	4.5	55
SB2	8.4.2004	4.5	4.6	112
SB2	14.1.2005	3.4	3.9	70

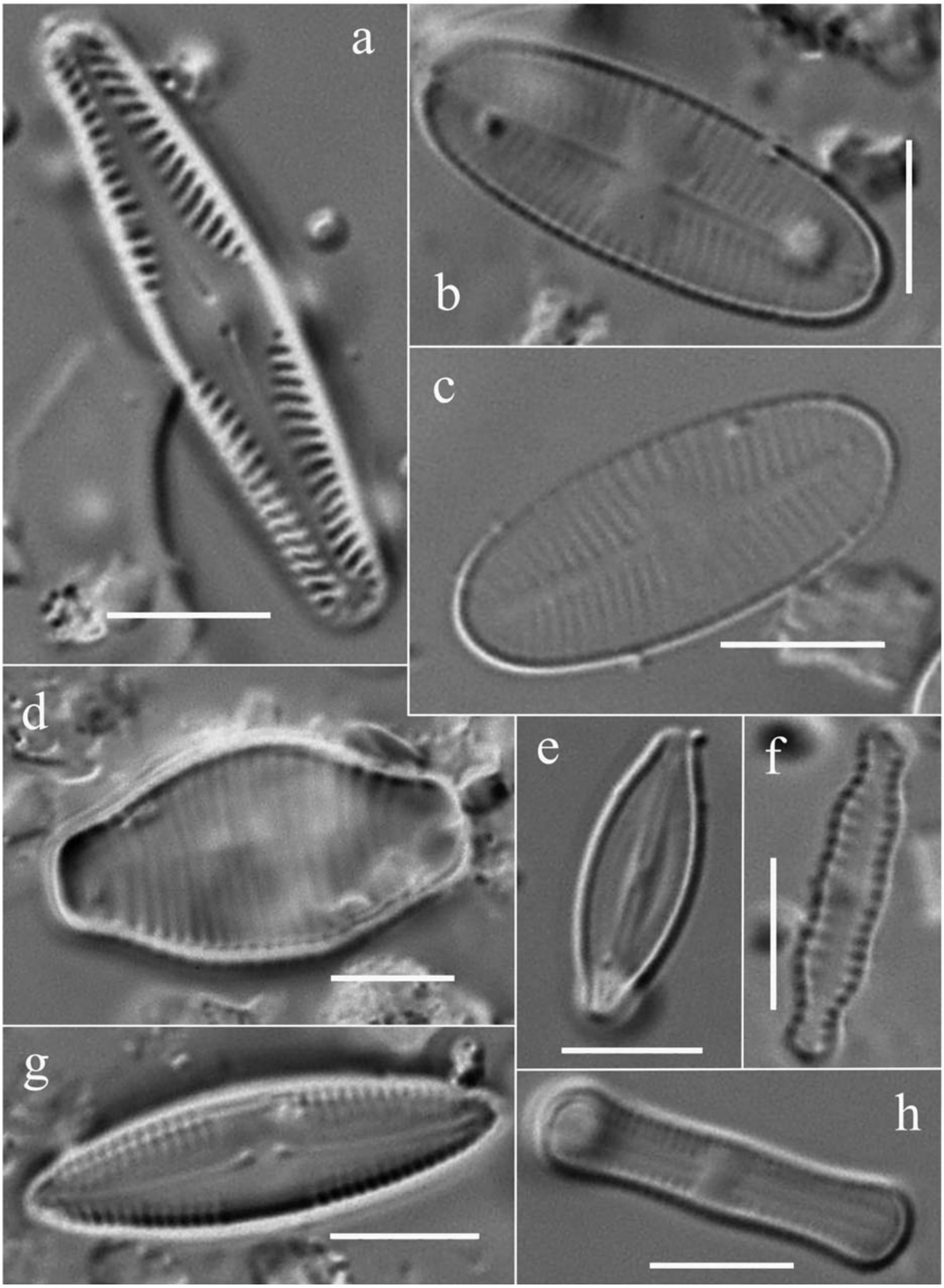

Fig. 3**:** BACILLARIOPHYCEAE: **a** *Pinnularia silvatica*, **b-c** *Achnanthes* cf. *bioretii*, **d** *Fragilaria virescens*, **e** *Navicula* cf. *minuscula* var. *minuscula*, **f** *Navicula soehrensis* var. *soehrensis*, **g** *Caloneis bacillum*, **h** *Diadesmis contenta*. Scale bar = 5µm.

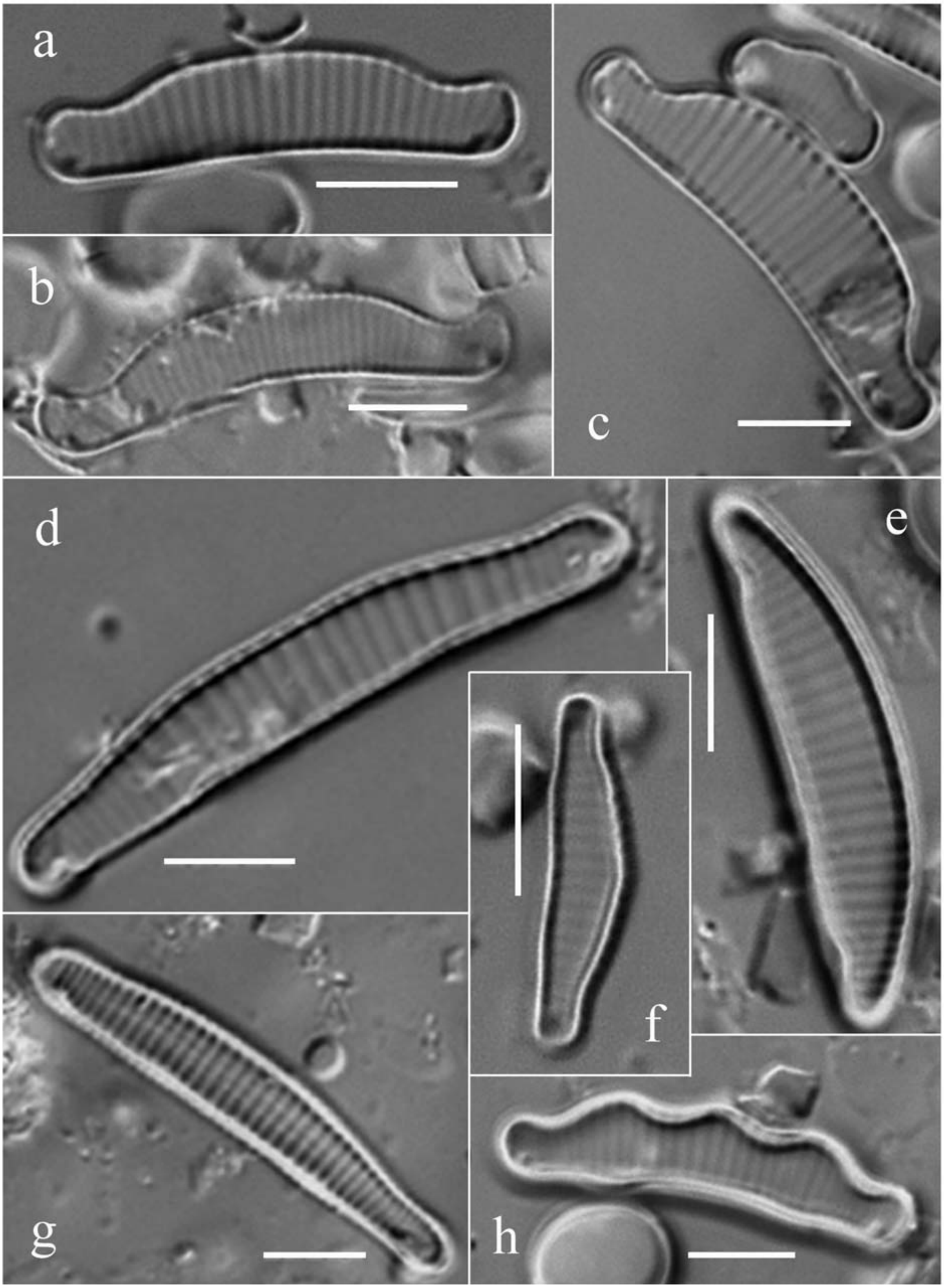

Fig. 4: BACILLARIOPHYCEAE: **a-b** *Eunotia exigua*, **c** *Eunotia septentrionalis*, **d** *Eunotia minor*, **e** *Eunotia incisa*, **f-g** *Eunotia paludosa* var. *trinacria*, **h** *Eunotia muscicola* var. *tridentula*. Scale bar = 5µm.

Discussion

The majority of taxa (77%) found in the brook Suchá Bělá belongs to Bacillariophyceae. Diatoms were the most diverse group of algae in published studies of running waters (HOLOPAINEN et al. 1988; PRINGLE 1990; SABATER et al. 1998; PIIRSOO 2003). The estimation of quantity of identified diatom taxa (Tab. 1) coincides with research of VILBASTE (2001), who observed a small number of species with high abundance and a large number of rare or sporadic taxa. More than half of the diatoms are characteristic species in springs or mountain streams, in water with low electrolyt content, and in oligotrophic habitats (FOTT 1967; ETTL 1980; KRAMMER & LANGE-BERTALOT 1986, 1988, 1991; LANGE-BERTALOT 1996; POULÍČKOVÁ 1998). Nine predominant or common diatom species which are known from sandstone or silica rich substrates (SCHORLER 1914; KRAMMER & LANGE-BERTALOT 1986, 1988, 1991), proved the dependence on geological bedrock (MÖLDER 1964, HOLOPAINEN et al.1988). Some *Eunotia* species are restricted to environments with naturally acid reaction (without anthropogenic acidification; ALLES et al. 1991).

The periodicity of desiccation of the stream bedrock bears also a very important effect on algal flora. 76% of identified algae were found in aero-terrestrial habitats (ETTL & GÄRTNER 1995). Algae can withstand dry periods in moist mosses (ALLES et al.1991), in isolated pools (LELLÁK & KUBÍČEK 1992), due to infiltration into the stream bedrock (POULÍČKOVÁ 1998) or they have specialised desiccation-resistant thallus (HINDÁK 1978).

The PCA diagram demonstrated (Fig. 1) the spatial variability in algal assemblages within and between sampling sites. In addition, the greatest variability in data set was explained by sampling sites. Substantial influence of spatial variability on benthic algal communities was stated in surveys of DILLARD (1969) and LINDSTRØM et al. (2004).

Results from multivariate statistical methods - PCA (Fig. 1), permutation test - proved the seasonal variation in species composition as insignificant. This is probably caused by considerable differences between samples within and between sampling sites. A longterm study of LINDSTRØM et al. (2004) shows strong seasonal variation (within a year) but high temporal stability (during 12 years) of periphyton communities, except diatoms, in streams. In addition, differences in species composition and diversity were small between years, but the abundance data were extremely variable. STEVENSON & HASHIM (1989) and VILBASTE (2001) observed that the annual differences in diatom communities in running waters were smaller than the differences between habitats and between streams.

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Sampling site	SB1 2004									SB2 2004					SB1 2005						SB2 2005			
Taxon / Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
BACILLARIOPHYCEAE																								
Achnanthes cf. *bioretii* (Fig.3/b,c)		1		1	2	1	1	1		1	1	1		2	1	2	2	1	2	1	2	1	2	2
Achnanthes lanceolata (BRÉBISSON) GRUNOW																	1					1		
Brachysira brebisonii ROSS		2		2	2	2	2	2	2	1	1	2			2	1	1	1	1	2	1	1	1	1
Caloneis bacillum (GRUNOW) CLEVE (Fig.3/g)					2			2	1	1	1	1		1	1	2	2	1		1	1	1		1
Diadesmis contenta (GRUNOV) MANN (Fig.3/h)		1		1	2	1	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2
Diadesmis laevissima (CLEVE) MANN				1			1			1		1	1	2		1					2	2	2	2
Diadesmis perpusilla (GRUNOV) MANN				1	1				1		1	1		1		2	1	1		1	1	2		1
Diatoma mesodon (EHRENBERG) KÜTZING					1		1				1	1				1			1			2		
Eunotia bilunaris (EHRNBERG) MILLS											2			1							1	1	1	2
Eunotia exigua (BRÉBISSON ex KÜTZING) RABENHORST (Fig.4/a,b)	3	2	3	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	3	2	2
Eunotia implicata NÖRPEL & LANGE-BERTALOT											1													
Eunotia incisa GREGORY (Fig.4/e)	2	2	2	2	3	1	1	2	3	2	1	1		1	3	2	2	2	2	3		2	1	1
Eunotia minor (KÜTZING) RABENHORST (Fig.4/d)	1	1	1	1	1	1	1	1	2	1		1		1	2	2	1	1	2	1	1	1		1
E. muscicola var. *tridentula* NÖRPEL & LANGE-BERTALOT (Fig.4/h)					1	1	1	1	1						1	2	2	1	1	1		1		
Eunotia paludosa var. *paludosa* GRUNOW					1																	2	1	
Eunotia paludosa var. *trinacria* (GRUNOW) NÖRPEL (Fig.4/f,g)		1	1		2		1	1	1	2	1	2		2	1	2	2	1	2	1	1	2	2	2
Eunotia praerupta var. *bigibba* (KÜTZING) GRUNOW					1	1	1		1	2	1			1						1		2	2	1
Eunotia septentrionalis OESTRUP (Fig.4/c)	2	2	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
Fragilaria cf. *ulna*												1											1	
Fragilaria virescens RALFS (Fig.3/d)	3	2	3	3	1	2	2	3	3	2	2	2	2	2	3	2	2	1	1	3	2	3	2	3
Frustulia crassinervia (BRÉB.) LANGE-BERTALOT & KRAMMER		2		1	1	1	2	1	2	2					1	1	1	1	1	2		1	1	1
Frustulia saxonica RABENHORST					1				1	1	1	1		1							1	1	1	1
Frustulia vulgaris (TWAITES) DE TONI																						1		
Gomphonema gracile EHRENBERG										1						1								
Gomphonema parvulum (KÜTZING) KÜTZING		1	1	1							1	1		1		2	1	1	1	1	1	1	1	
Meridion circulare var. *constrictum* (RALFS) VAN HEURCK				1	1	1	1				1				1	1	1	1	1	1		2		
Navicula cf. *cocconeiformis*																1	1					1		
Navicula cf. *minuscula* var. *minuscula* (Fig.3/e)			1	2	1		1	1		2	2	2		2		1	1			1	2	2	2	2
Navicula mutica KÜTZING											1	1		1		1	1		1			1		
Navicula radiosa KÜTZING		1					1																	

Table 2 - List of identified benthic algal taxa with frequency of occurence in samples from the brook Suchá Bělá.

Sampling site	SB1 2004									SB2 2004					SB1 2005						SB2 2005			
Taxon / Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
BACILLARIOPHYCEAE																								
Navicula soehrensis var. *soehrensis* KRASSKE (Fig.3/f)	1		1	1	2	1	1	1	1	2	1	2		2	1	1	2	1	2	2	2	2	2	2
Pinnularia borealis EHRENBERG														1		1								
Pinnularia cf. *schoenfelderi*				1	1	1		1	2	2		2	1	1	1	2	1	1	2	1	2	2	2	2
Pinnularia silvatica PETERSEN (Fig.3/a)		1		2	2	1	1	2	1	2	2	2	2	2	2	2	2	1	2	2	3	2	2	2
Pinnularia subcapitata GREGORY		1			1			1		2	2	2	2	2		2				2	3	2	2	2
Surirella linearis W. SMITH									1															
Tabellaria flocculosa (ROTH) KÜTZING			1	2	1		1	1	1	1	1	1	1		1	1	1			2	1	2	1	1
CHLOROPHYCEAE																								
Coccomyxa+Pseudococcomyxa spp.	2	2	1			3	2			3	2	3	2	3			2	3	3				3	
Desmococcus sp.														1										
Chlorella sp.							2																2	
Keratoccocus bicaudatus (A.BRAUN) J.B. PETERSEN											1	1												
Klebsormidium flaccidum SILVA, MATTOX & BLACKWELL	1	3		1			3	1	2	1	3	1		2	1		2	2	2	1	2	1	1	2
Koliella cf. *corcontica*							1																	
Microthamnion kützingianum NÄGELI														1		1		1	1				1	
Monoraphidium terestre (BRISTOL) KRIENITZ							2								1		3	2						
Stichococcus fragilis GAY													3	2										
EUGLENOPHYCEAE																								
Trachelomonas sp.															1									
ZYGNEMATOPHYCEAE																								
Penium (Actinotaenium) sp.	2	1	1	1		2	2	2				2	1	2	1						1			1
Total taxa	**9**	**17**	**12**	**20**	**24**	**17**	**26**	**20**	**20**	**23**	**26**	**27**	**12**	**28**	**21**	**28**	**26**	**22**	**21**	**23**	**22**	**32**	**26**	**24**

Table 2 (continuation) - List of identified benthic algal taxa with their relative abundance in samples from the brook Suchá Bělá.

sample – microhabitat

1, 2, 3, 4, 10, 11, 18, 19, 23 - stone

5, 13, 14, 15, 16, 21, 24 - stream bedrock

6, 7, 17 - wood

8, 9, 12, 20, 22 – bryophyte

frequency of occurence

3 - dominant

2 - common

1 - rare