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Algae of the Bohemian Forest. 1. Species richness

† Filip Lederer[1] & Jaromír Lukavský[2,*]

[1]*University of West Bohemia, Department of Botany, Klatovská 51, CZ–320 13 Plzeň, Czech Republic*
[2]*Institute of Botany AS CR, Dukelská 135, CZ–379 82 Třeboň, Czech Republic*
**lukavsky@butbn.cas.cz*

Abstract
The Bohemian Forest (Šumava Mts. and Bayerischer Wald) is one of the biggest mountain and forested regions in Central Europe. Its area and the variability of stands offer a very great diversity of environment for cyanobacteria and algae. Historical papers about algae are elder than a century and could be used for the comparison of development of algal flora in the region. The paper presents the basic data about species richness of principal stands as brooks, lakes, bogs, cryoseston, aerophyts and subaerophyts.

Key words: Bohemian Forest, species richness, biodiversity, algae, cyanobacteria, lakes, brooks, rivers, bogs, aerophyts, subaerophyts, cryoseston

Introduction

Silva Gabreta (ancient name for the Bohemian Forest, i.e. Šumava Mts. plus Bayerischer Wald) is one of the biggest mountain and forested regions in Central Europe. Research of algal flora of this region came back to the 19th century (e.g. Maly 1895, Prowazek 1899, Pascher 1903, 1906, Prát 1919, Cejp 1929, Fott 1937, 1938, Rosa 1941, Růžička 1954, 1957, Ettl & al. 1957, etc.).

The greatest attention was paid to lakes, especially to Černé Lake. The first expedition to the lake was performed by A. Frič and Hellich in 1871, more detailed research, with a "portable hydrobiological laboratory", followed in 1890s (Frič & Vávra 1898). After this pioneer study, Jírovec & Jírovcová (1937) measured first pH there, and living algae were concentrated by centrifugation for the first time by B. Fott at 1935–1937 (unpublished data from his field book). Lake Wall and its subaerophytic algae were studied by Rosa (1941). Research in the second half of the 20th century was restricted because of prohibited entry to frontier zone. Regular hydrobiological research has been reintroduced by J. Fott, who sampled Černé Lake 108 years after A. Frič. More detailed body of information about research in the Bohemian Forest was published by Veselý (1994) and Vrba & al. (2000), the history of cryptogamological research was compiled by Vaňa (1996, 2001), the bibliography of lakes of the Bohemian Forest was recently published by Vrba (2000).

Results of more recent research were published by Lukavský (1992), Veselý (1993, 1994), Lederer (1995a, 1995b, 1997), Lederer & Lukavský (1998), Zahrádková (1996). At present, the area has been intensively visited by biologists of Charles University in Prague, University of South Bohemia, University of West Bohemia, Hydrobiological Institute and Institute of Botany AS CR, etc. Also international co-operation is developing, algae of brooks along the Czech–Bavarian frontier were studied recently by Bauer & al. (1997), Lukavský & al. (in press).

Disadvantages of some above mentioned papers are that they deal often just by one taxonomic group of organisms and omitted another algae. The lists of all algae at principal localities, however, are desired to evaluate present diversity of life there.

Aim of the paper is to collect and compare basic data about species richness of basic sites in the Bohemian Forest. More detailed papers about taxonomy of individual species or groups are, or should be, published step by step.

Results

Algae of brooks

The Bohemian Forest is represented by greater rivers and streams as Vltava, Vydra or Otava. Small brooks, rivulets etc. are, however, the major part of water network. Brooks in this region are often unpolluted and algae of katharobic waters are surprisingly rich there. Phytobentos of stones is composed mainly of Bacillariophyceae (*Tabellaria flocculosa, Diatoma hyemalis,* genus *Pinnularia* etc.) and cyanobacteria (*Chamaesiphon* spp.). Chlorophyta are represented by filamentous algae as genera *Ulothrix, Klebsormidium, Microspora, Stigeoclonium* and *Draparnaldia*. Indicator species of katharobic waters is a bad smelling *Hydrurus foetidus* (*Chrysophyceae*), Rhodophyta are represented here by *Batrachospermum moniliforme, Audouinella* (*Chantransia*) and Phaeophyta by *Lemanea fluviatilis*.

Algae need some time to settle a stone, elder stones are richer. Brooks with sandy bottoms are very poor of algae, because of its non-stability. Also chemical composition of stones is important, e.g. common gneiss is settled with brown layer of Bacillariophyceae and cyanobacteria, limestone which is occasionally present in brooks because of building activity was covered by a different, bright-blue cyanobacteria *Leptolyngbya foveolarum*.

The most important for settlement of stones are: the gradient along brook (difference between stony fast running brook in upper part, and slow, muddy rivulet in its down part), > acidification > industrial activity > sewage > agriculture. Traffic activity was surprisingly not significant (Lukavský & al., in press). The effect of continuous input of even diluted nutrients is often magnified with increasing of light intensity in autumn, stones are sometimes densely covered by green filamentous algae.

With respect to biomass or number if individual cells are dominating Bacillariophyceae and cyanobacteria especially small species as *Chamaesiphon*, which are very common and are feeding for many of water animals. Filamentous Zygnematophyceae, also common, are recognised as indicators of acidification, too. In 63 brooks (Lukavský & al., in press) found 256 species of algae, range 35–40 species/brook, the most common were Bacillariophyceae (148). Comparable species diversity of diatoms found Kubečková (1995) in upper part of the Vltava River, maximum was 21 species/brook there. Zahrádková (1996) found 47 species of cyanobacteria and algae in 14 sampling sites in the Teplá Vltava River, Modravský and Roklanský brooks, the highest species diversity was found in cyanobacteria (18), Chlorophyta (9), Bacillariophyceae (8), Chrysophyceae and Conjugatophyceae (4), and Rhodophyta (3).

Algae of bogs

Bogs in the Bohemian Forest represent a great mosaic of microbiotops (water and subaerophytic) with a wide spectrum of conditions that are settled with a specific algal flora. Generally they are organisms adapted to a low pH and to the shortage of available nutrients in soil and water (bogs are poor in N and P). Phytoplankton of pools in the bogs is relatively poor and its composition shows typical seasonal dynamic. The most common species are Chrysophyceae as *Bitrichia ollula, Synura sphagnicola* and *Dinobryon pediforme*, genera *Gymnod-*

inium and *Peridinium* from Dinophyceae, common are also Cryptophyta as genus *Cryptomonas*. Chlorophyta are represented by e.g. *Ankistrodesmopsis gabretae-silvae* and *Oocystis solitaria*. The most important cyanobacteria are *Anabaena augstumnalis* and *Merismopedia angularis*. Rich are also the algae growing in *Sphagnum* – metaphyton, or growing on submerged branches and plants – epiphyton. These societies are composed by a wide spectrum of species, with dominants of *Hapalosiphon fontinalis* and *Chroococcus turgidus* from cyanobacteria, *Binuclearia tectorum*, genera *Microspora* and *Oedogonium* from Chlorophyta. Attractive and beautiful, for bogs typical, but not dominant Desmidiales and Zygnematophycae are represented by genera *Arthrodesmus, Cosmarium, Bambusina, Cylindrocystis, Mougeotia, Euastrum, Staurastrum, Spondylosium, Hyalotheca, Desmidium* and many others. Bacillariophyceae are here represented mainly by genera *Eunotia* and *Pinnularia*. The first genus is indicating acidification. Some bogs are in littoral settled with a rare Rhodophyte *Batrachospermum vagum*, or by clusters of filamentous *Spirogyra* and *Zygnema*. In shallow hollows and on fresh peat dominating is *Zygogonium ericetorum*, and simple desmids of genera *Netrium, Penium, Actinotaenium* and *Cylindrocystis*, from cyanobacteria *Chroococcus turgidus* and typical flagellate from Euglenales – *Euglena mutabilis*, and often lichenised species of the genus *Coccomyxa*. Total species richness of algae, from bogs in the Bohemian Forest is ca 230 species of cyanobacteria and algae (Lederer & al., in press). Their taxonomic correspondence is presented in Table 1.

Aerophytic algae

Inherent part of the Bohemian Forest landscape are stones, rocks, walls of stones and Calvaries which surfaces are yellowish, reddish, brownish or green because of biological settlement. Part of the growths are lichens, another are algae. Very bright could be green growth of a primitive filamentous green alga *Desmococcus vulgaris*, which is common here. More rare are species of genus *Trentepohlia*, which is doing prominent brown-reddish colour of bark of trees in watershed of river Otava (this is *Trentepohlia umbrina)*, less common *Trentepohlia aurea* is covering as gold-yellow cotton some branches and stones. On bark at base of trees and on wet tree stumps they are, in mucilage growing, species of chlorococal alga *Coccomyxa* and often also desmid *Mesotaenium chlamydosporum*.

Algae of subaerophytic stands

Algae and cyanobacteria growing on surface of wet stones, stony slopes etc. are settled by a specific and interesting flora. Exclusively are only here e.g. *Gloeocapsopsis magma* and *Gloeothece rupestris* from cyanobacteria, also species with a wider distribution as *Stichococcus bacillaris, Klebsormidium flaccidum* (Chlorophyta) and *Cyanothece aeruginosa* (cyanobacteria). The margins of drainage ditches from some bogs (e.g. Březník, Mlynářská bog) are covered, on wet peat, with a high mountain species *Monoraphidium tatrae* together with many another species. The most detailed study of algal flora of Lake Wall (a prominent nature reserve, the stony slope rising above the lake) of Černé Lake was published by Rosa (1941). He found 59 species on rocks, subaerophyts and another 20 species of phytoplankton in the lake.

Algae of lakes

The greatest, and the most studied **Černé Lake** (Table 1) is home for 205 species of algae and cyanobacteria, including Lake Wall (Lukavský in prep.). Phytoplankton represents only some part of the total species richness, 65 species. Dominant species in phytoplankton are Chrysophyta as *Bitrichia ollula*, and *Dinobryon divergens*. Another common flagellates are *Peridinium inconspicuum* (syn. *P. umbonatum*), *Amphidinium larvae* and *Gymnodinium uberrimum* from Dinophyceae.

Table 1. – Taxonomic determination of Algae and Cyanobacteria in different lakes (in %) and total species richness (in absolute numbers). Explanations: LUKAV. – Černé Lake, LUKAVSKÝ (in prep.); SANCH. – lakes of Sierra Nevada (Granada, Spain), SANCHEZ-CASTILLO (1988); STARM – lake Wielki Staw, the High Tatra Mts., STARMACH (1973); JURIŠ – lakes in the High Tatra Mts., JURIŠ & KOVÁČIK (1987); WEILN. – lakes in the Bavarian Forest, WEILNER (1997), GA= Grosser Arbersee, KA= Kleiner Arbersee, RA= Rachelsee.

	JURIŠ	SANCH.	STARM.	LUKAV.	WEILN.		
					GA	KA	RA
Cyanophyta	5.6	21	30	15	16	20	14
Chromophyta					40	40	55
Chrysophyceae total	20.5	5			16	14	17
Chrysomonadales				3.9			
Dinophyceae	5.6	2		5.8	5.6	7	5.5
Bacillariophyceae	22.4	51	65	27	12.2	15.3	30
Heterokontae	0.6			0.5			
Cryptophyta	2.5				2	1	
Chlorophyta	27.9	28	4.3	43	23.6	21	19.4
Desmidiales	12.4			18.8	12.3	7	5.5
Zygnemaceae		34		3			
Euglenophyta	2.5	8			3	3,5	3
Rhodophyta			0.7	2	1	1	
Chytridiales, Fungi				1	2	6	3
Total spec. richness	**161**	**149**	**140**	**64**	**106**	**85**	**36**

Majority of species richness in Černé Lake was concentrated to littoral, surface of stones in lake (21), submerged trees (8), surface of mud of bottom (98, mainly Bacillariophyceae) in shallow and irradiated parts of the lake and 36 species in plankton. Similar situation is in lakes in Bavaria (WEILNER 1999) where the numbers of species are comparable to lakes in Czech side. The data are comparable also with lakes in the High Tatra Mts., where the species richness of phytoplankton was 13 – 2, inversely proportional to their altitudes (1300–2200 m a.s.l., LUKAVSKÝ 1994).

In core of bottom from **Čertovo Lake** (VESELÝ & al. 1993) there was a rich spectrum of Bacillariophyceae, total 144 species. Phytoplankton of the lake is very similar to neighbouring Černé Lake, which is similar with its morphology and geology. Interesting is alga *Botryococcus braunii*, which was dominant in past, (BŘÍZOVÁ 1996 found it in depth of mud 0.75–1 m as dominant), but it is missing at present.

Laka Lake is quite specific among the Czech lakes (small retention time, shallow, rich vegetation, floating peat islands) it is the most similar to Bavarian Kleiner Arbersee. Prominent species is a Rhodophyte *Batrachospermum vagum,* in output of the lake is a unique freshwater Phaeophyte *Lemanea fluviatilis*, submerged woods in the lake are covered with a filamentous green alga *Binuclearia tectorum,* which is recognised as postglacial relict (LUKAVSKÝ 1970). These algae are included into the Red List of the Czech Republic (KOTLABA & al. 1995). Planktonic species here are cyanobacteria *Eucapsis alpina* and macroscopical colonies of *Aphanocapsa hyalina*, different species of *Dinophyta* and *Chrysophyceae*. *Sphagnum* growing in littoral is home for many desmids and cyanobacterial species e.g. *Cyanothece aeruginosa.* Littorals of floating islands are settled with a filamentous Cyanobacterium *Hapalosiphon fontinalis*.

AMBROŽOVÁ (1995) determined 21 species in phytoplankton of Černé and Čertovo lakes,

NEDBALOVÁ (2001) found ca 30 species, in the phytoplankton from 7 lakes sampled in 1997–1999. In lakes Černé, Čertovo, Prášilské, Grosser Arbersee and Kleiner Arbersee, the most common were dinoflagellates as *Gymnodinium uberrimum* and *Peridinium umbonatum*, chrysomonads as *Dinobryon* spp. In lakes Plešné and Rachelsee dominated Chlorophyta as *Monoraphidum dybowski* and *Carteria* sp. Plešné Lake was the most eutrophic lake settled with the highest biomass of algae, whereas Rachelsee was the most oligotrophic one with the lowest species diversity (WEILNER 1997).

Cryoseston

Cryoseston was found for the first time in the Czech Republic in the Krkonoše (Giant Mts.) in 1976 (FOTT & al. 1978) and again in 1986. The Bohemian Forest is a suitable locality for cryoseston because of altitude above 1 000 m, and snow fields persisting till late spring, but colour snow was found, for the first time, as far as in 1992. A prominent colour snow was visible only by Plešné Lake, but snow algae were present in almost all old snow spots, by lakes Černé and Prášilské (LUKAVSKÝ 1992). Maybe that the algae are quite common in old snow, but rarely they reach the concentration which is necessary to be apparent as colour (ca 10^6 cells.ml^{-1}). The algae which were in snow by Černé Lake were red–coloured *Cryocystis brevispina* and light green alga *Cryodactylon glaciale*. By Prášilské Lake the cryoseston consisted of green cells of genus cf. *Chlamydomonas*, also yellow-green cells of Xanthophyceae. Fungi *Chionaster nivalis* and *Selenotila nivalis* were present, too. The snow was colonised with green flagellate *Chloromonas brevispina* by Plešné Lake. There were 13 species of algae in cryoseston determined in the Bohemian Forest till now, from the total number of 98 known cryosteston organisms.

Table 2. – Species richness (in absolute numbers) and taxonomy affinity of algae and cyanobacteria in different stands of the Bohemian Forest. **Brooks** – from LUKAVSKÝ & al. in press), **Cryoseston** – LUKAVSKÝ (1992), **Slopes** – ROSA (1941), **Bogs** – unpublished data of LEDERER.

	Species richness				
	Brooks	Lakes	Bogs	Cryoseston.	Slopes
Cyanophyta	28	35	30	1	29
Rhodophyta	6	4	3		2
Cryptophyta	1	3	2		0
Dinophyta	2	12	6		2
Chromophyta					
Chrysophyceae	15	9	14		0
Bacillariophyceae	148	56	26		19
Xanthophyceae	5	1	9		1
Raphidophyceae	0	1	1		0
Chlorophyta	50	88	97	7	10
Chlorophyceae	34	43	56	7	19
Zygnematophyceae	16	45	41		21
Euglenophyta	3	3	7		1
Total	**258**	**212**	**195**	**8**	**94**

Conclusions

Biodiversity of cyanobacteria and algae of the Bohemian Forest

The Bohemian Forest is a suitable area for cyanobacteria and algae; it consists of a rich mosaic of stands and biotopes. Recent results of evaluation of species richness of principal typical stands are presented in Table 2. The list of species of the Bohemian Forest should be continuously completed from papers of elder authors, and step by step also from lists of species from another types of stands, e.g. artificial reservoirs, soil algae, springs, ancient ponds so called "Klausen" etc.

Recent research also contributed toward mapping of distribution or occasion of some rare, threatened and species protected by low (Kotlaba & al. 1995). Some of the species are common in the Bohemian Forest or joined with specific stands, e.g. *Clastidium setigerum*, *Hydrurus foetidus* also *Batrachospermum moniliforme*, *Chantransia* sp. div. *Lemanea fluviatilis* in mountain poor brooks, *Batrachospermum vagum* in pools on bogs and in lakes (Laka, Černé).

Some species are specific strictly to quite unique stands e.g. – *Eucapsis alpina*, *E. starmachi*, *Aphanocapsa hyalina*, *Cyanodictyon turfosum*, *Hapalosiphon hibernicus*, *Rhabdoderma vermicularis*, *Rhabdogloea linearis*, *Chroococcus subnudus*, *Chroococcus obliteratus*, *Microchaete tenera*, *Ankistrodesmopsis gabretae-silvae*, *Botryococcus pila*, *Dictyosphaerim elegans*, *Oocystis solitaria*, *Eremosphaera viridis Monoraphidium tatrae*, *Zygogonium ericetorum* are in bogs. *Gloeothece rupestris* and *Gloeocapsopsis magna* are on wet stone slopes. We regret that we are not capable to confirm the presence of some species, mentioned by ancient authors.

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