

Microvegetation on the top of Mt. Roraima, Venezuela

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Abstract: Venezuelan Table Mountains (tepui) are among world's most unique ecological systems and have been shown to have high incidence of endemics. The top of Roraima, the highest Venezuelan tepui, represents an isolated enclave of species without any contact with the surrounding landscape. Daily precipitation enables algae and cyanobacteria to cover the otherwise bare substrate surfaces on the summit in form of a black biofilm. In the present study, 139 samples collected over 4 years from various biotopes (vertical and horizontal moist rock walls, small rock pools, peat bogs, and small streams and waterfalls) were collected and examined for algal diversity and species composition. A very diverse algal flora was recognized in the habitats of the top of Mt. Roraima; 96 Bacillariophyceae, 44 Cyanobacteria including two species new to science, 37 Desmidiaceae, 5 Zygnematales, 6 Chlorophyta, 1 Klebsormidiales, 1 Rhodophyta, 1 Dinophyta, and 1 Euglenophyta were identified. Crucial part of the total biomass consisted of Cyanobacteria; other significantly represented groups were Zygnematales and Desmidiaceae. Investigated biotope types were demonstrated to have different composition of algal communities.

Key words: algae, Cyanobacteria, endemism, new species, Roraima, Table Mountain, tepuis

Introduction

Terrestrial biotopes such as bare rock surfaces are often exposed to unstable water regimes, high insolation and great temperature fluctuations. Therefore the occurrence and composition of living organisms of these biotopes depend highly on environmental conditions, in particular on chemical and physical conditions.

Algae and cyanobacteria are common inhabitants of the terrestrial habitats, often forming contiguous films that cover the rock surface. These biofilms are usually formed by mixed communities of unique composition, which is determined by different requirements of each of the living form. Terrestrial cyanobacteria are able to desiccate and are thus adapted to the unstable water regime, but for their metabolic activity and photosynthesis they require water in liquid state, whereas eukaryotic algae are able to utilize water vapour (LANGE et al. 1988; BÜDEL & LANGE 1991; JEFFRIES et al. 1993a, b).

Because of the extreme character of habitats on rock surfaces, the organisms that are able to survive such conditions are of substantial

interest to biologists. In the first half of the 20th century, three comprehensive studies on rock-inhabiting microorganisms were conducted: DIELS (1914) investigated dolomites, NOVÁČEK (1934) serpentinites, and JAAG (1945) limestones and silicates. However, only fairly recently have such mountain terrestrial habitats received great attention of phycologists (BÜDEL et al. 1994 in south America; WATANABE & KOMÁREK 1994 in Nepal; CASAMATTA et al. 2006 in North America; NEUSTUPA & ŠKALOUD 2008 in Southeast Asia; HAUER & PAŽOUTOVÁ 2009 in Europe).

Mt. Roraima

Venezuelan Table Mountains are a result of more than 1 billion-year-long weathering of the thick quartzite and sandstone sedimentary cover of the Guyana shield (STEYERMARK et al. 1995). The mineral content of the parent rocks is low and the soils above them are poor in nutrients (P, Ca, N) but rich in aluminium compounds that represent yet another stress factor for the region's vegetation (FÖLSTER & HUBER 1984; FÖLSTER 1986).

Venezuela's highest tepui, Mt. Roraima, is situated on the border of Venezuela, Guyana, and

Brazil (Fig.1). The mountain is 2806 m tall and the upper plateau (meseta; ca 40 km²) is elevated 800–1100 m above the surrounding savanna. This condition limits any contact of the species on the meseta with the surrounding landscape, resulting in high endemism (fungi: STROBEL et al. 1999, 2001; mosses: BUCK & CRUM 1993; higher plants: STEYMARK 1987; STEYERMARK et al. 1995; MICHELANGELI 2000; insects: SPANGLER 1985 a,b; SPANGLER & FAITOUTE 1991 and vertebrates: PEREZAPATA 1992; CAMPBELL & CLARKE 1998, MYERS & DONNELLY 2001). Moreover, the world's longest cave system found in quartz rock – Cueva Ojos de Cristal (Crystal Eyes Cave) – was discovered and reported by AUDY (2008), adding to the unique features of the locality.

The average annual temperature is approximately 10–15 °C, but the temperature of the rock surface fluctuates rapidly, as the weather continually changes. For instance, 7 °C was the measured minimum (6 AM) and 42 °C the maximum measured at 10:30 AM on the same day (27th Jan. 2000). The nutrient cycles on tepuis are thought to be affected considerably by levels of sunlight

due to photosynthetic activity of the flora on the surface (BRICENO et al. 1990). The characteristic water regime of the tepuis formed by daily ample precipitations in combination with air humidity and soil moisture is a result of a unique geomorphology. This regime rich in frequent fogs and rains allow for the creation of various microhabitats suitable for the biofilms formation.

Aims of the study

The primary goal of the present work was to provide a basic floristic survey of the algal and cyanobacterial vegetation living on the top of Roraima Tepui. Since this locality provides a variety of habitats differing considerably in physical conditions, a comparison of these different habitat types was also carried out with respect to algal and cyanobacterial flora. In addition, the results of the floristic/taxonomic work were used to determine whether the algal and cyanobacterial flora reflects the levels of endemism found in animals, fungi, and higher plants.



Fig. 1. Mt. Roraima

Materials and methods

An expedition from the Faculty of Science, University of South Bohemia sampled different types of habitats on the upper plateau of Mt. Roraima in January 2000, 2004, 2006, and 2009. The sampling included vertical rock walls (17 samples), horizontal rocks (23), small rock pools (lacking an organic layer on the bottom – 14), peat bogs (23), streams (26), waterfalls (17), and rock overhangs (19). A total of 31 samples were collected in 2000, 6 in 2004, 36 in 2006, and 66 in 2009. Samples were obtained by careful scraping off the substrata with a knife and were subsequently fixed in 1.5 % formaldehyde solution and transported (samples from 2006 and 2009 were preserved by drying only).

Preserved samples were directly analyzed using a light microscope Olympus BX 51 with high resolution Nomarski DIC optics equipped with digital camera Olympus DP 71 and software DP Controller (Olympus Inc.). From samples containing significant amount of diatom frustules, permanent diatom slides were prepared following protocol by HOUK (2003), using hydrogen peroxide for digestion, and Pleurax artificial resin (FOTT 1954) as a mounting medium.

For the estimation of relative density of species we used the phycological variation of the geobotanical Braun–Blanquet scale (KAŠTOVSKÝ et al. 2008). The data were analyzed by CCA and DCA analysis using CANOCO for Windows (TER BRAAK & ŠMILAUER 2002).

Results and discussion

All species found on Mt. Roraima and their relative abundances in particular biotopes are listed in Supplementary Table 1. (electronic version only at <http://fottea.czechphycology.cz>)

Cyanobacteria

With respect to biomass, the most important group of algae found on the top of Roraima were Cyanobacteria, represented by 44 species. The most abundant genera were *Stigonema* (especially *S. ocellatum* (DILLWYN) THURET ex BORNET et FLAHAULT and *S. hormoides* (KÜTZING) BORNET et FLAHAULT, Figs. 2/13 and 2/9) and *Gloeoecapsa* (especially *G. sanguinea* (C. AGARDH) KÜTZING, Figs. 2/1 and 2). In addition to species identifiable using available literature (GEITLER 1932; KOMÁREK & ANAGNOSTIDIS 1998, 2005), we found numerous cyanobacteria of unclear taxonomic affiliation. These forms are listed and characterized below.

Schizothrix cf. *telephoroides* (Fig 2/10), found in all types of habitats, abundant especially on vertical rocks and peat bogs. Cells 2–3 µm wide,

1.5–2 times longer than wide. Trichomes green, 1–2 per sheath. Sheath red to red–brown, closed at tip, distinctly lamellated, (15) 17–20 (25) µm wide. This morphology does not entirely fit any currently recognized species. *S. telephoroides* (MONTAGNE) GOMONT is the closest match but has considerably wider cells (4–9 µm). GOLUBIĆ (1967b) reported this species from wet rock walls in Venezuela, and indicated its cell width similar to our findings (3.2–3.5 (4) µm).

Porphyrosiphon cf. *notarisii* (Fig.2/11), found rarely but represented in all habitats except flowing water. Cells isodiametric, 5 µm in size, distinctly constricted at cross walls, granulated, yellow–brown. Sheath lamellated, yellow to brown, open at tip, considerably longer than trichome. Generally one trichome per sheath, two in rare cases of branching. Filament including sheath 40–50 µm wide. Such sheath width and character is not common in this genus. *P. notarisii* (MENEHINI) KÜTZING ex GOMONT is *Porphyrosiphon* with the widest sheath (up to 30 µm) but it has cells of more than double the size observed here.

More subtle differences (small discrepancies in size, colour, somewhat atypical habitat) from known species were found in a number of cyanobacteria from Roraima. For example, *Xenotholos* cf. *kernerii* (Figs.2/3 and 7; epiphytic on *Stigonema* spp.) had brown to brown–yellow cells, whereas the original description of the species reports green cells. *Homoeothrix* cf. *juliana* (Figs. 2/6 and 8), an inhabitant of rocks in waterfalls and streams, had very dark–brown sheaths as opposed to the originally described yellow sheaths in *H. juliana* (THURET ex BORNET et FLAHAULT) KIRCHNER. Moreover, the original is supposedly fairly strictly tied to limestone streams. *Hapalosiphon* cf. *luteolus* (Figs. 2/14 and 15) was of identical dimensions and morphology to the type species (especially the conspicuous and frequent secondary branching of side branches), but unlike the yellow–sheathed original, the Roraima inhabitant had colourless sheaths. *Merismopedia* cf. *elegans* (Fig. 2/4) was found in the epipsammon in a calmly flowing cave stream, but *M. elegans* A. BRAUN ex KÜTZING is a species inhabiting the littoral of eutrophic or slightly acidic standing waters. Character of cells of a taxon designed as *Gloeothece* sp. 1 (Fig. 2/5) notably resembled the genus *Rhabdoderma* SCHMIDLE et LAUTERBORN, but *Rhabdoderma* was never observed to form sheaths around individual

Table 1. Differences of newly described and other ecologically or morphologically similar *Entophysalis* species.

| | colony shape | colony size (µm) | cell size (µm) | sheaths | ecology |
|---|---------------------------|------------------|----------------|---------------------------|----------------------------------|
| <i>Entophysalis granulosa</i> KÜTZING | macroscopic, shrub-like | < 1000 | 2–5 | brown, yellow, colourless | marine (splash zone) |
| <i>Entophysalis violacea</i> GARDNER | microscopic, cushion-like | > 80 | 1.5–2.5 | violet | rocks |
| <i>Entophysalis arboriformis</i> sp. nov. | macroscopic, shrub-like | ~ 1000 | 4–6 | red to colourless | aerophytic, wet rocks, sandstone |

Table 2. Differences between *A. torulosa* and *A. roraimae*.

| | ecology | color | hormogonia | filament width (µm) | cells width (µm) | cells length (µm) |
|-------------------------------------|---|------------|----------------|---------------------|------------------|-------------------|
| <i>Albrightia torulosa</i> Copeland | epiphyte on bigger cyanobacteria, thermal springs | blue-green | mostly 2 cells | 5–8.5 | 3.2–4 | 3.3–9.0 |
| <i>Albrightia roraimae</i> sp. nov. | benthos from rock pool, wet rock epilith | brown | mostly 5 cells | 14–16.5 | (4) 5.3–8 | (4) 15–19 |

cells in a colony.

Two cyanobacterial taxa occurring on Mt. Roraima were morphologically significantly different from any currently recognized species. We here propose these as new species, even if solely based on a botanical–morphological approach.

***Entophysalis arboriformis* sp. nov. (Fig. 3)**

Diagnosis: Coloniae micro- vel macroscopicae, gelatinosae, amorphae, despues plus minusve erectae, irregulares, ramosae lobataeque, divaricatae, ad 1000 µm longae, rubrae, cum cellulis solitariis vel irregulariter aggregatis in subcoloniis parvis cum involucra mucilaginosa circumdatis, praecipue in partes marginalibus coloniae agglomeratis. Cellulae plus minusve ovales ad irregulares, olivaceo virides, intendum contentu granuloso, 4–6 µm in diametro. Involucra interna ad 11 (13) µm lata, concentrice lamellosa, granulosa, diffuentes, intense rubra. Involucra externa lata, sine colore, mucilaginosa, cum matrice externa confluentes. Nanocytae sporaque carentes.

Ecologia: Aerophytice ad rupes humidias areanrias inter species cyanoprocaryoticis.

Locus classicus: Mons Roraima Dictus, Venezuela.

Holotypus: specimina conservata in herbarium BRNM (Museum Moravicum Brno, Res Publica Bohemia) deposita (BRNM HY 2259).

Icona typica: figura nostra 3

Micro-, later macroscopic shrub-like gelatinous colonies composed of ensheated solitary cells joined into smaller subcolonies concentrated on periphery of the colony. Cells more or less oval or irregular, olive green, sometimes granulated, 4–6 µm in diameter. Inner mucilaginous envelopes up to 11 µm wide, concentrically lamellated, granulated, diffluent, red. Outer envelopes large, diffluent, colorless, forming inner mass of the colony. Nanocyte production and resting cells not observed.

Ecology: Aerophytic cyanobacterium, growing



Fig. 2. Cyanobacteria: (1, 2) *Gloeocapsa sanguinea*; (3, 7) *Xenotholos* cf. *kernerii*; (4) *Merismopedia* cf. *elegans*; (5) *Gloeotheca* sp. 1; (6, 8) *Homoeothrix* cf. *Juliana*; (9) *Stigonema hormoides*; (10) *Schizothrix* cf. *telephoroides*; (11) *Porphyrosiphon* cf. *notarisii*; (12) *Stigonema informe*; (13) *Stigonema ocellatum*; (14, 15) *Hapalosiphon* cf. *luteolus*. Scale bars 100 µm (6, 8, 12, 13); 20 µm (1–5, 7, 9–11, 14).

on wet walls among other, especially filamentous cyanobacteria.

Locus classicus: Mount Roraima, Venezuela.

Samples: rare, found in five samples, all in relative abundance up to 3.

Holotype: Preserved material deposited at the herbarium of the Moravian Museum Brno (BRNM HY 2259).

Icona typica: our Figure 3

Differences from other ecologically or morphologically similar *Entophysalis* species are summarized in Table 1.

***Albrightia roraimae* sp. nov. (Fig.4)**

Diagnosis: Filamenta intertextata, 14–16.5 µm lata, recte ramosa, ramuli ad angulum latum patentes. Trichomata ramique uniseriatae, cylindrica, moniliformes, ad dissepimenta clare constrictae, ad apices non attenuatae. Cellulae fuscae, barriliformes ad ovales, interdum cum connectivis cytoplasmaticis connectae, (4) 5.3–8 µm latae, (4) 15–19 µm longae. Vaginae firmae, latae, homogeneae, luteo-fuscae. Heterocytae akinetesque carentes. Reproductio cum hormogoniis 5–7-cellularis, 40–55 µm longis (cum cellulis 18–21 µm latis, 6.5–8 µm longis), de ramulis curtis vel lateraliter de filamentis principalibus crescentes.

Ecologia: benthice, periphytice, inter cyanobacteria filamentosa in fossis petrosis ad saxa humida.

Locus classicus: Mons Roraima dictus, Venezuela.

Holotypus: specimina conservata in herbarium BRNM (Museum Moravicum Brno, Res Publica Bohemia) deposita (BRNM HY 2260).

Icona typica: figura nostra 4

Trichomes uniseriate, cylindrical, composed of moniliform row of cells, with deep constrictions at cross walls. Branches formed at wide angles and of the same morphology and size as main filaments. Cells brown, barrel-shaped to oval, sometimes with visible cytoplasmatic connections. Sheaths thick, firm, homogenous and yellow-brownish. Heterocytes and akinetes not observed.

Width of filaments 14–6.5 µm, cells (4) 5.3–8 wide, (4) 15–19 µm long. Reproduction by few-celled (5–7 cells) hormocytes (ensheated hormogonia, similar to hormocytes of more known genus *Westiella*), 40–55 µm long. Unlike *Westiella* hormocytes are not at the end of long lateral branch but on very short branch or directly on the main filament. Width of hormocytes cells 18–21 µm, length 6.5–8 µm.

This species' morphology corresponds with the monotypic genus *Albrightia* COPELAND 1936, but not with the only existing species *A. torulosa* COPELAND (COPELAND 1936) – see Table 2.

Ecology: Benthic and periphytic among other filamentous cyanobacteria, in rock pools and on wet rocks.

Locus classicus: Mount Roraima, Venezuela.

Samples: rare, in rock pools (one sample) and on horizontal rocks (one sample), in both in relative abundance 2.

Holotype: Preserved material deposited at the herbarium of the Moravian Museum Brno (BRNM HY 2260).

Icona typica: our figure 4

Differences from other described *Albrightia* species are summarized in Table 2.

Apart from these two taxa, we found other morphologically unusual cyanobacteria (cf. *Cyanokybus*, cf. *Gomphosphaeria*, cf. *Romeria*) that we were not confident to assign even to a genus. These forms were extremely rare (one to few individuals found) and therefore there was not enough material for their thorough examination.

Conjugatophyceae

The second-most important group was the Conjugatophyceae, represented by 42 species (37 Desmidiaceae, 5 Zygnematales); however their biomass was relatively low in all sampled habitats, with the exception of *Zygogonium* sp., the densities of which were fairly high in peat bogs and on vertical rocks. A complete overview of desmids found on Roraima is presented in Supplementary Table 1 and in Supplementary Figures 1 and 2 (electronic version only at fottea.czechphycology.cz). The most common and/or taxonomically important taxa are discussed below.

Some species were observed frequently (*Actinotaenium cucurbita* (BRÉBISSEON ex RALFS) TEILING – Suppl. Fig. 1/4, and all varieties of *Micrasterias arcuata* BAILEY – Suppl. Fig. 2/1–4), while others were only seen once or a few times. In the latter case, when no match for the observed form was found in the literature, no taxonomic conclusions were drawn.

Vincularia roraimae FUČÍKOVÁ et KAŠTOVSKÝ was morphologically so distinct from any desmid described so far, and was found in high enough abundance and in all life stages including sexual reproduction, that it was possible to describe it as a new taxon (FUČÍKOVÁ & KAŠTOVSKÝ 2009). *V. roraimae* occurs abundantly in streams on the summit of Roraima and is peculiar in its production of thick unbranched filaments gro-

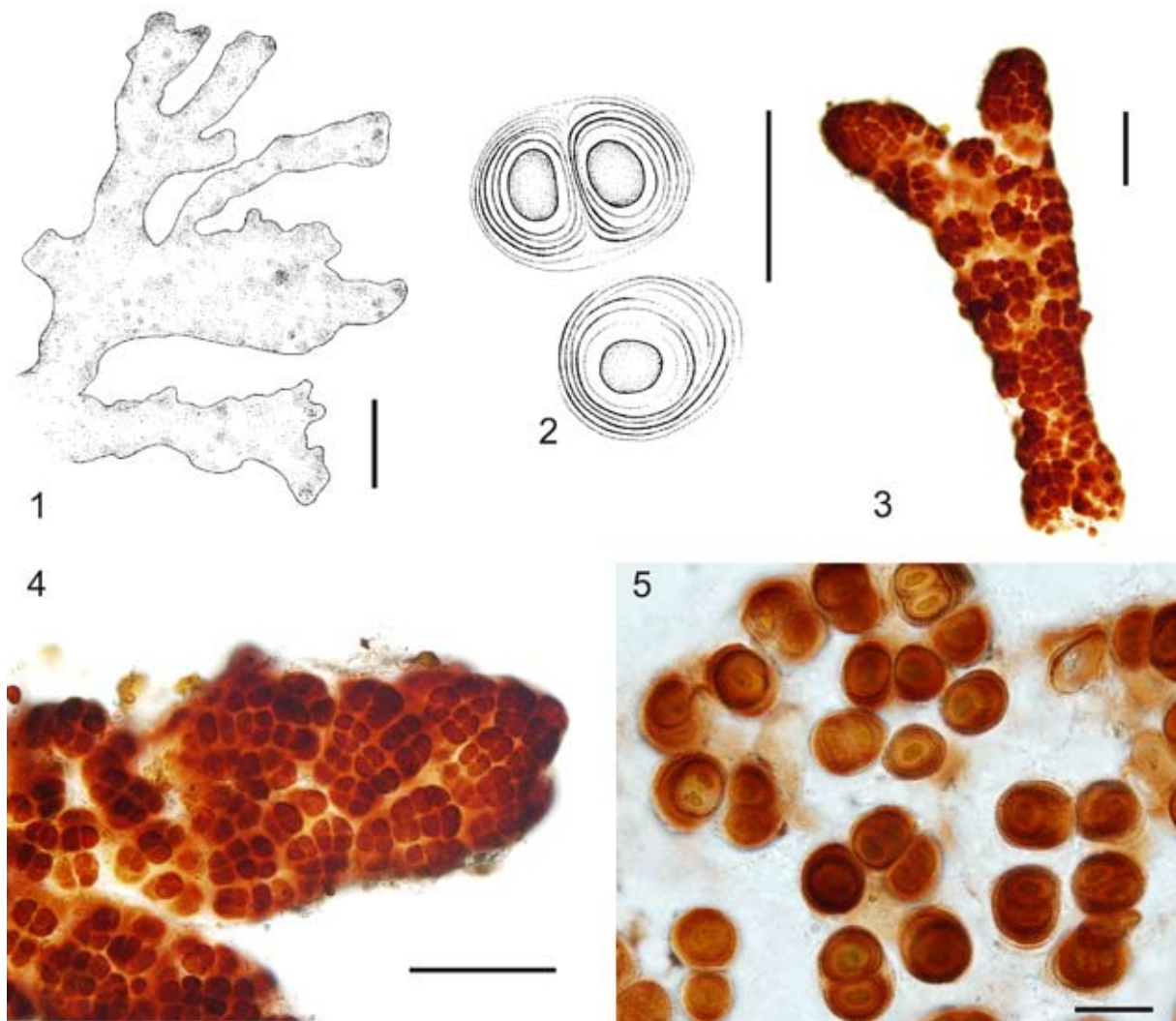


Fig. 3. *Entophysalis arboriformis* sp. nov. Scale bars 0.5 mm (1); 20 µm (2, 5); 100 µm (3, 4).

wing from each cell (Suppl. Fig. 1/24).

Other desmid taxa observed in the present study were found to differ in some characters from their closest morphological matches in the literature. In some cases this was due to bad physical condition of specimens, a small number of specimens found, or, such as in the case of *Actinotaenium* cf. *diplosporum* (P. LUNDELL) TEILING (Suppl. Fig. 1/5), due to the fact that zygospores, which are critical for reliable identification, were not observed. In other cases, desmids found on top of Mt. Roraima differed from described taxa in size, shape, or ecology. Such cases are listed below.

Cosmarium cf. *impressulum* is a medium-sized desmid that differs from the taxon described by LENZENWEGER (1999) in wall ornamentation and possibly also ecological requirements. *C. impressulum* ELFVING is thought to avoid

peat bogs and prefer alkaline environments (LENZENWEGER 1999, but contradicted by COESEL & MEESTERS 2007 who reports slightly acidic to slightly alkaline habitats) which is not the case on Mt. Roraima. Morphological differences include series of undulations/bumps on the semicell face that are concentric with the marginal undulations in the Roraima form, whereas *C. impressulum*'s semicell face is smooth. Another taxon with interesting ecology is *Cosmarium* sp.1 (Suppl. Fig. 1/11), which seems to inhabit exclusively vertical rock outcrops. Morphologically, this taxon did not match any species described in the literature used. Similarly, *Euastrum* sp. 1 (Suppl. Fig. 1/19), a rare taxon collected from a stream, does not match any described taxon. Its overall shape resembles *E. intermedium* CLEVE, but its width is considerably smaller than that of the *E. intermedium*, which is 32–45 µm broad, whereas the *Euastrum* sp 1. from Roraima Tepui is only 27

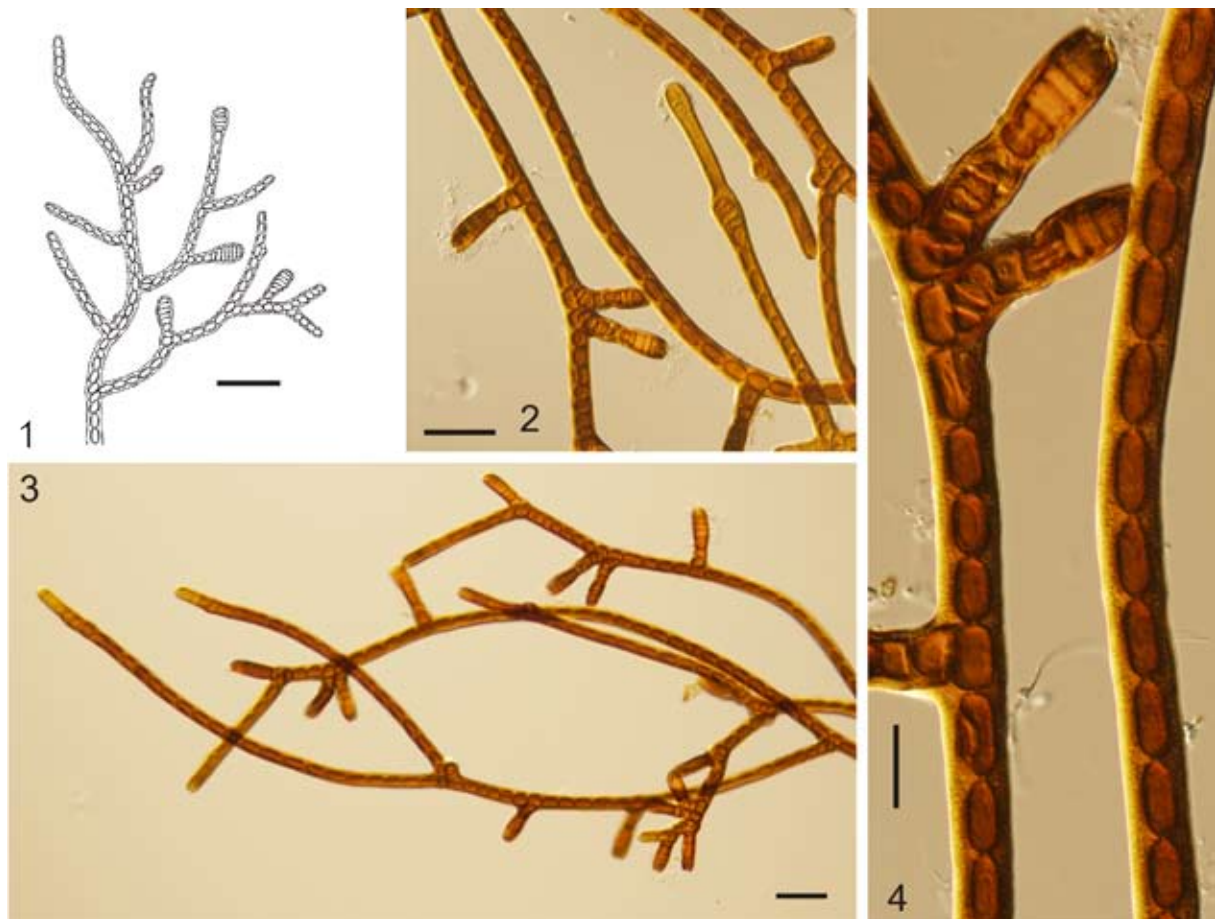


Fig. 4. *Albrichtia roraimae* sp. nov. Scale bars 50 µm (1–3); 20 µm (4).

µm broad. Species reported in the present study as *Staurastrum* cf. *quadrispinatum* (Suppl. Fig. 2/17) differs from *S. quadrispinatum* W.B. TURNER by its much more deeply incised median constriction. *Staurastrum* cf. *teliferum* (Suppl. Fig. 2/18) exceeds considerably the size of *S. teliferum* RALFS, but matches it otherwise in morphology and ecology. The spines of *Stauroidesmus* cf. *calyxoides* (Suppl. Fig. 2/11) are about half the length of those of *S. calyxoides* (WOLLE) CROASDALE. However, this difference may not be a taxonomically important one because of the great morphological variability generally observed in tropical desmids and even among the specimens observed in Roraima samples. A similar species, *Stauroidesmus* cf. *wandae* (Suppl. Fig. 2/12–14), differs from the previous taxon in its smaller size (19.75 x 22.22 µm for *S. cf. wandae* vs. 30 x 35–37 µm for *S. cf. calyxoides*) and penta- or less commonly heptaradial symmetry when viewed apically (*S. cf. calyxoides* is always hexaradial). It is possible that the two forms represent intraspecific variation of a single taxon. *Stauroidesmus* sp. does not match

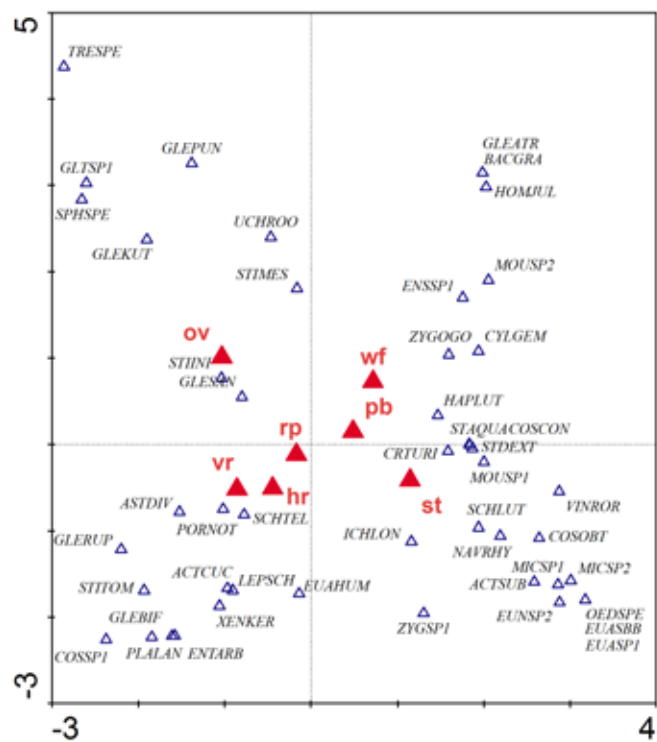
any taxon described in the available literature sources. It resembles *Ichthyocercus longispinus* (BORGE) KRIEGER (Suppl. Fig. 2/5,6) somewhat, but lacks any prominent cell wall ornamentation and is mostly triradiate (but considerably variable in shape), whereas *I. longispinus* is described as biradiate. None of the taxa mentioned above have been described as new to science because of the insufficient amount of material for a credible circumscription.

Bacillariophyceae

The most diverse group of photosynthetic microorganisms found on top of Mt. Roraima were diatoms (Bacillariophyceae), represented by 96 taxa. However, the total biomass was negligible, as only 8 species reached more than 1% of the total sample biomass in some samples (see Suppl. Table 1). An overview of diatoms found on Roraima is presented in Supplementary Figures 3 and 4 (electronic version only at <http://fottea.czechphycology.cz>)

Species that were in some samples

Fig. 5. CCA analysis: (ACTCUC) *Actinotaenium cucurbita*; (ACTSUB) *Actinotaenium* cf. *subpalangula*; (ASTDIV) *Asterocapsa* cf. *divina*; (BACGRA) *Bacularia* cf. *gracilis*; (COSCON) *Cosmarium* cf. *contractum*; (COSOBT) *Cosmarium obtusatum*; (COSSP1) *Cosmarium* sp.1; (CRTURI) *Chroococcus* cf. *turicensis*; (CYLGEM) *Cylindrocapsa geminella*; (ENSSP1) *Encyonopsis* sp.1; (EUAHUM) *Euastrum humberitii* var. *brasiliense*; (EUASBB) *Euastrum subbinale*; (EUASP1) *Euastrum* sp.; (EUNSP2) *Eunotia* sp. 2; (GLEATR) *Gloeocapsa* cf. *atrata*; (GLEBIF) *Gloeocapsa bififormis*; (GLEKUT) *Gloeocapsa kuetzingiana*; (GLEPUN) *Gloeocapsa punctata*; (GLERUP) *Gloeocapsa rupicola*; (GLESAN) *Gloeocapsa sanguinea*; (ENTARB) *Entophysalis arboriformis*; (GLTSP1) *Gloeotheca* sp. 1; (HAPLUT) *Hapalosiphon* cf. *luteolus*; (HOMJUL) *Homeothrix* cf. *juliana*; (ICHLON) *Ichthyocercus longispinus*; (LEPSCH) *Leptolyngbya* cf. *schmidlei*; (MICSP1) *Microspora* sp.1; (MICSP2) *Microspora* sp.2; (MOUSP1) *Mougeotia* sp. steril 1; (MOUSP2) *Mougeotia* sp. steril 2; (NAVRHY) *Navicula rhynchocephala*; (OEDSPE) *Oedogonium* sp.; (PLALAN) *Planothidium lanceolatum*; (PORNOT) *Porphyrosiphon* cf. *notarisii* var. *minor*; (SCHLUT) *Schizothrix lutea*; (SCHTEL) *Schizothrix* cf. *telephoroides*; (SPHSPE) *Sphaerococcomyxa* sp.; (STAQUA) *Staurastrum* cf. *quadrispinatum*; (STDEXT) *Staurodesmus extensus*; (STINF) *Stigonema informe*; (STIMES) *Stigonema* cf. *mesentericum*; (STITOM) *Stigonema tomentosum*; (TRESPE) *Trentepohlia* sp.; (UCHROO) unidentified *Chroococcales*; (VINROR) *Vincularia roraimeae*; (XENKER) *Xenotholus* cf. *kernerii*; (ZYGOGO) *Zygonium* sp. steril; (ZYGSP1) *Zygnema* sp. steril 1.



represented by more than 10 frustules and thus can be rated as relatively abundant and characteristic for the locality were: *Eunotia acutuariola* LANGE–BERTALOT (Suppl. Fig. 3/1), *Eunotia fennica* (HUSTEDT) LANGE–BERTALOT (Suppl. Fig. 3/2), *Encyonopsis* sp. 1 (Suppl. Fig. 3/11), *Encyonema sparsipunctatum* KRAMMER (Suppl. Fig. 3/12), *Brachysira rostrata* (KRASSKE) METZELTIN et LANGE–BERTALOT (Suppl. Fig. 4/1), *Brachysira serians* (BRÉBISSON ex KÜTZING) ROUND et MANN (Suppl. Fig. 4/2), *Brachysira* sp. 1 (Suppl. Fig. 4/3), *Frustulia altimontana* METZELTIN et LANGE–BERTALOT, *Frustulia pararhomboides* var. *pararhomboides* LANGE–BERTALOT (Suppl. Fig. 4/9), *Frustulia undosa* METZELTIN et LANGE–BERTALOT (Suppl. Fig. 4/10), and *Kobayasiella* cf. *micropunctata* (Suppl. Fig. 4/12).

We also identified some typical South American taxa, which were recently described from the area: *Actinella subperonoides* (Suppl. Fig. 3/7; METZELTIN & LANGE–BERTALOT 2007: plates 44, 45, 46), *Amphora* sp. (Suppl. Fig. 3/10; METZELTIN & LANGE–BERTALOT 1998: tafel 145/8, 9), *Brachysira rostrata* (METZELTIN & LANGE–BERTALOT 2007: plate 101/1–7),

Encyonema sparsipunctatum (KRAMMER 1997, tafel 95/1–5), *Eunotia acutuariola* (METZELTIN & LANGE–BERTALOT 1998: tafel 44/2–8), *Eunotia fennica* (METZELTIN & LANGE–BERTALOT 2007: Plate 91/1–8) *Encyonopsis buhriana*, METZELTIN & LANGE–BERTALOT 2007: plate 202/11–13), *Eunotia* cf. *geniculata* (Suppl. Fig. 3/5; METZELTIN & LANGE–BERTALOT 2007: plate 67/3,4), *Eunotia noerpeliana* (Suppl. Fig. 3/3; METZELTIN & LANGE–BERTALOT 1998: tafel 59/1–6, METZELTIN & LANGE–BERTALOT 2007: plate 99/3), *Fragilarioforma spinulosa* (Suppl. Fig. 4/15; METZELTIN & LANGE–BERTALOT 2007: plate 20), *Frustulia altimontana* (METZELTIN & LANGE–BERTALOT 1998: tafel 113/1–5), *Frustulia pararhomboides* var. *pararhomboides* (METZELTIN & LANGE–BERTALOT 1998: tafel 114/1–9), and *Kobayasiella* cf. *micropunctata* (METZELTIN & LANGE–BERTALOT 1998: tafel 94/10,11; METZELTIN & LANGE–BERTALOT 2007: plate 143/11–17).

Some species fit into worldwide distributed diatom taxa, some possessed slight morphological or ecological differences and were assigned to a species with uncertainty (labelled cf.), and others did not fit into any known taxon. Many of those

belonging to the third category likely deserve to be described as new species (especially in the genus *Eunotia*, in which 9 unknown taxa were recognized – see Suppl. Fig. 3, and *Brachysira* with 4 unidentified species), but this would require more thorough examination of the material using SEM, which is beyond the scope of the present study.

The high number of diatom taxa identified from our samples might not in reality reflect the current species richness of diatoms living on the top of Roraima. This is due to the standard method used for species identification in which only diatom frustules without living content (and any other organic material) are observed (see Materials and Methods). After the cell's death, the extremely stable siliceous cell wall can persist on site for years. This phenomenon is likely pronounced in the aerial and standing water habitats abundant on Mt. Roraima, in which there is low chance of old material being removed. Therefore, the taxa listed in Suppl. Table 1 consist of both currently flourishing species and species common in the past and now possibly extinct on the locality.

Other groups

Other major taxonomic groups of algae occurred rarely and were represented only by 7 species in the case of Chlorophyceae (most abundant species was *Cylindrocapsa geminella* WOLLE), 1 species of Rhodophyta (*Batrachospermum* sp.) in creeks, and a rare occurrence of 1 Dinophyta species (*Gloeodinium* sp.) on wet walls. Ecologically interesting is the occurrence of *Euglena* sp. in the digestive liquid inside the insect trap of the carnivorous plant *Brocchinia reducta*.

Statistical analysis of species distribution by habitats

In the CCA ordination based on microvegetation community composition, locality types were used as explanatory variables (Fig. 5). The significance of their effect was supported by a Monte Carlo permutation test (999 permutations, F-ratio = 3.476, P-value = 0.0010). The first and second axes account for 4.5 and 2.9% variability in species data, respectively.

Species only occurring in a single sample were excluded from the analysis (this was a common case in some diatoms and desmids). One of the excluded samples was 2000/37, which contained a single species, *Batrachospermum* sp. found in a stream.

At the examined localities, several dominant cyanobacterial species occurred abundantly in all habitat types (*Gloeocapsa sanguinea*, *Stigonema ocellatum*, *S. hormoides*, *S. informe* KÜTZING). Diatoms were generally found in very low biomass; taxa occurring in most habitat types and more often than only as sporadic solitary frustules were *Brachysira rostrata*, *B. serians*, *Kobayasiella* cf. *micropunctata*, and *Navicula rhynchocephala* KÜTZING. Among desmids, the most frequent taxa were *Actinotaenium cucurbita*, *Micrasterias arcuata*, and *Staurostrum pseudozonatum* var. *minutissimum* FÖRSTER, all of which also occurred in all habitat types except waterfalls and overhangs. Green filamentous algae were represented by a smaller number of taxa (esp. *Mougeotia*, *Zygonium*, *Microspora*, and *Cylindrocapsa geminella*), but in habitats with larger amounts of water (peatbogs, streams, waterfalls and some rock pools) their biomass was fairly high. Below summarized results clearly demonstrate that differences in microhabitat types have great influence on species composition of algal communities.

Overhangs: CCA showed overhangs as the most divergent locality type, likely due to colonization by shade-tolerant organisms that do not occur elsewhere. In contrast to other localities, no desmids were found on overhangs. *Gloeocapsa sanguinea*, which occurred in all biotopes as one of the dominants, was found to be the main dominant species on overhangs. *Gloeocapsa punctata* NÄGELI, a taxon rarely found in other habitats was very common here, as were *Gloeocapsa kuetzingiana* NÄGELI and a green coccoid *Sphaerococcomyxa* sp. *Trentepohlia* sp. occurred exclusively in this type of habitat. Overhangs also harbor the widest spectrum of habitat-specific diatoms (found in no other habitat type): *Anomooneis* sp., *Caloneis* sp., *Aulacoseira* cf. *alpigena*, *Cyclostephanos dubius* (HUSTEDT) ROUND, *Eunotia* cf. *geniculata*, *Eunotia paludosa* GRUNOW, *Eunotia* sp. 4, *Eunotia* sp. 5, *Eunotia* sp. 6, *Gomphonema* cf. *bohemicum* ssp. *angustiminus*, *Luticola* sp., and *Peronia* sp. 2. However, all of the above listed diatoms were found only in one sample and in very low relative abundances (mostly a single frustule per species), and therefore no strong conclusions can be drawn. Detrended correspondence analysis (DCA, data not shown) corroborated the most divergent character of overhangs. This analysis also emphasized the partial specificity of waterfalls, streams and peat bogs more than the CCA. The partial similarity

of waterfalls, streams and peat bogs (somewhat surprising in the case of peat bogs) is caused by the abundance of large filamentous algae, which are much more rare in other habitats (see above). Each of these three locality types harbours a specific algal community (see below).

Waterfalls: Almost no desmids were found in waterfalls (*Actinotaenium cucurbita* was present in three samples, *A. cf. cucurbita* f. *minus* in one sample, *Netrium oblongum* (DE BARY) LÜTKEMÜLLER in one sample, all in relative abundance 1) with the exception of *Vincularia roraimeae*, which reached relative abundance of 4 in one sample; the cyanobacterium *Homeothrix cf. juliana* occurred exclusively and in high abundance here and in one stream sample. The cyanobacterium *Gloeocapsa cf. atrata*, the rare cyanobacterium *Bacularia cf. gracilis*, and the diatom *Frustulia pararhomboides* var. *pararhomboides* LANGE–BERTALOT were found exclusively in this habitat, reaching high abundances in some samples. The otherwise common *Stigonema informe* did not inhabit waterfalls; similarly, the widespread *Schizothrix cf. telephoroides* was rather rare here (one sample, relative abundance 4). *Gloeocapsa sanguinea*, which was dominant in other habitats, had the least representation in waterfalls.

Streams: The cyanobacterium *Schizothrix lutea* FRÉMY, the diatom *Navicula rhynchocephala*, desmids *Actinotaenium cf. subpalangula*, *Vincularia roraimeae*, *Cosmarium obtusatum* (SCHMIDLE) SCHMIDLE, and the rhodophyte *Batrachospermum* sp. were the taxa most tied to this habitat type.

Peat bogs: *Hapalosiphon cf. luteolus* was abundant here but avoided other locality types. All members of the genus *Chroococcus* found on Mt. Roraima also occurred most frequently in peat bogs. The highest diversity of desmids was found here, the most abundant being *Actinotaenium cf. diplosporum*. Also the biomass of *Eunotia fennica* (HUSTEDT) LANGE–BERTALOT was pronouncedly higher in bogs than anywhere else.

The second subgroup of similar localities (in both CCA and DCA) comprises of rock pools, vertical rocks and horizontal rocks. Cyanobacteria that typically occurred in these biotopes were *Asterocapsa cf. divina*, *Porphyrosiphon cf. notarisii*, and *Schizothrix cf. telephoroides* (also present, although in lower abundance, in half of bog samples). *Actinotaenium cucurbita*, a generally common taxon, was the most abundant here. Again, despite their overall similarities,

each of the three habitat types harboured its own characteristic algal community.

Horizontal rocks: The dominant and ubiquitous *Stigonema ocellatum* reached its maximum abundance in this habitat, along with its epiphyte *Xenotholos cf. kernerii*. The otherwise very rare diatom *Eunotia acutuariola* LANGE–BERTALOT was fairly common here (three samples, rel. abundance 2 and 3); *Pinnularia cf. transversiformis* and *Stauroneis phoenicenteron* (NITZSCH) EHRENBERG occurred here as well (and also, but less frequently, on vertical rocks)

Rock pools: With the exception of *Brachysira serians* (one sample, rel. abundance 1), no diatoms were found in this habitat type. All common desmid species and *Zygonium* sp. were relatively abundant here.

Vertical rocks: The otherwise rare *Gloeocapsa rupicola* KÜTZING was abundant here (to a limited extent, some horizontal rock samples were also rich in this species). Seven diatom species were only found in this habitat, but only as single frustules: *Navicula tenelloides* HUSTEDT and especially *Nitzschia* – *N. acicularis* (KÜTZING) W.SMITH, *N. cf. amphibia*, *N. cf. paleacea*, *N. palea* (KÜTZING) W.SMITH, *N. pusilla* GRUNOW and *N. sp.1*.

Previous studies on tepuis

There are not many works we can compare our results with, as due to their limited accessibility, tepuis have received little phycological attention to date. Only three studies have been published on this topic, none of them floristically exhaustive. *Gloeocapsa sanguinea*, *Schizothrix* sp., *Petalonema (Scytonema) crassum* (NÄGELI in KÜTZING) MIGULA, *Scytonema ocellatum* (DILLWYN) LYNGBYE ex BORNET et FLAHAULT, *Stigonema hormoides*, *Stigonema ocellatum*, and *Xenococcus* sp. were reported in the study by LAKATOS et al. (2001) from Roraima Tepui, but this paper focused on carotenoid composition, not on detailed floristics. *Stigonema ocellatum*, *St. minutum* HASSALL ex BORNET et FLAHAULT, *Gloeocapsa sanguinea*, and *Schizothrix telephoroides* were reported from the blackish–red sandstone rock surface of Serrania Paru Tepui (BÜDEL et al. 1994). In a 1999 study, *Gloeocapsa rupicola*, *Scytonema ocellatum* and *Xenococcus* sp. were added to the species list (BÜDEL 1999). On “felt-like crusts on part of rock where soil formation took place” *Zygonium* sp. was found along with *St. ocellatum* (BÜDEL et al. 1994). The genus *Stigonema* was reported as the

overall dominant for this tepui.

B. Büdel also investigated Auyan Tepui and found *Gloeocapsa sanguinea* (dominant in reddish-coloured areas), *Chroococcus* sp., *Plectonema* sp., *Stigonema hormoides*, *St. ocellatum*, *St. panniforme* BORNET et FLAHAULT, and *Scytonema crassum* (the last three were dominant in blackish-green areas) (BÜDEL 1999). In a later study, LAKATOS et al. (2001) added *Scytonema hoffmanni* AGARDH ex BORNET et FLAHAULT, *Sc. myochrous* (DILLWYN) C. AGARDH ex BORNET et FLAHAULT and *Stigonema mamillosum* AGARDH ex BORNET et FLAHAULT to the species list.

Partial information on algal flora is available from Kukenán Tepui, where rock walls were dominated by *Gloeocapsopsis* sp., *Chondrocystis* sp., and *Stigonema* spp., and bogs were inhabited by Zygnematales as well as the genera *Stigonema* and *Scytonema* (POKORNÝ 1996).

Any meaningful comparison of these less detail-rich floristic studies with our results is problematic. However, our overall conclusions are similar and the observed taxa and dominants mostly agree with these studies. Interestingly, according to published results, the most divergent flora was found on the closely adjacent Kukenán, but a comparable detail-focused study of Kukenán would be required to address this issue properly.

On the endemism of microorganisms

The question whether or not endemic species exist in algae and cyanobacteria is not an easy one to discuss. Considerable complications bring the fact that the real biogeography of microorganisms is not as well understood as that of larger organisms (e.g., vascular plants), particularly in regions more difficult to research than the North Temperate Zone (e.g., the tropics) (MANN & DROOP 1996; GIULIETTI et al 2005; ADL et al. 2007), and that the species concept is often not clear even in major groups of algae (e.g. BROADY 1996; VYVERMANN 1996).

Theoretically, the distribution of algae and cyanobacteria may be viewed from two perspectives. First is a theory of neutral dispersal model (FINLAY 2002; FENCHEL & FINLAY 2004), which was proposed for eukaryotic microorganisms based on observations of ciliates, and also has been applied to the distribution of bacteria (FINLAY et al. 1999), including cyanobacteria. Based on this theory, e.g., cyanobacteria can be viewed as organisms with cosmopolitan to ubiquitous distribution (CASTENHOLZ 2005) with diversity comprised of a small number of extremely

variable entities (RIPPKA et al. 1979; DROUET 1981; CASTENHOLZ 2001; CASTENHOLZ & NORRIS 2005). Presently, only 63 forms (genera) are recognized by main determination source of this school – the bacteriological “Bible”, Bergey’s Manual (CASTENHOLZ 2001).

However, the validity of neutral dispersal model is challenged or at least disputed in case of many other algal groups (e.g., ŘEZÁČOVÁ & NEUSTUPA 2007; NEUSTUPA & ŘEZÁČOVÁ 2007; COESEL & KRIENITZ 2008; KRISTIANSEN 2008). If we define ubiquitous species as ones capable of living in any environment on any continent, then there are probably very few of such “weedy” taxa – e.g., *Pseudococcomyxa simplex* (MAINX) FOTT, or *Stichococcus* spp. (NOVIS et al. 2008). A narrower term cosmopolitan species stands for inhabitants of similar kinds of biotopes but different geographic regions. This is often the case in species living in very specific conditions, such as a thermal cyanobacterium *Mastigocladus laminosus* COHN ex KIRCHNER (KAŠTOVSKÝ & JOHANSEN 2008). Likely, the most common mode of distribution still in agreement with the neutral dispersal model would be that of the species living in similar habitats and spanning a larger but limited geographic zone (circumpolar, pantropical, etc.). Thus, if the endemism did not exist in microalgae, we should be always able to confirm the occurrence of any taxon in comparable habitats of different locations. However, this seem to not be the case, as majority of the taxonomic studies focused on previously unexplored geographical locations report occurrence of new forms in various algal groups that do not fit any known description: desmids – COESEL, 1996, 2000, 2002, 2003; FUČÍKOVÁ & KAŠTOVSKÝ 2009; green algae – NEUSTUPA & ŠEJNOHOVÁ 2003; NEUSTUPA 2005; STOYNEVA et al. 2005, 2006; RINDI & LOPEZ-BAUTISTA 2008; Cryptophyta – MENEZES & NOVARINO 2003; Euglenophyta – WYDRZYCKA 1996; Dinophyta – CARTY & WUJEK 2003; TAYLOR et al. 2008; Cyanobacteria – KOMÁREK & CRONBERG 2001; KOMÁREK 2003; CRONBERG & KOMÁREK 2004; KOMÁREK & KOMÁRKOVÁ-LEGNEROVÁ 2007; FIORE et al. 2007; MAREŠ et al. 2008; KORELUSOVÁ et al. 2009; FLEMING & PRUFERT-BEBOUT 2010. Moreover, because sexual reproduction is an obligate stage in the life cycle of most diatom species, the neutral dispersal model likely does not apply to this whole group (MANN & DROOP 1996, VYVERMAN et al. 2007, VANORMELINGEN et al. 2008), which is also an evidence standing against general

adoption of the theory to the microorganisms.

Therefore, we accept the “botanical” way of thinking, in cyanobacteria depicted particularly in monographs by KOMÁREK & ANAGNOSTIDIS (1998 and 2005), and summarized in the CyanobDB.cz database (KOMÁREK & HAUER 2010). In this concept, 252 validly described cyanobacterial genera are recognized and endemic species are generally accepted. In agreement with previous knowledge on endemism of other taxonomic groups, endemic species in algae and cyanobacteria tend to occur in isolated areas: Australia (TYLER 1996; CROOME et al. 1998; SABBE et al. 2001; D’ARCHINO et al 2010), or islands such as Madagascar (METZELTIN & LANGE–BERTALOT 2002; SPAULDING & KOCIOLEK 2003; BIXBY et al. 2009), New Caledonia (MOSER et al. 1998), or Tierra del Fuego (VIGNA & KRISTIANSEN 1996). If such an area also has extreme ecological conditions, the effect is even more pronounced (Antarctica – VINCENT 2000; DE WEVER et al. 2009; RYBALKA et al 2009; VAN DE VIJVER et al. 2010).

Mt. Roraima most likely fits the type of locality with high probability of occurrence of endemics – it is very isolated and contains extreme habitats. In many groups of organisms, endemism has been already documented there (see introduction). Therefore, we do not find surprising the fact that species demonstrably new to science were found here, as well as others that did not have a good morphological match in the literature.

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Supplementary material

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Table S1. 1 = estimated relative abundance <0.1%; 2 = 0.1–1%; 3 = 1–5%; 4 = 5–20%; 5 = 20–50%; 6 = 50–90%; 7 = 90–100%. Numeric values for frequency in parentheses = species occurred in this frequency in fewer than 3 samples. ST = streams, WF = waterfalls, PB = peatbogs, VR = vertical rocks, HR = horizontal rocks, RP = rock pools, OV = overhangs.
**Euglena* sp. was found in the digestive liquid inside the insect trap of the carnivorous plant *Brocchinia reducta*.

| | ST | WF | PB | VR | HR | RP | OV |
|---|-------|---------|--------|-------|--------|-------|---------|
| Cyanobacteria | | | | | | | |
| <i>Albrighritia roraimae</i> sp. nov | 0 | 0 | 0 | 0 | 0 (3) | 0 (3) | 0 |
| <i>Aphanocapsa</i> cf. <i>musciicola</i> | 0–(3) | 0 (3) | 0–1(3) | 0 (3) | 0 (1) | 0 (1) | 0 |
| <i>Asterocapsa</i> cf. <i>divina</i> | 0 (3) | 0 (1–3) | 0 (1) | 0–4 | 0(1–4) | 0 (3) | 0 (1–3) |
| <i>Bacularia</i> cf. <i>gracilis</i> | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| cf. <i>Cyanokybus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Cyanothece aeruginosa</i> (NÄGELI) KOMÁREK | 0 (1) | 0 (1) | 0–1(3) | 0 | 0–1 | 0–1 | 0 |
| <i>Cyanosarcina</i> sp. | 0 | 0 (1) | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Eucapsis alpina</i> CLEMENTS et SCHANTZ | 0 | 0 | 0(1) | 0 | 0 | 0 | 0 |

Table S1 Cont.

| | | | | | | | |
|---|----------------|------------------|--------------|---------------|-----------|---------|----------------|
| <i>Geitlerinema splendidum</i> (GREVILLE) ANAGNOSTIDIS | 0 (2) | 0 (2) | 0 | 0 | 0 | 0 | 0 |
| <i>Gloeocapsa</i> cf. <i>atrata</i> | 0 | 0–(4) | 0 | 0 | 0 | 0 | 0 |
| <i>Gloeocapsa biformis</i> ERCEGOVIĆ | 0 | 0 | 0 | 0–(3) | 0–(3) | 0 | 0 |
| <i>Gloeocapsa kuetzingiana</i> NÄGELI | 0 (2) | 0 | 0–(3) | 0 (2) | 0–3 | 0 | 0–5 |
| <i>Gloeocapsa punctata</i> NÄGELI | 0 | 0–4 | 0 | 0 (3) | 0 | 0–3 | 0–5 |
| <i>Gloeocapsa rupicola</i> KÜTZING | 0 | 0 | 0 (3) | 2–4 (6) | 0–3 (4) | 0 | 0–2 (6) |
| <i>Gloeocapsa sanguinea</i> (C. AGARDH) KÜTZING | 0–3 (4) | 0–4 | 0–5(6) | 3–5 | (0)3–4(6) | 3–5 | (0) 3–5 (7) |
| <i>Gloeocapsa arboriformis</i> sp. nov. | 0 | 0 | 0 | 0 (4) | 0 (4) | 0 | 0 |
| <i>Gloeotheca tepidariorum</i> (BRAUN) LAGERHEIM | 0 | 0 | 0 | 0 | 0 | 0 | 0 (2) |
| <i>Gloeotheca</i> sp. 1 | 0 | 0 | 0 | 0 (2) | 0 (3) | 0 | 0–3(4) |
| cf. <i>Gomphosphaeria</i> | 0 | 0 | 0 | 0 | 0 (2) | 0 | 0 |
| <i>Hapalosiphon</i> cf. <i>luteolus</i> | 0 (2,3) | 0 | 0–4 | 0 | 0 (2) | 0 | 0 |
| <i>Heteroleibleinia</i> cf. <i>pusilla</i> | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Homeothrix</i> cf. <i>juliana</i> | 0 (2) | 0–3(5,6) | 0 | 0 | 0 | 0 | 0 |
| <i>Chroococcus</i> cf. <i>turgidus</i> | 0 (2) | 0 (2) | 0–2 (3) | 0 | 0 (2) | 0 (2) | 0 |
| <i>Chroococcus</i> cf. <i>turicensis</i> | 0 (2) | 0 (2) | 0–1 (2) | 0 | 0 (2) | 0 | 0 |
| <i>Chroococcus minor</i> (KÜTZING) NÄGELI | 0 | 0 (2) | 0 (1,2) | 0 | 0 | 0 | 0 |
| <i>Chroococcus minutus</i> (KÜTZING) NÄGELI | 0 (1) | 0 (2) | 0 (1,3) | 0 | 0 (2) | 0 | 0 |
| <i>Komvophoron</i> cf. <i>schmidlei</i> | 0 (2) | 0 (2) | 0 (2) | 0 (2) | 0 | 0 | 0 |
| <i>Leptolyngbya tenuis</i> (GOMONT) ANAGNOSTIDIS et KOMÁREK | 0 (2,3) | 0 (3) | 0 (3,4) | 0 | 0–2 (3) | 0–2 (3) | 0 (2) |
| <i>Leptolyngbya</i> cf. <i>schmidlei</i> | 0 (3) | 0 (3) | 0 (2) | 0–4 | 0–3 | 0 | 0 |
| <i>Merismopedia</i> cf. <i>elegans</i> | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Merismopedia glauca</i> (EHRENBERG) KÜTZING | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Porphyrosiphon</i> cf. <i>notarisii</i> var. <i>minor</i> | 0 (3) | 0 (2,5) | 0 (3) | 0–4 | 0–4 (5) | 0–2 (6) | 0–3 |
| cf. <i>Romeria</i> | 0 | 0 (2) | 0 (2) | 0 | 0 | 0 | 0 |
| <i>Scytonema</i> cf. <i>multiramosum</i> | 0 | 0 | 0 | 0 (1) | 0 (3) | 0 | 0 |
| <i>Scytonema</i> cf. <i>myochrous</i> | 0(2,3) | 0 | 0(2,3) | 0 | 0(2–4) | 0–4(5) | 0 |
| <i>Schizothrix</i> cf. <i>telephoroides</i> | 0(4–6) | 0 (4) | 0–4 | (0) 2–5(6) | 0–4(5) | 0–4 | 0–3(4) |
| <i>Schizothrix lutea</i> FRÉMY | (0,4) 5 (6) | 0 (2) | 0–4 | 0 | 0 (3,5) | 0 (2) | 0 |
| <i>Stigonema</i> cf. <i>mesentericum</i> | 0 | 0 | 0–3 (4) | 0 | 0 | 0–2 | 0 (4,5) |
| <i>Stigonema hormoides</i> (KÜTZING) BORNET et FLAHAULT | 0–4 (5,6,7) | 0–4 (5) | 0–4 (6) | 0–4 (5) | 0–4 (5) | 0–4 (5) | 0 (2–4) |
| <i>Stigonema informe</i> KÜTZING | 0 (1–3) | 0 | 0–4 (5,6) | 0–3(4) | 0–3 | 0 (2) | 0–2 (3,4,5) |
| <i>Stigonema ocellatum</i> (DILLWYN) THURET ex BORNET et FLAHAULT | 0–3, 5 (6) | (0–2) 4–5 (6) | 0–6 | 0–5 | 3–6 | 3–5(6) | 0–3 |
| <i>Stigonema tomentosum</i> (KÜTZING) HIERONYMUS | 0 | 0 | 0 | 0–2 (3) | 0–2 (4) | 0 | 0(3) |
| <i>Xenotholos</i> cf. <i>kernerii</i> | 0 (1) | 0 | 0 | 0 (1,2) | 0–3 | 0–2 | 0 |
| unidentified Chroococcales | 0 | 0 (3,4) | 0–3 | 0 (3) | 0 | 0 (2) | 0 (2,5) |
| Bacillariophyceae | | | | | | | |
| <i>Achanthes</i> cf. <i>oblongella</i> | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Actinella subperonoides</i> LANGE–BERTALOT | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |

Table S1 Cont.

| | | | | | | | |
|--|---------|---------|---------|-------|---------|-------|-------|
| <i>Amphora</i> sp. | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Anomoeoneis</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Brachysira brebissonii</i> ROSS | 0 | 0 (1) | 0 (1,2) | 0 | 0 | 0 | 0 (1) |
| <i>Brachysira macroserians</i> METZELTIN et LANGE-BERTALOT | 0 (2) | | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Brachysira rostrata</i> (KRASSKE) METZELTIN et LANGE-BERTALOT | 0 (2) | 0 (1) | 0(3) | 0(3) | 0(3) | 0 | 0 (1) |
| <i>Brachysira serians</i> (BRÉBISSON ex KÜTZING) ROUND et MANN | 0 (1,2) | 0 (1) | 0-3 | 0 | 0 (1-3) | 0 (2) | 0 (1) |
| <i>Brachysira</i> sp. 1 | 0 | 0 | 0 (2) | 0 | 0 (1) | 0 | 0 (1) |
| <i>Brachysira</i> sp. 2 | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Brachysira</i> sp. 3 | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Brachysira</i> sp. 4 | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Caloneis</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| cf. <i>Aulacoseira alpigena</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| cf. <i>Chamaepinnularia</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| cf. <i>Hantzschia</i> | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| cf. <i>Melosira varians</i> | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| cf. <i>Pinnularia acoricola</i> | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| cf. <i>Stephanocyclus atomus</i> | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| cf. <i>Trybrionella</i> sp. 1 | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Cyclostephanos dubius</i> (HUSTEDT) ROUND | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 (1) |
| <i>Diatoma mesodon</i> (EHRENBERG) KÜTZING | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Diploneis</i> sp. | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Encyonema</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Encyonema silesiacum</i> (BLEISCH) MANN | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Encyonema sparsipunctatum</i> KRAMMER | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 (1) |
| <i>Encyonopsis buhriana</i> METZELTIN et LANGE-BERTALOT | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Encyonopsis</i> cf. <i>blancheanum</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Encyonopsis subminuta</i> KRAMMER et REICHARDT | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Encyonopsis</i> sp.1 | 0 (1,2) | 0 (1-3) | 0 (1,2) | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia acutuariola</i> LANGE-BERTALOT | 0 | 0 | 0 (1,2) | 0 | 0 (2-3) | 0 | 0 (1) |
| <i>Eunotia</i> cf. <i>circumborealis</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Eunotia</i> cf. <i>fallax</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Eunotia</i> cf. <i>geniculata</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia</i> cf. <i>noerpeliana</i> | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Eunotia</i> cf. <i>tenela</i> | 0-1 (2) | 0 (1) | 0 (2) | 0 (1) | 0 (2) | 0 | 0 |
| <i>Eunotia fennica</i> (HUSTEDT) LANGE-BERTALOT | 0 | 0 (1) | 0 (1,2) | 0 | 0 (1) | 0 | 0 (1) |
| <i>Eunotia gibbosa</i> GRUNOW | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia noerpeliana</i> METZELTIN et LANGE-BERTALOT | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Eunotia paludosa</i> GRUNOW | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia</i> sp. 1 | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Eunotia</i> sp. 2 | 0-2 | 0 | 0 | 0 | 0 (1) | 0 | 0 |

Table S1 Cont.

| | | | | | | | |
|--|---------|----------|-------|-------|----------|---|-------|
| <i>Eunotia</i> sp. 3 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Eunotia</i> sp. 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia</i> sp. 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia</i> sp. 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Eunotia</i> sp. 7 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Eunotia</i> sp. 8 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Eunotia</i> sp. 9 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Fragilaria capucina</i> DESMAZIÈRES | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Fragilarioforma spinulosa</i> (PATRICK) LANGE–BERTALOT | 0 (2) | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Frustulia altimontana</i> METZELTIN et LANGE–BERTALOT | 0 | 0 | 0 (1) | 0 | 0 (1) | 0 | 0 |
| <i>Frustulia</i> cf. <i>undosa</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Frustulia pararhomboides</i> var. <i>pararhomboides</i> LANGE–BERTALOT | 0 | 0 (3) | 0 | 0 | 0 | 0 | 0 |
| <i>Frustulia undosa</i> METZELTIN et LANGE–BERTALOT | 0 | 0 (1) | 0 (1) | 0 | 0 (1) | 0 | 0 (1) |
| <i>Frustulia vulgaris</i> (THWAITES) DE TONI | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Gomphonema</i> cf. <i>bohemicum</i> ssp. <i>angustiminus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Gomphonema gracile</i> EHRENBERG | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Gomphonema micropus</i> var. <i>micropus</i> LANGE–BERTALOT | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Gomphonema parvulum</i> (KÜTZING) KÜTZING | 0 (2) | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Hantzschia amphioxys</i> (EHRENBERG) GRUNOW | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Kobayasiella</i> cf. <i>micropunctata</i> | 0 (2) | 0 (1) | 0 (2) | 0 (1) | 0 (1) | 0 | 0 (1) |
| <i>Kobayasiella pseudosubtilissima</i> (MANGUIN) LANGE–BERTALOT et REICHARDT | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 (1) |
| <i>Kobayasiella</i> sp. 1 | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Kobayasiella</i> sp. 2 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Kobayasiella subtilissima</i> (CLEVE) LANGE–BERTALOT | 0 (1) | 0 (1) | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Luticola muticopsis</i> (VAN HEURCK) MANN | 0 | 0 | 0 (1) | 0 | 0 (1) | 0 | 0 |
| <i>Luticola</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Mastogloia</i> sp. | 0 | 0 (1) | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Navicula cincta</i> (EHRENBERG) RALFS | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Navicula gregaria</i> DONKIN | 0 (2) | 0 | 0 | 0 (2) | 0 (1) | 0 | 0 |
| <i>Navicula rhynchocephala</i> KÜTZING | 0–2 (3) | 0 (1, 2) | 0–2 | 0 (1) | 0 (1, 2) | 0 | 0 |
| <i>Navicula tenelloides</i> HUSTEDT | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Nitzschia acicularis</i> (KÜTZING) W.SMITH | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Nitzschia amphibia</i> GRUNOW | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Nitzschia</i> cf. <i>amphibia</i> | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Nitzschia</i> cf. <i>paleacea</i> | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Nitzschia fonticola</i> (GRUNOW) GRUNOW | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Nitzschia hantzschiana</i> RABENHORST | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 (1) |
| <i>Nitzschia palea</i> (KÜTZING) W.SMITH | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |

Table S1 Cont.

| | | | | | | | |
|---|----------------|---------|----------------|----------|----------|--------------|-----------|
| <i>Nitzschia pusilla</i> GRUNOW | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Nitzschia</i> sp. 1 | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| <i>Nitzschia</i> sp. 2 | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Peronia</i> sp. 1 | 0 | 0 (1) | 0 | 0 | 0 | 0 | 0 |
| <i>Peronia</i> sp. 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 (1) |
| <i>Planothidium lanceolatum</i> (BRÉBISSON ex KÜTZING) LANGE-BERTALOT | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Pinnularia</i> cf. <i>sinistra</i> | 0 | 0 | 0 | 0 | 0 (1) | 0 | 0 |
| <i>Pinnularia</i> cf. <i>transversiformis</i> | 0 | 0 | 0 (1) | 0 (2) | 0 (4) | 0 | 0 |
| <i>Pinnularia</i> sp. 1 | 0 | 0 | 0 (1) | 0 | 0 (1) | 0 | 0 |
| <i>Stephanocyclus meneghiniana</i> (KÜTZING) SKABITSHEVSKY | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Stauroneis phoenicenteron</i> (NITZSCH) EHRENBERG | 0 (2) | 0 | 0 | 0 (1) | 0 (1,4) | 0 | 0 |
| <i>Surirella minuta</i> BRÉBISSON | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Synedra ulna</i> (NITZSCH) EHRENBERG | 0 | 0 | 0 | 0 (1) | 0 (1,2) | 0 | 0 |
| <i>Trybrionella</i> sp. 2 | 0 | 0 (1) | 0 | 0 | 0 (1,2) | 0 | 0 (1) |
| unidentified centric diatom | 0 | 0 | 0 | 0 (1) | 0 | 0 | 0 |
| unidentified pennate diatom | 0 | 0 | 0 (2) | 0 (1) | 0 | 0 (1) | 0 |
| Chlorophyta | | | | | | | |
| <i>Cylindrocapsa geminella</i> WOLLE | 0–4 | 0–4(5) | 0–3 (4–6) | 0 | 0 | 0 (3) | 0 (2) |
| <i>Microspora</i> sp.1 (5–8 um) | 0 (2,4,5,6) | 0 | 0 (3) | 0 (2) | 0 | 0 (2) | 0 |
| <i>Microspora</i> sp.2 (more 10 um) | 0, 4 (7) | 0 | 0 (3) | 0 | 0 | 0 | 0 |
| <i>Sphaerococcomyxa</i> sp. | 0 | 0 | 0 | 0 (3) | 0 (2) | 0 (2) | 0 (2,3,5) |
| <i>Oedogonium</i> sp. | 0 (2,4) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Trentepohlia</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0,2 |
| Streptophyta | | | | | | | |
| Klebsormidiales | | | | | | | |
| <i>Klebsormidium</i> cf. <i>flaccidum</i> | 0 | 0 | 0 (2) | 0 | 0 | 0 | 0 |
| Desmidiiales | | | | | | | |
| <i>Actinotaenium cucurbita</i> (BRÉBISSON ex RALFS) TEILING | 0–2 | 0 (1,2) | 0–2 | 0–3(4,5) | 0–2(4,5) | 0–2 (3,4) | 0 |
| <i>Actinotaenium</i> cf. <i>cucurbita</i> f. <i>minus</i> | 0 (1) | 0 (1) | 0 | 0 | 0 (1) | 0 (1) | 0 |
| <i>Actinotaenium</i> cf. <i>diplosporum</i> | 0–1(2) | 0 | 0–2 (3,4,5) | 0–2 | 0 (1,2) | 0 (1) | 0 |
| <i>Actinotaenium</i> cf. <i>globosum</i> | 0 | 0 | 0–1(2) | 0 (2) | 0 (2) | 0–1 | 0 |
| <i>Actinotaenium</i> cf. <i>obcuneatum</i> | 0 | 0 | 0 | 0 | 0 (1) | 0 (1) | 0 |
| <i>Actinotaenium</i> cf. <i>palangula</i> | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Actinotaenium</i> cf. <i>subpalangula</i> | 0(2,3,4) | 0 | 0 | 0 | 0 | 0(1,2) | 0 |
| <i>Cosmarium</i> cf. <i>contractum</i> | 0 (1,2) | 0 | 0–1(2,3) | 0 | 0 | 0 | 0 |
| <i>Cosmarium</i> cf. <i>impressulum</i> | 0 (1) | 0 | 0 (1,2) | 0 | 0 | 0 | 0 |
| <i>Cosmarium</i> cf. <i>laeve</i> | 0–1 | 0 | 0 (1) | 0 | 0–1 | 0 (1,2) | 0 |
| <i>Cosmarium</i> cf. <i>regnelli</i> | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Cosmarium obtusatum</i> (SCHMIDLE) SCHMIDLE | 0–1(2) | 0 | 0–1 | 0 | 0 | 0 | 0 |
| <i>Cosmarium</i> sp.1 | 0–1 | 0 | 0 | 0 | 0 | 0 | 0 |

Table S1 Cont.

| | | | | | | | |
|---|----------------|-----------|----------------|---------|-----------|---------|---|
| <i>Cosmarium</i> sp.2 | 0 | 0 | 0 (1) | 0 | 0 | 0 | 0 |
| <i>Cosmarium</i> sp.3 | 0 (1) | 0 | 0 (1,2) | 0 | 0 | 0 | 0 |
| <i>Cosmarium tinctum</i> var. <i>intermedium</i> NORDSTEDT | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Euastrum humbertii</i> var. <i>brasiliense</i> FÖRSTER | 0 (2) | 0 | 0 (1,2) | 0 (2) | 0,2 | 0 | 0 |
| <i>Euastrum macrocephalum</i> FÖRSTER et ECKERT | 0 (1) | 0 | 0 | 0 (1) | 0 (1) | 0 | 0 |
| <i>Euastrum sublobatum</i> BRÉBISSEON ex RALFS | 0 (1,2) | 0 | 0(2,3) | 0 (1,2) | 0 | 0 | 0 |
| <i>Euastrum subbinale</i> GUTWINSKI | 0 (1) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Euastrum</i> sp. | 0–1 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Ichtyocercus longispinus</i> (BORGE) KRIEGER | 0–1 | 0 | 0 (1) | 0 | 0 (1) | 0 (1) | 0 |
| <i>Micrasterias arcuata</i> BAILEY | 0 (1,2) | 0 | 0–3 | 0–1(2) | 0 (1) | 0 (1) | 0 |
| <i>Netrium oblongum</i> (DE BARY) LÜTKEMÜLLER | 0 | 0 (1) | 0–1(2) | 0 | 0 (1,2) | 0 (1,2) | 0 |
| <i>Staurastrum cosmarioides</i> NORDSTEDT | 0 (1) | 0 | 0 (1) | 0 (1) | 0 | 0 | 0 |
| <i>Staurastrum elongatum</i> BARKER | 0 | 0 | 0–1 | 0 | 0 | 0 | 0 |
| <i>Staurastrum</i> cf. <i>quadrispinatum</i> | 0 (1,2) | 0 | 0–1(2) | 0 | 0 | 0 | 0 |
| <i>Staurastrum</i> cf. <i>teliferum</i> | 0 | 0 | 0–1(2) | 0 | 0 | 0 | 0 |
| <i>Staurastrum hystrix</i> RALFS | 0 | 0 | 0–1 | 0 | 0 | 0 | 0 |
| <i>Staurastrum pseudozonatum</i> var. <i>minutissimum</i> FÖRSTER | 0 (1) | 0 | 0–2 (3) | 0 (1,2) | 0–1 (2) | 0 (1,2) | 0 |
| <i>Stauroidesmus</i> cf. <i>calyxoides</i> | 0 | 0 | 0 (1,2) | 0 | 0 (2,3,5) | 0 (2) | 0 |
| <i>Stauroidesmus</i> cf. <i>wandae</i> | 0 (1) | 0 | 0–2 | 0 | 0 | 0 | 0 |
| <i>Stauroidesmus extensus</i> (BORGE) TEILING | 0 (1) | 0 | 0–1 | 0 | 0 | 0 | 0 |
| <i>Stauroidesmus omearii</i> (ARCHER) TEILING | 0 (1,2) | 0 | 0–2 | 0 | 0 (2) | 0–1(2) | 0 |
| <i>Stauroidesmus</i> sp. | 0 (1) | 0 | 0–2 | 0 | 0 | 0 | 0 |
| <i>Tetmemorus laevis</i> KÜTZING ex RALFS | 0 | 0 | 0 | 0 | 0 | 0 (1) | 0 |
| <i>Vincularia roraimaeae</i> FUČÍKOVÁ et KAŠTOVSKÝ | 0 (1,2,3,6) | 0(4) | 0 | 0 | 0 | 0 | 0 |
| Zygnematales | | | | | | | |
| <i>Mougeotia</i> sp. steril 1 | 0,3,4(5,6) | 0,3(5,6) | 0 (2,3,5) | 0(4) | 0 (3) | 0(4) | 0 |
| <i>Mougeotia</i> sp. steril 2 | 0(5) | 0,4(5) | 0 | 0 | 0 | 0 | |
| <i>Zygnema</i> sp. steril 1 | 0 (3,4) | 0 | 0 | 0(4) | 0 | 0 | 0 |
| <i>Zygnema</i> sp. steril 2 | 0(4) | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Zygogonium</i> sp. steril | 0 (4,5,6) | 0,4,5 (3) | 0,4 (3,5,7) | 0(3) | 0(2) | 0(4,5) | 0 |
| Dinophyta | | | | | | | |
| <i>Gloeodinium</i> sp. | 0 | 0 | 0(2) | 0 | 0 | | 0 |
| Euglenophyta | | | | | | | |
| <i>Euglena</i> sp. | 0 | 0 | 0* | 0 | 0 | 0 | 0 |
| Rhodophyta | | | | | | | |
| <i>Batrachospermum</i> sp. | 0 (7) | 0 | 0 | 0 | 0 | 0 | 0 |

Fig. S1: Desmids I: (1) *Cylindrocystis brebissonii*; (2) *Mesotaenium endlicherianum*; (3) *Netrium digitus*; (4) *Actinotaenium cucurbita*; (5) *Actinotaenium* cf. *diplosporum*; (6) *Actinotaenium* cf. *lobosum*; (7) *Actinotaenium* cf. *subpalangula*; (8) *Actinotaenium* cf. *obcuneatum*; (9) *Cosmarium* cf. *pseudobengalense*; (10) *Cosmarium obtusatum*; (11) *Cosmarium* sp.1.; (12) *Cosmarium* cf. *laeve*; (13, 14) *Actinotaenium* cf. *cucurbita* f. *minus*; (15) *Cosmarium tinctum* var. *intermedium*; (16) *Cosmarium regnelli*; (17) *Cosmarium* sp.2.; (18) *Cosmarium* sp.3.; (19) *Euastrum* sp. 1.; (20) *Euastrum sublobatum*; (21) *Euastrum subbinale*; (22) *Euastrum macrocephalum*; (23) *Euastrum humberitii* var. *brasiliense*; (24) *Vincularia roraimae*. Scale bar 10 μ m.

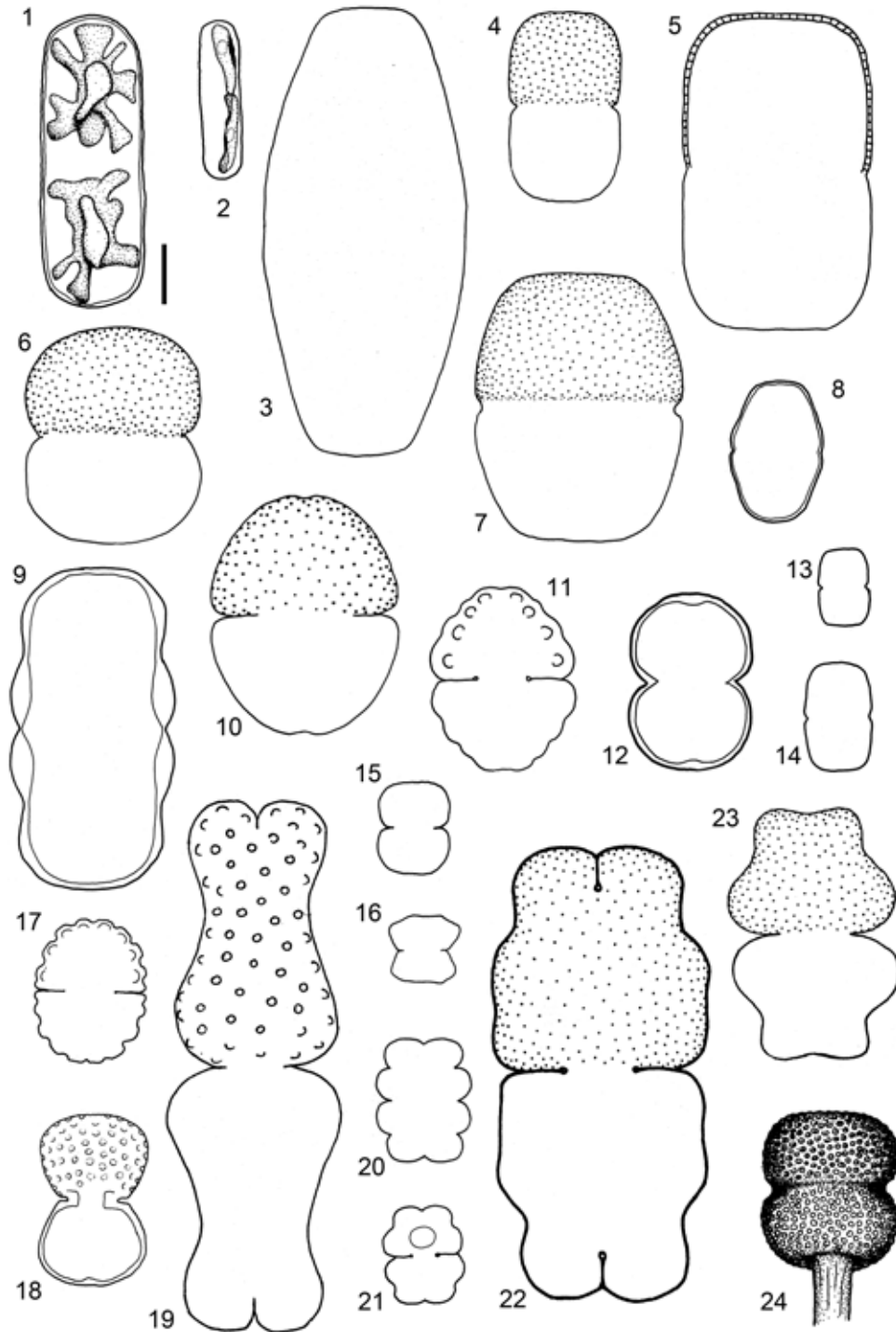


Fig. S2: Desmids II: (1) *Micrasterias arcuata* – unidentified variety; (2) *Micrasterias arcuata* var. *robusta* f. *goyazensis*; (3) *Micrasterias arcuata* var. *compacta*; (4) *Micrasterias arcuata* var. *borgei*; (5, 6) *Ichthyocercus longispinus*; (7) *Staurodesmus extensus* var. *vulgaris*; (8) *Staurodesmus omearii*; (9) *Staurastrum cosmarioides*; (10) *Staurastrum pseudozonatum* var. *minutissimum*; (11) *Staurodesmus calyxoides*; (12) *Staurodesmus* cf. *wandae* – apical view hexaradiate, (13) *Staurodesmus* cf. *wandae* – apical view pentaradiate; (14) *Staurodesmus* cf. *wandae*; (15) *Staurastrum hystrix*; (16) *Staurastrum elongatum*; (17) *Staurastrum* cf. *quadrispinatum*; (18) *Staurastrum* cf. *teliferum*. Scale bar 10 μ m.

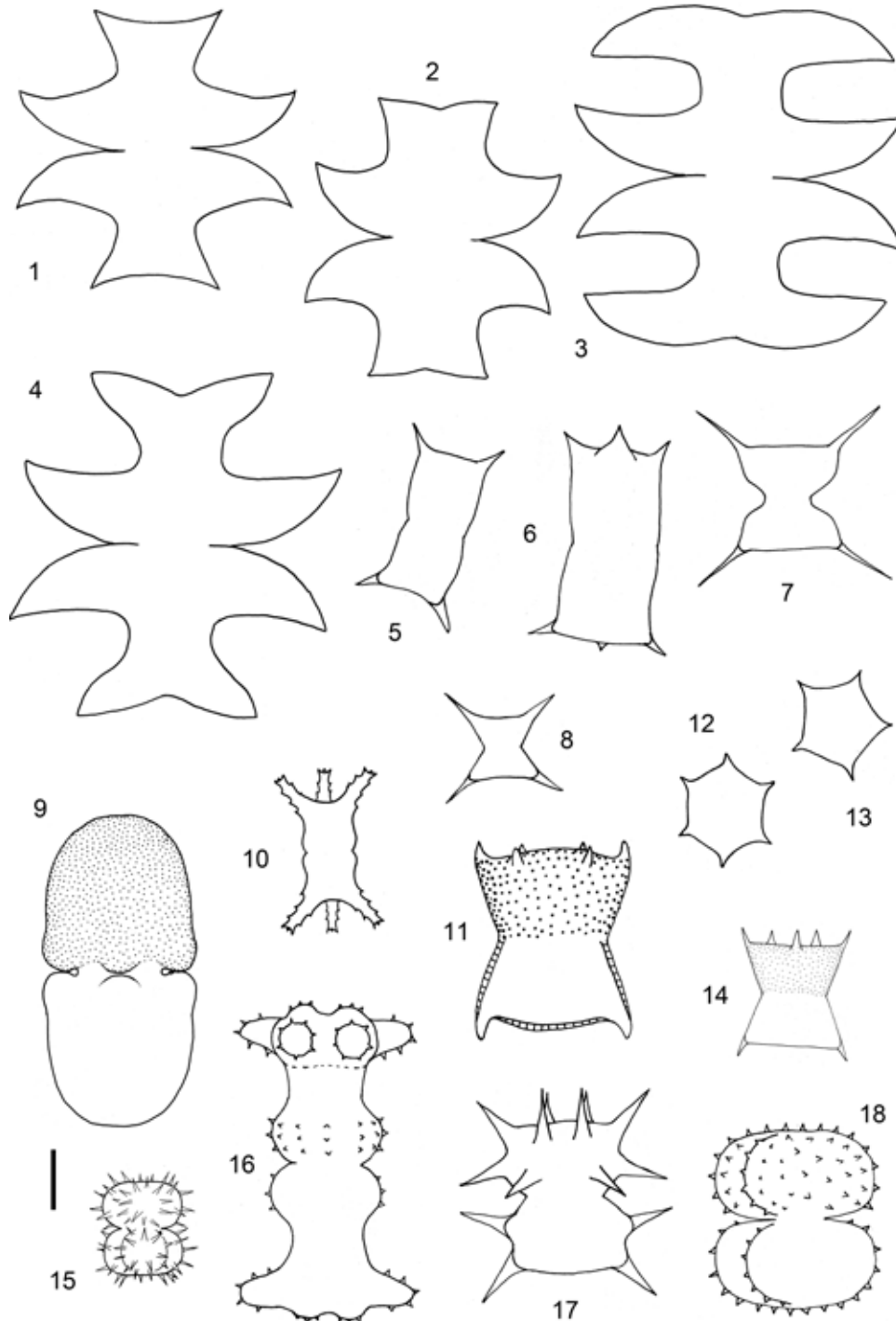


Fig. S3. Diatoms I: (1) *Eunotia acutuariola*; (2) *Eunotia fennica*; (3) *Eunotia noerpeliana*; (4) *Eunotia* sp. 6; (5) *Eunotia* cf. *geniculata*; (6) *Eunotia gibbosa*; (7) *Actinella subperenoides*; (8) *Peronia* sp. 1; (9) *Peronia* sp. 2; (10) *Amphora* sp.; (11) *Encyonopsis* sp. 1; (12) *Encyonema sparsipunctatum*; (13) *Eunotia* sp. 7; (14) *Eunotia* sp. 4; (15) *Eunotia* sp. 9; (16) *Eunotia* sp. 8; (17) *Eunotia* sp. 1. Scale bar 10 μ m.

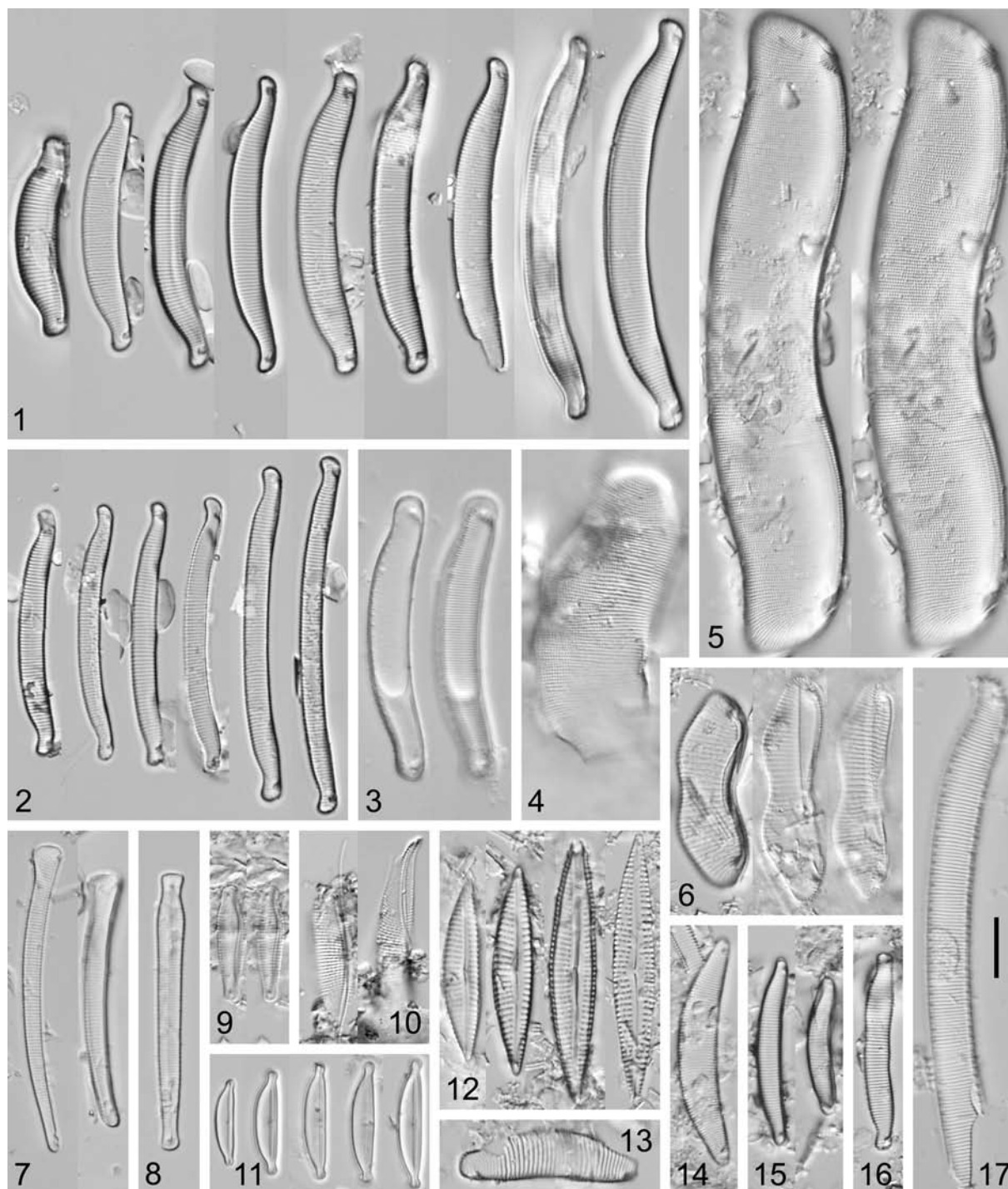


Fig. S4. Diatoms II: (1) *Brachysira rostrata*; (2) *Brachysira serians*; (3) *Brachysira* sp. 1; (4) *Luticola muticopsis*; (5) *Brachysira brebissonii*; (6) *Luticola* sp.; (7) *Nitzschia fonticola*; (8) *Nitzschia amphibia*; (9) *Frustulia pararhomboides* var. *pararhomboides*; (10) *Frustulia undosa*; (11) *Mastogloia* sp.; (12) *Kobayasiella pseudosubtilissima*; (13) *Kobayasiella* cf. *micropunctata*; (14) *Hantzschia amphioxys*; (15) *Fragilarioforma spinulosa*; (16) *Nitzschia pusilla*; (17) *Nitzschia hantzschiana*; (18) *Nitzschia palea*; (19) *Gomphonema micropus* var. *micropus*; (20) *Tryblionella* sp. 2; (21) *Pinnularia* cf. *transversiformis*. Scale bar 10 μm .

