



How diverse are coccoid cyanobacteria? A case study of terrestrial habitats from the Atlantic Rainforest (São Paulo, Brazil)

WATSON ARANTES GAMA JR.^{1,4}, HAYWOOD DAIL LAUGHINGHOUSE IV^{2,3} & CÉLIA LEITE SANT'ANNA¹

¹ Institute of Botany, Núcleo de Pesquisa em Ficologia, C.P. 3005, 1031-970 São Paulo, SP, Brazil

² Department of Biological Sciences, Smith College, Northampton, MA 01063, USA

³ Department of Botany, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013, USA

⁴E-mail: watsonarantes@gmail.com (corresponding author)

Abstract

The present study analyzed 267 samples of terrestrial habitats from different fragmented areas of the Atlantic Rainforest located in São Paulo State (southeastern Brazil), finding 61 taxa of coccoid cyanobacteria, 21 of which we were only capable of identifying at the generic level. The samples were examined using light microscopy and populations were morphometrically separated and taxonomically identified. Among the identified taxa, we propose the elevation of *Chroococcus turgidus* var. *subviolaceus* to *Chroococcus subviolaceus* comb. et stat. nov. Due to the high species richness found, we assume that the Atlantic Rainforest is a 'hotspot' of coccoid cyanobacterial diversity and should be better studied, in addition to other tropical ecosystems and terrestrial habitats, which have been shown to be suitable places for cyanobacterial diversity establishment.

Key Words: Brazilian forest, Chroococcales, cyanobacterial biodiversity, *combinatio nova*, *status novus*

Introduction

Coccoid cyanobacteria have historically been understood as presenting the 'simplest' morphology among cyanobacteria, since they cannot form 'true' filaments or specialized cells (heterocytes and/or akinetes). However, this idea underestimates these organisms, whose complexity extends beyond simple spherical or elongated cells and colonies. Despite their inability to form true filaments, these bacteria vary widely in colonial shape and they also have a complex process of cell division, such as asymmetrical, multiple and binary fission in different planes (Kováčik 1988, Komárek & Anagnostidis 1998). In addition, many taxa have complex life cycles, with different morphotypes, which can overlap in distinct genera/species, leading to misinterpretations (e.g. *Asterocapsa/Gloeocapsa/Gloeocapsopsis*) (Komárek 1993). These points, together with the difficulty in recognizing diacritical features are obstacles in identifying coccoid cyanobacteria. Moreover, the greatest variability of coccoid shapes and morphotypes are not found in aquatic sites, but mainly in terrestrial environments, which remain poorly investigated. This leads to a gap in the knowledge of these organisms, and hinders reconstructing true biogeographic and systematic scenarios. In terrestrial environments, cyanobacteria are widespread and play a crucial role as primary producers and pioneers, preparing the soil for subsequent colonization and biofilm establishment (Gorbushina 2007). Coccoid cyanobacteria are frequently dominant, compressing and sedimenting particles, mainly due to their excessive mucilage production (Golubic & Abed 2010). There is still a paucity of studies on tropical biodiversity, since most studies have been undertaken in temperate zones. Researchers have demonstrated over the past century the vast richness of coccoid species in the tropical zone (Fritsch 1907, Wille 1914, Printz 1921, Gardner 1927, Skuja 1949). Interestingly, a recent metagenomic study showed that unicellular and colonial cyanobacteria are abundant in tropical biofilms (Gaylarde *et al.* 2012), and they also dominate these habitats more frequently in tropical Latin America than in continental Europe (Gaylarde & Gaylarde 2005).

Among tropical and subtropical zones, the Atlantic Rainforest is highlighted as one of the most diverse biomes on Earth, considered a hotspot for biodiversity and should be conserved (Myers *et al.* 2000). The wide variability of distinct and particular landscapes in this ecosystem can explain the high number of endemic organisms, which is also true for microorganisms, including cyanobacteria. Twenty-two articles containing three new genera, 43 new species,

and three new varieties indicate the endemicity of these bacteria from Atlantic Rainforest terrestrial habitats (Sant'Anna 1988, Sant'Anna & Silva 1988, Silva & Sant'Anna 1988, Azevedo 1991, Sant'Anna *et al.* 1991a, 1991b, 2007, 2010, 2011a, 2011c, 2013, Azevedo & Sant'Anna 1993, 1994a, 1994b, Branco *et al.* 1994, 2006, Azevedo & Kováčik 1996, Komárek 2003, Fiore *et al.* 2007, Lemes-da-Silva *et al.* 2010, Gama-Jr. *et al.* 2012, Komárek *et al.* 2013). Despite the high biodiversity, the majority of these new taxa belong to heterocytous cyanobacteria (56%) with three new genera, while coccoids are the second most species-rich group (25%) (Sant'Anna *et al.* 2011b, Gama-Jr. *et al.* 2012, Komárek *et al.* 2013). We believe coccoid richness is underestimated, since studies rarely focus on them, in comparison to other cyanobacterial groups. Thus, the aim of the present study is to report the large variability and diversity of coccoid cyanobacteria in terrestrial habitats from the Atlantic Rainforest, while discussing the main features and novelties in their taxonomy.

Materials And Methods

Localities and sampling:—Sampling was carried out on soils, rocks, tree bark, concrete, and wood from six different Atlantic Rainforest conservation areas, all located in São Paulo state, southeastern Brazil. A total of 267 samples were collected and screened using a light microscope (Zeiss, Axioplan 2). We excluded those samples that did not contain any coccoid cyanobacteria from this study.

Sample processing:—Samples were collected from the substrate with a spatula, and then dried on paper bags in sunlight. In the laboratory, the sampled specimens were rehydrated in Petri dishes with distilled water for a minimum of one day. Afterwards, they were analyzed with a light microscope, and a minimum of 30 individual cells of each population was measured using AxioVs40 v 4.8.2.0 software. In the description, the measurements are listed as length × diameter (diam.), and the extreme values are given in parenthesis. Whenever necessary, China ink or 1% methylene blue solution was used to show the mucilage. The rehydrated samples were fixed in 4% formaldehyde, and deposited in the Herbarium of the Institute of Botany (SP), São Paulo, Brazil. From some samples, strains were isolated into ASM-1 and BG-11 media as proposed by Jacinavicius *et al.* (2013). These are maintained in the Culture Collection of the Institute of Botany (CCIBt, São Paulo, Brazil) under the follow conditions: 23±1° C, 40–50 µmol photon m⁻².s⁻¹, 14–10 h light/dark.

Results

We found a total of 61 coccoid cyanobacterial taxa, with 20 only identifiable at the generic level and one at family-level. We analyzed 60 samples from a total of 267, since only these had a satisfactory number of populations for morphological study.

Family Synechococcaceae Komárek & Anagnostidis (1986: 210).

Aphanothec saxicola Nägeli (1849: 60) (Figs. 1A–1B).

Round to irregular colonies, 8.3–80.3 µm diam. Sheath gelatinous, hyaline to brownish, inconspicuous to conspicuous. Cells sparsely disposed, oblong to ellipsoidal, 2.7–4.2 × 1.5–2.6 µm, 1.5–2.4 times longer than wide. Cell content slightly granulated, blue-green.

Habitat:—Wet rocks.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427310); 24° 22.783' S, 47° 1.287' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427312); 24° 23.737' S, 47° 0.699' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427320); 24° 23.708' S, 47° 7.324' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427330).

Aphanothecce cf. castagnei (Brébisson) Rabenhorst (1865: 64) (Figs. 1C–1E).

Basionym: *Oncobryrsa castagnei* Brébisson in Kützing (1845: 9).

Round to elongated, irregular colonies, 17.8–386.1 µm diam. Sheath gelatinous, hyaline to brownish, inconspicuous to conspicuous. Cells sparsely disposed, oblong to ellipsoidal, 3.8–5.9 × 2.6–3.8 µm, 1.4–2.0 times longer than wide. Cell content slightly granulated, greyish green.

Habitat:—Wet rocks.

Notes:—Morphologically, the studied population is very similar to *Aphanothecce castagnei*. However, ecologically they are distinct and, according to Rabenhorst (1865), *A. castagnei* was found growing among submersed mosses, not on wet rocks as the present material.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427310); 24° 23.708' S, 47° 7.324' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427330).

Aphanothecce cf. densa Lemes-da-Silva, L.H.Z. Branco & Necchi-Júnior (2010: 917) (Figs. 1F–1G).

Round colonies, 20.1–48.8 µm diam. Sheath firm, hyaline to slightly brownish, conspicuous. Cells densely disposed, ellipsoidal, 3.6–4.6 × 2.6–3.7 µm, 1.3–1.6 times longer than wide. Cell content homogenous to slightly granulated, blue-green.

Habitat:—Tree bark.

Notes:—The studied population had a corticolous habitat. The colony, cell shape, and content color resembled *Aphanothecce densa*. This species was recently described based on a population found on the tree bark of a semi-deciduous forest, quite distinct from the Atlantic Rainforest. Besides, *A. densa* has larger cell dimensions (4.0–7.0 × 4.0–5.0 µm) than the presently described population (Lemes-da-Silva *et al.* 2010).

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.842' S, 47° 7.252' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427328).

Aphanothecce cf. microscopica Nägeli (1849: 59) (Figs. 1H–1I).

Round colonies, 24.6–77.8 µm diam., sub-colonies often present, 8.0–12.7 µm diam. Sheath firm, hyaline, conspicuous. Cells sparsely to densely disposed, cylindrical, rarely ellipsoid, 3.1–6.0(7.2) × 1.7–2.9 µm, 1.8–2.0 times longer than wide. Cell content slightly granulated, intense blue-green.

Habitat:—Waterlogged soil covered by vegetation.

Notes:—The studied specimens have a cell length smaller than what is proposed by Komárek & Anagnostidis (1998). Furthermore, the habitat of *Aphanothecce microscopica* is a little different (moorland freshwater). However, Desikachary (1959) reported the occurrence of *A. microscopica* in waterlogged soils from India, and Wille (1914) found this species among mosses.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401439).

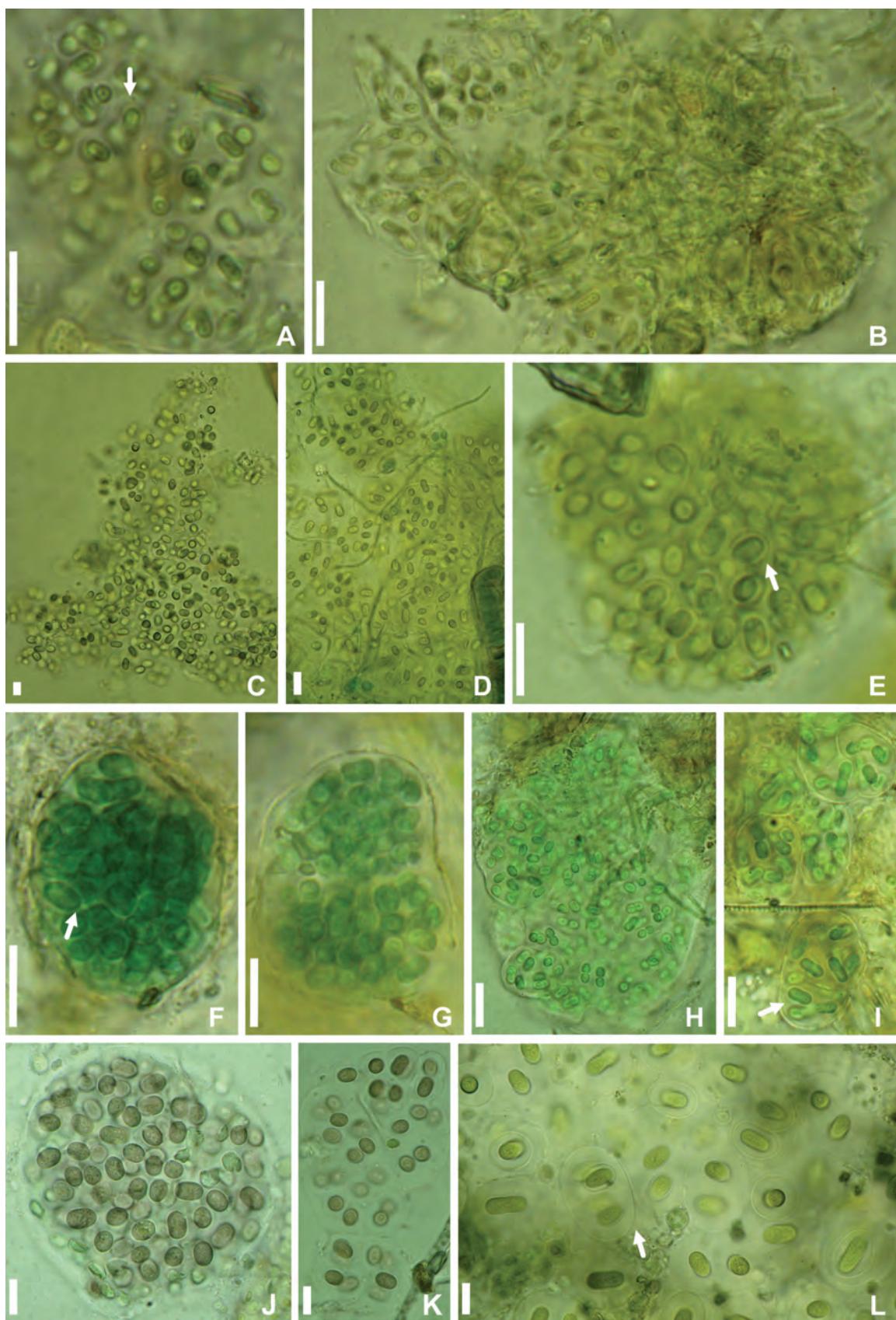
Aphanothecce sp. (Figs. 1J–1K).

Round to elongated colonies, 29.2–78.9 µm diam. Sheath firm to gelatinous, hyaline, conspicuous. Cells densely to sparsely disposed, ellipsoid, rarely cylindrical, 5.1–8.9 × 3.9–5.3 µm, 1.6–3.0 times longer than wide. Individual conspicuous cell sheaths can occur near colonial edge. Cell content granulated, pale purple.

Habitat:—Tree bark in the inner forest.

Notes:—The present population is distinct by its corticolous habitat, cell content color, dimensions and disposition. Probably, this Atlantic Rainforest *Aphanothecce* is a morphospecies new to science, and should be classified in the subgenus *Cyanogastrum* (Schiller 1956: 203) Komárek (1995: 82).

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 5' 8" S, 47° 55' 30" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401442, SP 401444).



FIGURES 1A–1B. *Aphanothece saxicola*. General colony habit with cells in an individual envelope (arrow).

FIGURES 1C–1E. *Aphanothece* cf. *castagniei*. General colony habit, with yellow-brown sheaths and a colony showing cells with individual envelope (arrow).

FIGURES 1F–1G. *Aphanothece* cf. *densa*. General colony habit and detail of an elliptic cell (arrow).

FIGURES 1H–1I. *Aphanothece* cf. *microscopica*. General colony habit and colonies with cylindrical cells and visible chromatoplasm (arrow).

FIGURES 1J–1K. *Aphanothece* sp.

FIGURES 1L. *Gloeothecae fuscolutea*.

Gloeothece fuscolutea (Nägeli) Nägeli (1849: 57) (Figs. 1L–2A).

Basionym: *Gloeocapsa fuscolutea* Nägeli ex Kützing (1849: 224).

Round to elliptical colonies, 10.7–24.0 µm diam. Sheath firm, hyaline to yellowish, conspicuous, non-lamellate to 1–4 lamellae, smooth. Cells oblong to ellipsoid, 6.7–11.1 × 3.9–5.6 µm, 1.9–2.1 times longer than wide. Cell content homogenous to slightly granulated, olive green.

Habitat:—Wet rocks and concrete wall.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 22.783' S, 47° 1.287' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427312); 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324); Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 November 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 427337).

Gloeothece interspersa Gardner (1927: 13) (Figs. 2B–2C).

Round to oblong colonies, 9.5–19.2 µm diam. Sheath firm, hyaline, conspicuous, intensely lamellate, smooth. Cells oblong to ellipsoid, 4.2–6.9 × 3–3.9 µm, 1.3–1.7 times longer than wide. Cell content finely granulated, blue-green.

Habitat:—Concrete wall.

Notes:—The cell length in the Atlantic Rainforest population was smaller than Gardner’s description for *G. interspersa*, which was 7.0–7.5 µm diam., but all other morphological features corresponded to this species, including the habitat.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.002' S, 47° 4.839' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427325).

Gloeothece rhodochlamys Skuja (1949: 18) (Figs. 2D–2G).

Round to elliptical, irregular colonies, 16.0–70.0 µm diam. Sheath firm, hyaline (rare) to orange reddish, conspicuous, concentric lamellate, finely granulated. Cells oblong to ellipsoid, 4.5–6.0(6.7) × (1.8)2.6–3.6(4.8) µm, 1.3–1.6 times longer than wide. Cell content homogeneous to finely granulated, olive green.

Habitat:—Rocky coast and dry rocks.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar”, Núcleo Santa Virgínia, 23° 20' 16" S, 45° 9' 0" W, 22 February 2010, W.A. Gama-Jr. (SP 401417); 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401428).

Gloeothece samoensis Wille (1913: 144) (Fig. 2H).

Round, oblong to elliptical colonies, 9.7–21.3 µm diam., with 2–4–8 cells, rarely more. Sheath firm to diffluent, hyaline, conspicuous, lamellate, smooth. Cells oblong to ellipsoid, 5.4–8.4 × 3.3–5.8 µm, 1.3–1.7 times longer than wide. Cell content granulated, blue-green to olive green.

Habitat:—Waterlogged soil covered by vegetation.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401439); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 22.747' S, 47° 4.729' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427323).

Gloeothece tepidariorum (A.Braun) Lagerheim (1883: 44) (Figs. 2I–2J).

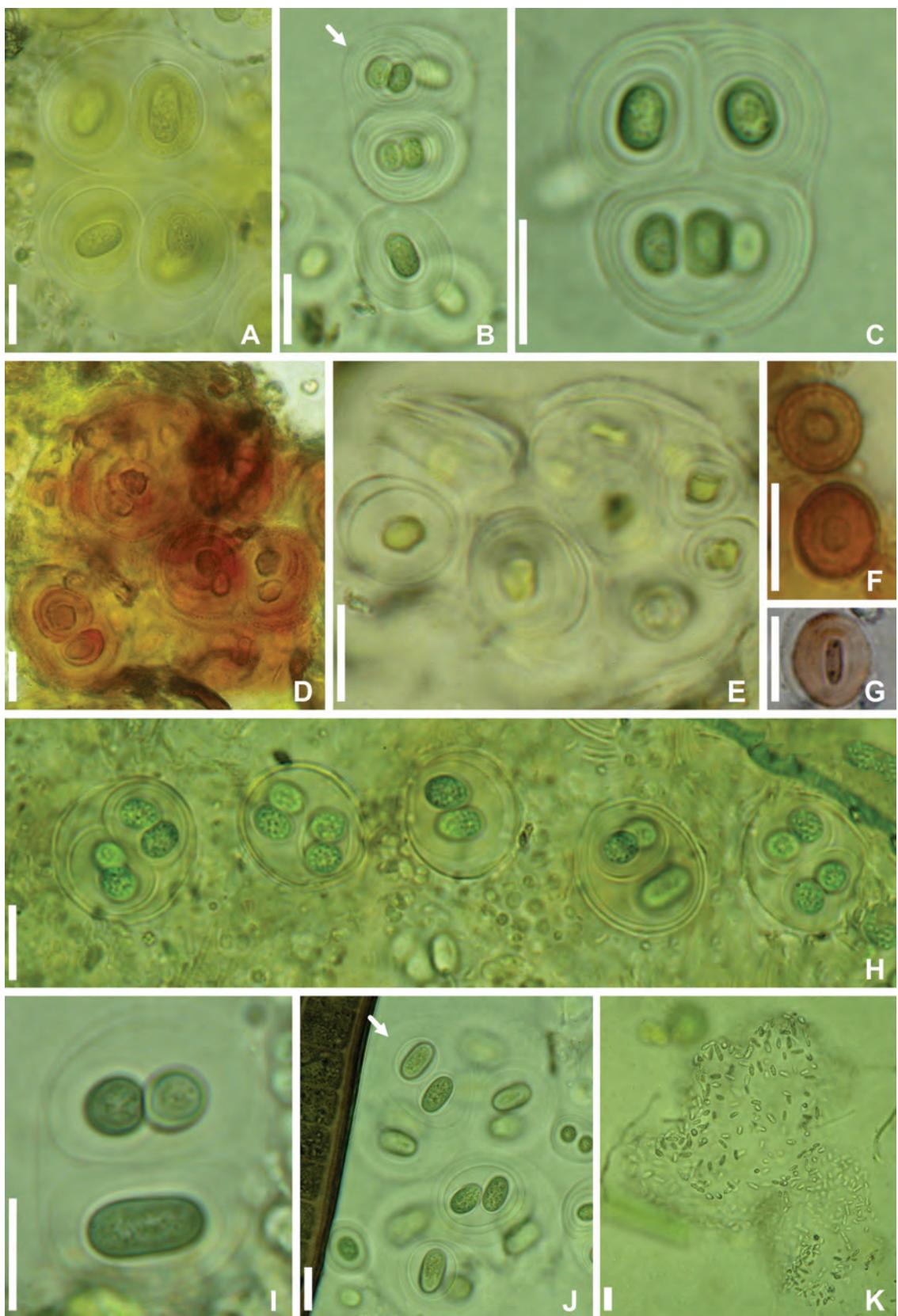
Basionym: *Gloeocapsa tepidariorum* A. Braun in Rabenhorst (1865: 38).

Round to oblong colonies, 18.9–45.7 µm diam. Sheath firm, hyaline, conspicuous, intensely lamellate, smooth to finely granulated (rare). Cells oblong to ellipsoid, 6.1–11.1 × 4.4–5.5 µm, 1.7–2.2 times longer than wide. Cell content finely granulated, greyish green to olive green.

Habitat:—Concrete wall.

Notes:—*Gloeothece tepidariorum* was found together with populations of *Gloeothece interspersa* Gardner (1927: 13), both differing mainly by cell dimensions, with *G. tepidariorum* larger than *G. interspersa*.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.002' S, 47° 4.839' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427325).



FIGURES 2A. *Gloeothecaceae fuscolutea*. General colony habit, with yellowish sheaths and a colony showing cells with an individual envelope (arrow).

FIGURES 2B–2C. *Gloeothecaceae interspersa*. General colony habit and detail of concentrically lamellate sheaths (arrow).

FIGURES 2D–2G. *Gloeothecaceae rhodochlamys*. **2D.** General colony habit with granular orange red sheaths. **2E.** General colony habit with colorless sheaths. **2F.** Resistant spores. **2G.** Detail showing a cell with concentrically lamellate sheaths.

FIGURE 2H. *Gloeothecaceae samoensis*.

FIGURES 2I–2J. *Gloeothecaceae tepidariorum*. General colony habit and detail of concentrically lamellate sheaths (arrow).

FIGURES 2K. *Lemmermanniella terrestris*.

Lemmermanniella terrestris W.A. Gama-Jr. in Gama-Jr *et al.* (2012: 320) (Figs. 2K–3A).

Hollow, round to elongated colonies, 43.7–243.7 µm diam., sub-colonies often present, 10.2–16.9 µm diam. Sheath gelatinous, hyaline, inconspicuous, following the colony outline. Cells ellipsoid, 2.5–7.1(8.8) × 1.4–2.5 µm, 2.4–3.1 times longer than wide, ends acuminate or round (rare). Pseudofilaments rarely found, 3–5 cells. Cell content granulated, pale blue-green to grey.

Habitat:—Dry soil.

Studied material:—BRAZIL. São Paulo: Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401446).

Family Merismopediaceae Elenkin (1933: 19).

Aphanocapsa intertexta Gardner (1927: 4) (Figs. 3B–3C).

Round to irregular colonies, 13.7–63.5 µm diam. Sheath gelatinous, hyaline, inconspicuous to conspicuous. Cells sparsely disposed, spherical, 2.4–3.0 µm diam. Cell content homogenous, sometimes slightly granulated, blue-green.

Habitat:—Wet rock.

Notes:—The colonies were always found mixed with other cyanobacteria, mainly trichomes of *Scytonema* Agardh ex Bornet & Flahault (1886: 85) and *Stigonema* Agardh ex Bornet & Flahault (1886: 62).

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 26.162' S, 47° 3.773' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427307); 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427310).

Aphanocapsa cf. intertexta Gardner (1927: 4) (Figs. 3D–3E).

Round to irregular colonies, 9.1–15.2 µm diam. Sheath gelatinous, hyaline, inconspicuous. Cells sparsely disposed, spherical, 1.4–2.2 µm diam. Cell content homogenous, pale blue-green.

Habitat:—Tree bark from inner forest.

Notes:—This morphotype is different from *Aphanocapsa intertexta* by having smaller cell dimensions and its habitat, since the present population was found on tree bark, while *A. intertexta* was described from rocks, among filamentous cyanobacteria.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401427).

Aphanocapsa sp. (Figs. 3F–3G).

Round colonies, 33.0–82.1 µm diam. Sheath gelatinous, hyaline, inconspicuous to slightly conspicuous. Cells sparsely disposed, spherical, 3.0–3.6 µm diam. Cell content homogenous, pale brown.

Habitat:—Tree bark.

Notes:—This population was found among bryophytes and is distinct from other *Aphanocapsa* Nägeli (1849: 52) species mainly by the corticolous habitat and cell content color.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 23.842' S, 47° 7.252' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427328).

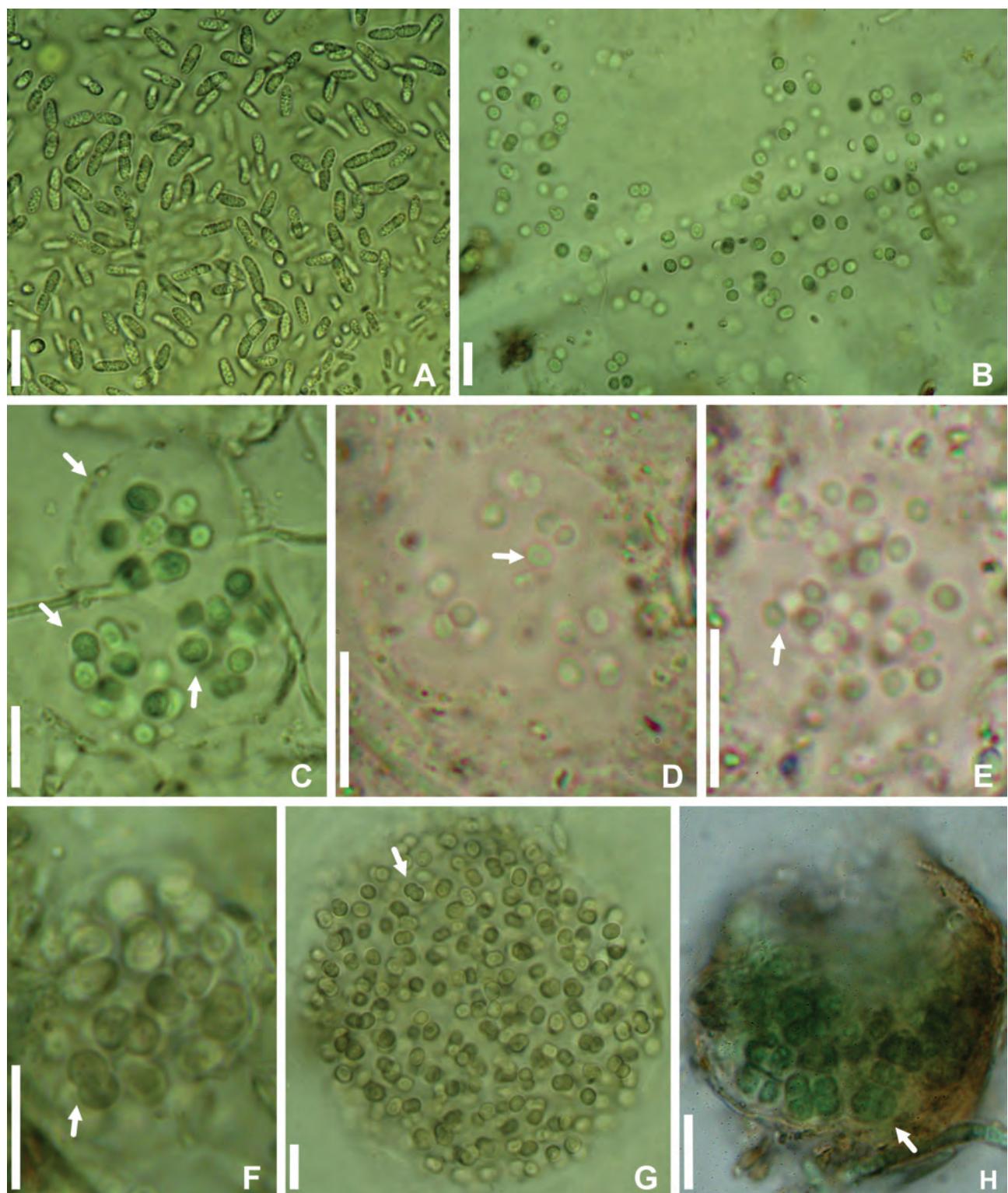
Coelosphaeriopsis sp. (Figs. 3H–4A).

Hollow, round to elliptical colonies, 12.0–106.3 µm diam. Sheath firm, hyaline, conspicuous. Cells grouped 2–4, elliptical to slightly polygonal, 2.3–3.8 µm diam., surrounded by individual hyaline sheaths. Cell content homogenous to granulated, blue-green to brown.

Habitat:—On rock covered by a water slide near a waterfall.

Notes:—*Coelosphaeriopsis* Lemmermann (1899: 352) is a rare and understudied genus, with only two species: *C. halophila* Lemmermann (1899: 352), described from saline environments, and *C. chlamydocystis* (Skuja 1964: 39) Komárek & Anagnostidis (1995: 17), found in a Swedish lake; both with habitats very different from the Atlantic Rainforest population.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401419).



FIGURES 3A. *Lemmermanniella terrestris*. General colony habit, showing cells disposed in one layer only and detail of cell morphology.
FIGURES 3B–3C. *Aphanocapsa intertexta*. General aspect of a colony without conspicuous mucilage and a conspicuous mucilage colony forming subcolonies (arrows).
FIGURES 3D–3E. *Aphanocapsa* cf. *intertexta*. Detail of cells showing visible chromatoplasm (arrows).
FIGURES 3F–3G. *Aphanocapsa* sp. General aspect of a colony and detail of cells in division, with two sub-spherical semi-cells (arrow).
FIGURES 3H. *Coelosphaeriopsis* sp.

Family Chroococcaceae Nägeli (1849: 45).

Asterocapsa aerophytica Lederer (2000: 24) (Figs. 4B–4D).

Round to elongated colonies, rarely irregular, 13.9–154.1 µm diam., isolated or in groups. Sheath firm, hyaline to reddish brown, conspicuous, rarely lamellate, granulated. Cells spherical to ellipsoid, 4.3–5.4 µm diam. Spores dark reddish brown, solitary or in groups after releasing, 5.6–6.3 µm diam. Cell content granulated, green to blue-green.

Habitat:—Dry wood.

Notes:—This species was found within a black mass growing on wood and epiphytic on *Scytonema* filaments, similar to the original habitat described by Lederer (2000).

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 26.392' S, 47° 4.536' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427304).

Asterocapsa sp. 1 (Figs. 4E–4F).

Round colonies, rarely irregular, 8.7–51.2 µm diam., isolated or in groups. Sheath firm, hyaline, conspicuous, non-lamellate, granulated. Cells ellipsoid, 3.3–5.5 × 2.3–4.0 µm. Spores not observed. Cell content granulated, pale purple.

Habitat:—Tree bark in the inner forest.

Notes:—As diacritical features, *Asterocapsa* sp. 1 has a corticolous habitat, ellipsoid cells, and hyaline and non-lamellate sheaths. *Asterocapsa hyalina* (Chu 1944: 153) Chu (1952: 100) and *Asterocapsa ocellata* H.X.Xiao (2000: 399) most resemble *Asterocapsa* sp. 1, differing by the epilithic habitat of both, and by spines on the individual sheath of *A. hyalina* and dark and verrucous cell envelopes in *A. ocellata*.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 5' 8" S, 47° 55' 30" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401442, SP 401444).

Asterocapsa sp. 2 (Figs. 4G–4I).

Round, elongated to irregular colonies, 5.5–79.7 µm diam., isolated or in groups. Sheath firm, hyaline to reddish-brown and violet, conspicuous, rarely lamellate, smooth to granulate. Cells ellipsoid to irregular, 3.8–5.7 × 2.5–3.9 µm. Spores dark reddish-brown, solitary, 5.4–7.4 × 3.5–5.6 µm. Cell content granulated, green to blue-green.

Habitat:—Dry concrete wall.

Notes:—*Asterocapsa* sp. 2 is a peculiar morphotype since the granulation in its sheaths are rarely observed, seen only under immersion (1000x). Despite this, the Atlantic Rainforest population has the typical life cycle described for *Asterocapsa* Chu (1952: 97), and differs from other species by sheath color, elliptical shape, and cell dimensions.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324); 24° 22.739' S, 47° 4.719' W, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427333); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401440, SP 401438).

Chroococcus subviolaceus (Wille) Gama-Jr., Laughinghouse IV & Sant’Anna, comb. et stat. nov. (Figs. 4J–4L).

Basionym: *Chroococcus turgidus* var. *subviolaceus* Wille in Hedwigia 53: 144. 1913.

Elliptical to irregular colonies, 13.0–48.0 µm diam., 2–4–8–16 celled, rarely more. Sheath firm, hyaline, conspicuous, slightly or non-lamellate, smooth. Cells ellipsoid, hemispherical to polygonal, (6.1)7.2–10.4(17.1) µm diam. Cell content homogeneous to granulated, brown-purple to purple.

Habitat:—Rocks near a waterfall and concrete.

Notes:—*Chroococcus turgidus* var. *subviolaceus* Wille (1913: 144) was first found growing on rocks, among *Plectonema* and *Tolypothrix* trichomes, in Samoa (Wille 1914). The features differing this variety from *C. turgidus* (Kützing 1846: 5) Nägeli (1849: 46) are the purple cell content, epiphytic habitat, non-lamellate sheath, and the smaller cell diameter. These characteristics are sufficient to classify *Chroococcus turgidus* var. *subviolaceus* as a separate

species from *C. turgidus*. According to the Atlantic Rainforest material, we suspect that *C. subviolaceus* is very common in tropical terrestrial habitats of humid forests. Komárek & Anagnostidis (1998) considered this variety a synonym of *Chroococcus westii* Boye-Petersen (1923: 263). However, this species was first described in small Iceland lakes, and besides the habitat, Boye-Petersen (1923) mentioned that *C. westii* is quite different from *C. turgidus* var. *subviolaceus* by its larger cell diameter and by the sheaths being distinctly lamellate. We are not in agreement with the proposal by Komárek & Anagnostidis (1998) and propose the new status of this variety.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 23.737' S, 47° 0.699' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427320); 24° 22.694' S, 47° 4.793' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427321); 24° 22.685' S, 47° 4.797' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427322); 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324); 24° 23.708' S, 47° 7.324' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427330); 24° 22.739' S, 47° 4.719' W, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427333).

***Chroococcus tenax* (Kirchner) Hieronymus (1892: 483) (Figs. 5A–5B).**

Basionym: *Chroococcus turgidus* var. *tenax* Kirchner (1878: 262).

Round to elliptical colonies, 18.0–54.7 µm diam., 2–4(8–16) celled. Sheath firm, hyaline, conspicuous, intensely lamellate, smooth. Cells ellipsoid to hemispherical after division, 12.7–20.7 µm diam. Cell content granulated, blue-green to olive green.

Habitat:—Waterlogged soil.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401439).

***Chroococcus varius* A. Braun in Rabenhorst (1876: 2451) (Fig. 5C).**

Round, elliptical to irregular colonies, 8.8–12.2 µm diam., 2–4–8–16 celled. Sheath firm, hyaline to brown, conspicuous, non-lamellate, smooth. Cells spherical to hemispherical, 3.2–4.6(5.1) µm diam. Cell content homogeneous to slightly granulated, blue-green to yellowish.

Habitat:—Wet rocks.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427310).

***Chroococcus cf. minor* (Kützing) Nägeli (1849: 47) (Figs. 5D–5E).**

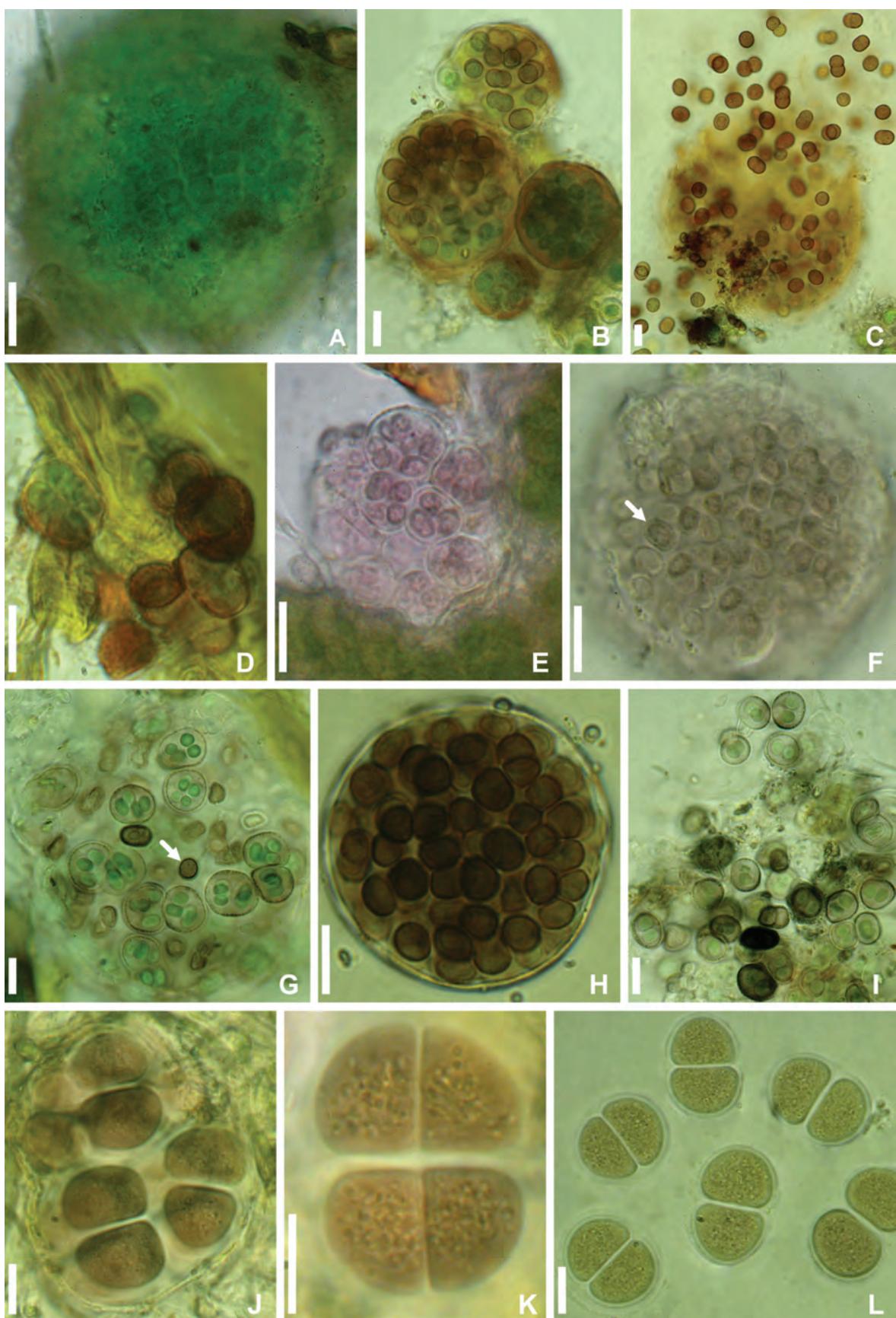
Basionym: *Protococcus minor* Kützing (1845: 144).

Irregular colonies, 8.6–24.2 µm diam., 2–4–8 celled. Sheath diffluent, hyaline, inconspicuous, homogeneous, smooth. Cells spherical to hemispherical, 2.8–3.4 µm diam. Cell content homogeneous to slightly granulated, blue-green.

Habitat:—Dry soil.

Notes:—*Chroococcus minor* is probably a polyphyletic species, since it is reported for distinct environments (Komárek & Anagnostidis 1998). Kützing (1845) predicted this variability when he described three different varieties for *C. minor*, separating them by habitat. Hence, the population found in the Atlantic Rainforest is similar to var. *mucosus* Kützing (1849: 198), since both grow on soils, a habitat not related to the typical *C. minor*. However, the use of varieties in cyanobacteria seems contradictory, since even a species concept is not well defined (Johansen & Casamatta 2005). Moreover, these varieties were never used, not cited by Nägeli (1849) or any other author thereafter.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401425); Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401446).



FIGURES 4A. *Coelosphaeriopsis* sp. General aspect of a colony and detail of cells in individual envelopes (arrow).

FIGURES 4B–4D. *Asterocapsa aerophytica*. **4B.** General colonial aspect. **4C.** Released spores. **4D.** Colonies growing on a filament of *Scytonema*.

FIGURES 4E–4F. *Asterocapsa* sp. 1. **4E.** General colonial aspect. **4F.** Detail of a cell with a granulated sheath (arrow).

FIGURES 4G–4I. *Asterocapsa* sp. 2. **4G.** Mature colony forming spores (arrow) and young colonies. **4H.** Agglomerate of young colonies.

4I. Colony with cells densely packed and surrounded by colored sheaths.

FIGURES 4J–4L. *Chroococcus subviolaceus*. **4J.** Isolated cells. **4K.** General colony habit. **4L.** Cells in tetrad arrangement.

Chroococcus cf. turgidus (Kützing) Nägeli (1849: 46) (Figs. 5F–5G).

Basionym: *Protococcus turgidus* Kützing (1846: 5).

Elliptical colonies, 17.7–25.8 × 13.4–16.8 µm, 2–4 celled, rarely more. Sheath firm, hyaline, conspicuous, non-lamellate, smooth. Cells hemispherical, rarely elliptical, 7.8–14.1 µm diam. Cell content granulated, blue-green to olive green.

Habitat:—Dry soil.

Notes:—*Chroococcus turgidus* is a problematic species. Kützing (1846) described this species with a wider cell diameter, 20.0–71.4 µm (1/100–1/28"'), converted as proposed by Stearn (1992)), and did not indicate the habitat, only separating two varieties by color. Nowadays, there are many different related species/varieties similar to *C. turgidus*, but none of them are typically terrestrial, which makes the Atlantic Rainforest population distinguishable from *C. turgidus* and its relatives.

Studied material:—BRAZIL. São Paulo: Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401446).

Chroococcus cf. varius A. Braun in Rabenhorst (1876: 2451) (Figs. 5H–5I).

Round, elliptical to irregular colonies, 8.8–17.4 µm diam., 2–4–8 celled, forming packets. Sheath firm, hyaline, conspicuous, distinctly lamellate to non-lamellate, smooth. Cells spherical to hemispherical, 2.5–4.2 µm diam. Cell content homogeneous to slightly granulated, olive green to yellowish.

Habitat:—Dry wood and tree bark.

Notes:—The present population is different from *C. varius* in relation to habitat, since it was found on wood and it is typically described from rocks (Komárek & Anagnostidis 1998).

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401420); 23° 20' 12" S, 45° 8' 44" W, 23 February 2010, W.A. Gama-Jr. (SP 401421); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 46" S, 47° 55' 8" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401441).

Cyanosarcina sp. (Figs. 5J–5L).

Irregular packed and rare colonies, isolated cells often present. Sheath firm to diffused, hyaline to dark red, conspicuous to inconspicuous, non-lamellate, smooth. Cells spherical, hemispherical to irregular, (4.4)5.2–6.7 µm diam. Cell content homogeneous to slightly granulated, brownish purple.

Habitat:—Dry concrete wall.

Notes:—This morphotype resembles both the genera *Cyanosarcina* Kováčik (1988: 175) and *Chroococcus* Nägeli (1849: 45). With the first, it has the giant sarcinoid cells in common, formed by successive divisions. With the second, this population shares the isolated cell shape and the colored sheaths. In spite of this, we chose to keep this material identified as *Cyanosarcina* due to ‘giant cells’ (Fig. 5K), which are not described in *Chroococcus*. We judge this to be a more relevant character than sheath color, since envelopes only color in senescent stages. However, we do not discard the possibility that this population is a new genus, distinct from both. This morphotype was only found in culture.

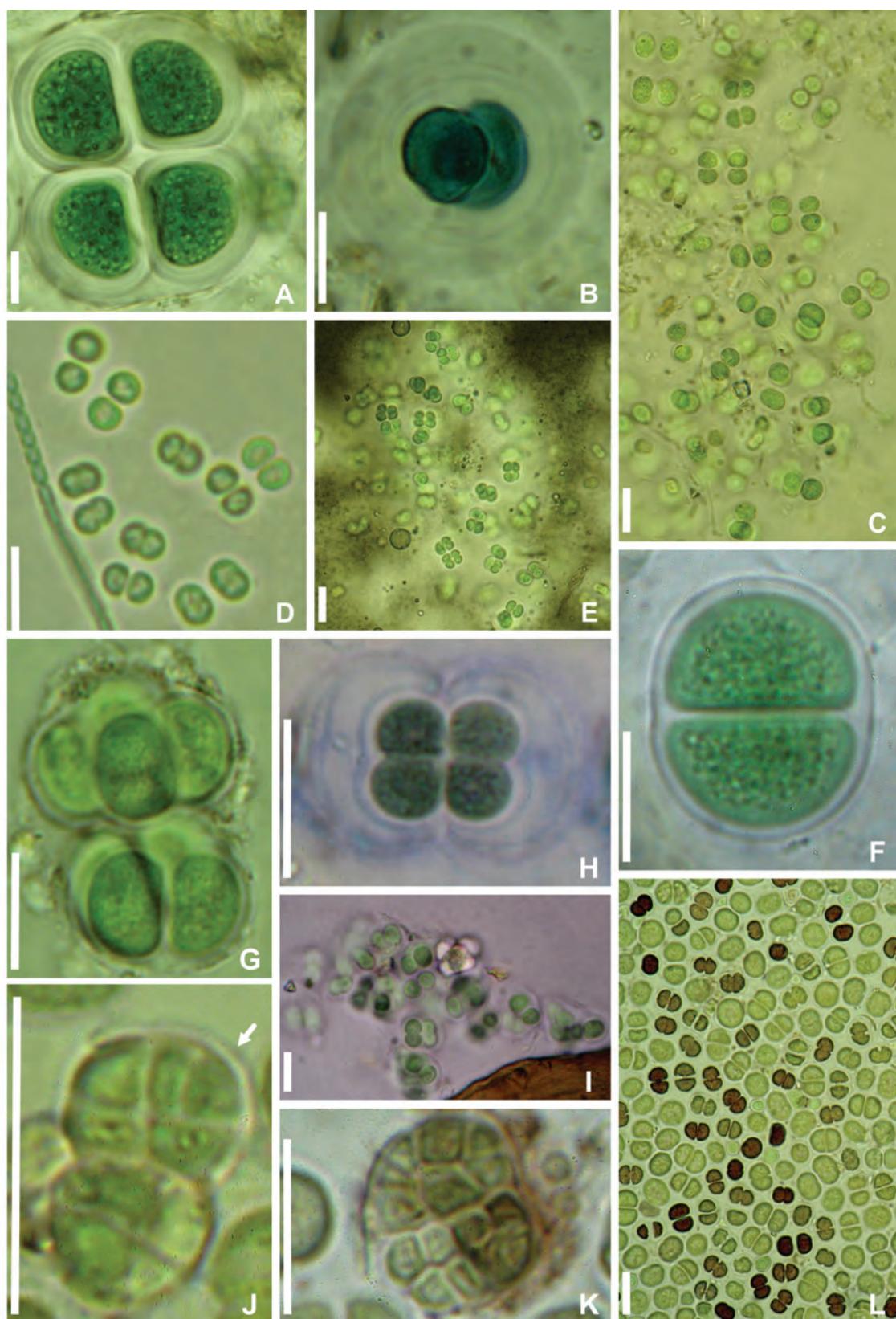
Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401439).

Cyanostylon gelatinosus Azevedo & Sant’Anna (1994a: 76) (Figs. 6A–6D).

Dendroid to irregular, dense gelatinous colonies, 3–50 celled, to more. Mucilaginous stalks tubular, round to elliptical, branched, firm, hyaline, conspicuous, lamellate, 5.7–8.4 µm diam. Cells spherical, (1.2)1.5–2.7(3.2) µm diam., 1–2 disposed at the stalk end. Cell content homogeneous, blue-green.

Habitat:—Cave wet walls.

Studied material:—BRAZIL. São Paulo: Ubatuba, “Sununga” Beach (Gruta-que-chora), 23° 31' S, 45° 8' W, 12 April 2003, M.T. Fujii et al. (SP 401448).



FIGURES 5A–5B. *Chroococcus tenax*. **5A.** General colony habit highlighting the lamellated sheaths. **5B.** Desiccated cell showing concentrically lamellate sheaths and blue color.

FIGURE 5C. *Chroococcus varius*

FIGURES 5D–5E. *Chroococcus* cf. *minor*. **5E.** Colony sheath highlighted by China ink.

FIGURES 5F–5G. *Chroococcus* cf. *turgidus*

FIGURES 5H–5I. *Chroococcus* cf. *varius*. General colony habit and detail of a colony dyed with methylene blue solution, highlighting the lamellate sheath.

FIGURES 5J–5L. *Cyanosarcina* sp. **5J.** Detail of cell in a successive division (arrow). **5K.** Cell after consecutive divisions—‘giant cell’. **5L.** General colony habit, *Chroococcus*-like.

Cyanostylon cf. *gelatinosus* Azevedo & Sant'Anna (1994a: 76) (Fig. 6E).

Dendroid, dense gelatinous colonies, 3–30 celled, rarely more. Mucilaginous stalks tubular, round to elliptical, simple, firm, hyaline to slightly brown, conspicuous, lamellate, 3.1–7.5 µm diam. Cells spherical, 1.7–2.4 µm diam., 1–2 disposed at the stalk end. Cell content homogeneous, pale blue-green.

Habitat:—Concrete wet walls.

Notes:—*Cyanostylon gelatinosus* was described from caves at the seafront, different from the habitat where the present population was found, which is on concrete directly exposed to sunlight near the forest. Despite the habitat, they are morphologically similar, except for stalk color, which can be brown in *C. cf. gelatinosus* and is always hyaline in *C. gelatinosus* (Azevedo & Sant'Anna 1994).

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401423).

Cyanostylon sp. (Figs. 6F–6G).

Dendroid, stratified, dense gelatinous colonies, 8–50 celled, often more. Mucilaginous stalks tubular, short, round to elliptical, simple, firm, hyaline to slightly brown and purple, conspicuous, lamellate, 8.0–9.5 × 3.1–7.5 µm. Cells spherical, (2.5)3.0–4.5 µm diam., 1–4 disposed at the stalk end. Cell content homogeneous, pale olive-green.

Habitat:—Wet rocks near a waterfall.

Notes:—This population is similar to *Stilocapsa lilacina* Xiu & H.X. Xiao (2004: 206), mainly due to the coloration and structure of the colonies, and also the cell diameter. They differ in relation to the cell content and stalk diameter, which are respectively granulated and wider in *S. lilacina* (15.0–26.0 µm diam.). However, this species is invalidly published since the authors did not designate a type (as well as a habitat). Since *Stilocapsa* Ley (1947: 77) is synonymous to *Cyanostylon* Geitler (1928a: 441), we maintained the Atlantic Rainforest population as *Cyanostylon* sp.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.708' S, 47° 7.324' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427330); 24° 23.703' S, 47° 7.330' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant'Anna (SP 427331).

Endospora rubra Gardner (1927: 28) (Figs. 6H–6I).

Sarcinoid to irregular colonies, 13.0–51.2 µm diam., sub-colonies paired with each other. Sheath firm, hyaline to rusty red, conspicuous, lamellate to non-lamellate, finely granulated. Cells polygonal, (4.4)6.5–9.5(16.3) µm diam. Cell content granulated, blue-green.

Habitat:—Wet rocks and dry roof.

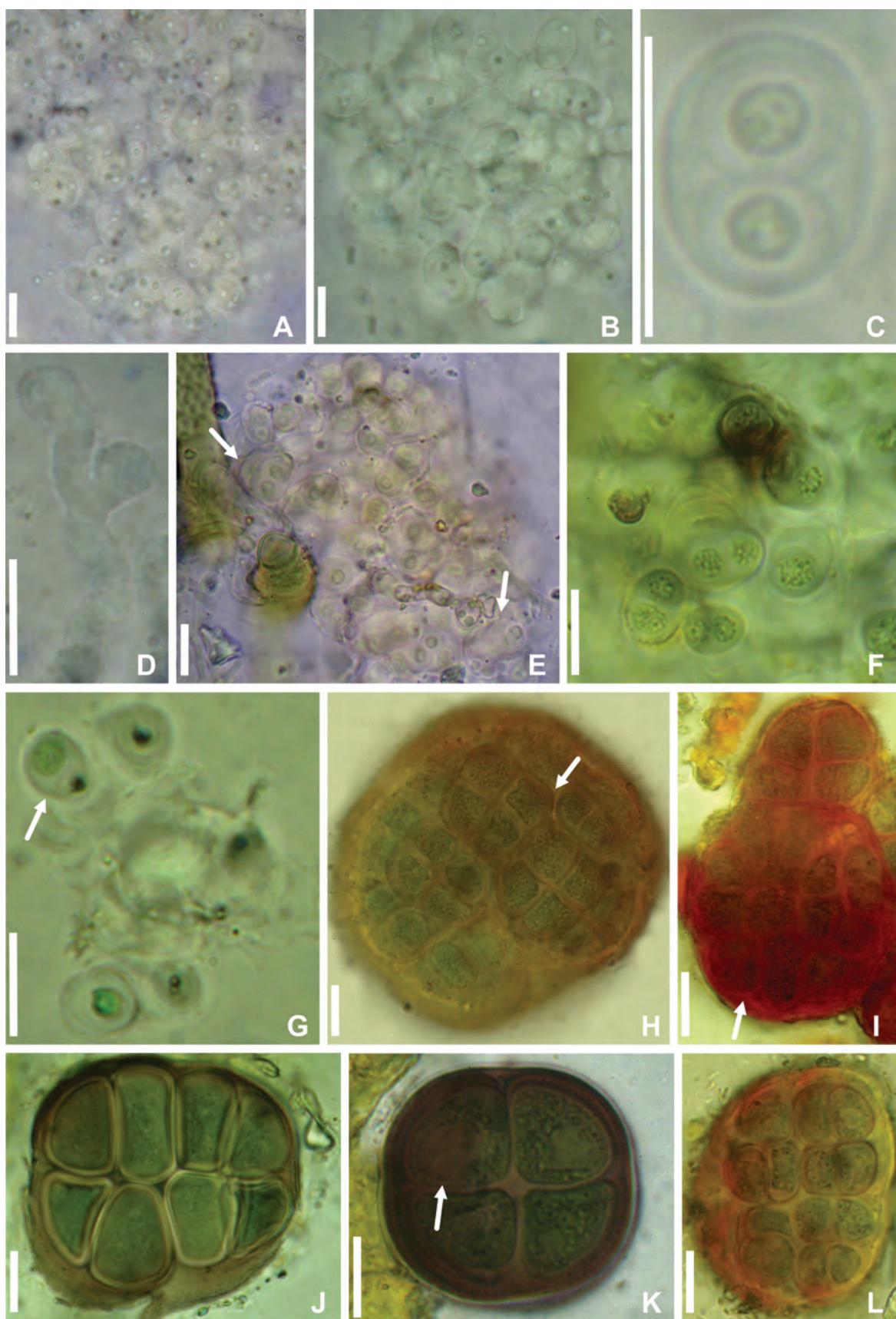
Notes:—Bourrelly (1970) considered *Endospora rubra* in the genus *Myxosarcina* Printz (1921: 35). However, neither this author, nor Gardner (1927), described the typical baeocyte formation for this species, which is diacritical in *Myxosarcina*. Komárek & Anagnostidis (1998) suggested that *E. rubra* belonged to the genus *Cyanosarcina* Kováčik (1988: 175), since this species had the typical sarcinoid colonial arrangement. However, *Cyanosarcina* is not described as having colored envelopes, which is typical for *E. rubra*. The genus *Gloeocapsopsis* Geitler ex Komárek (1993: 23) has all these features: 1) the sarcinoid arrangement of colonies; 2) the colored sheaths; and 3) the formation of resistant cells by thickening of cell envelopes when they are inside the colony. Based on morphological features and since baeocytes were never found in the Brazilian material, we suggest that *E. rubra* truly belongs to the genus *Gloeocapsopsis*. However, due to lack of information on the phylogenetic position of *Gloeocapsopsis* and its related genera like *Cyanosarcina* and *Asterocapsa* Chu (1952: 97), we choose not to synonymize these taxa yet.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 01" W, 22 February 2010, W.A. Gama-Jr. (SP 401418); 23° 20' 10" S, 45° 8' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401434).

Gloeocapsopsis chroococcoides (Nováček) Komárek (1993: 24) (Figs. 6J–6K).

Basionym: *Gloeocapsa chroococcoides* Nováček (1934: 100, 139).

Sarcinoid, round to elongated colonies, rarely irregular, 15.5–50.0 µm diam., sub-colonies absent. Sheath firm, violet-rosy to dark violet, conspicuous, rarely lamellate, smooth to finely granulated. Cells ellipsoid, hemispherical to polygonal, 10.1–16.8 µm diam. Cell content granulated, blue-green to olive green, a vacuole-like body frequently present.



FIGURES 6A–6D. *Cyanostylon gelatinosus*. **6C.** Cells detail. **6D.** Mucilage stalk detail.

FIGURE 6E. *Cyanostylon cf. gelatinosus*. General colony habit with detail of mucilage stalks (arrows).

FIGURES 6F–6G. *Cyanostylon* sp. **6G.** Mucilage stalk detail (arrow).

FIGURES 6H–6I. *Endospora rubra*. General colony habit with cell packets showing individual envelopes (arrows).

FIGURES 6J–6K. *Gloeocapsopsis chroococcoides*. **6K.** Colonies showing vacuole-like structures (arrow).

FIGURES 6L. *Gloeocapsopsis dvorakii*. Colony collected from a rock.

Habitat:—Dry concrete wall.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401425); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401438); 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401440); São Paulo, Institute of Botany, 23° 38' 32" S, 46° 37' 21" W, 29 November 2011, W.A. Gama-Jr. (SP 427335).

Gloeocapsopsis dvorakii (Nováček) Komárek & Anagnostidis ex Komárek (1993: 24) (Figs. 6L–7B).

Basionym: *Gloeocapsa dvorakii* Nováček (1929: 1).

Sarcinoid, round to irregular colonies, 11.0–134.4 µm diam., sub-colonies present, overlapping. Sheath firm, orange to rusty red, conspicuous, slightly lamellate, smooth to finely granulated. Cells ellipsoid, hemispherical to polygonal, 3.5–9.2 µm diam. Cell content granulated, blue-green.

Habitat:—Dry rope and roof, and wet rocks.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401432); 23° 20' 10" S, 45° 8' 44" W, W.A. Gama-Jr. (SP 401433); 23° 20' 10" S, 45° 8' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401434); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 12" S, 47° 55' 27" W, 26 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401436).

Gloeocapsopsis sp. 1 (Figs. 7C–7E).

Sarcinoid, round to irregular colonies, 14.6–159.4 µm diam., sub-colonies often present, overlapping. Sheath firm, hyaline to orange, rusty red, conspicuous, lamellate, finely granulated. Cells ellipsoid, hemispherical to polygonal, 6.1–10.6 µm diam. Cell content granulated, blue-green to olive-green.

Habitat:—Dry tree bark.

Notes:—The studied population is morphologically similar to *G. dvorakii* and *G. magma* (Brébisson in Brébisson & Godey 1835: 40) Komárek & Anagnostidis ex J. Komárek (1993: 24). Usually, these species do not have lamellate sheaths and the coloration pattern found in *Gloeocapsopsis* sp. 1 is different than the other species of *Gloeocapsopsis*. These features were consistently observed in all three populations found in the Atlantic Rainforest. Except for *G. ferruginea* Komárek & Watanabe (1998: 123), which was found epiphytic on filamentous algae in a lake, all *Gloeocapsopsis* species are described from rocks, a different habitat than the analyzed material.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401424); 23° 20' 36" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401429); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.018' S, 47° 4.847' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427326).

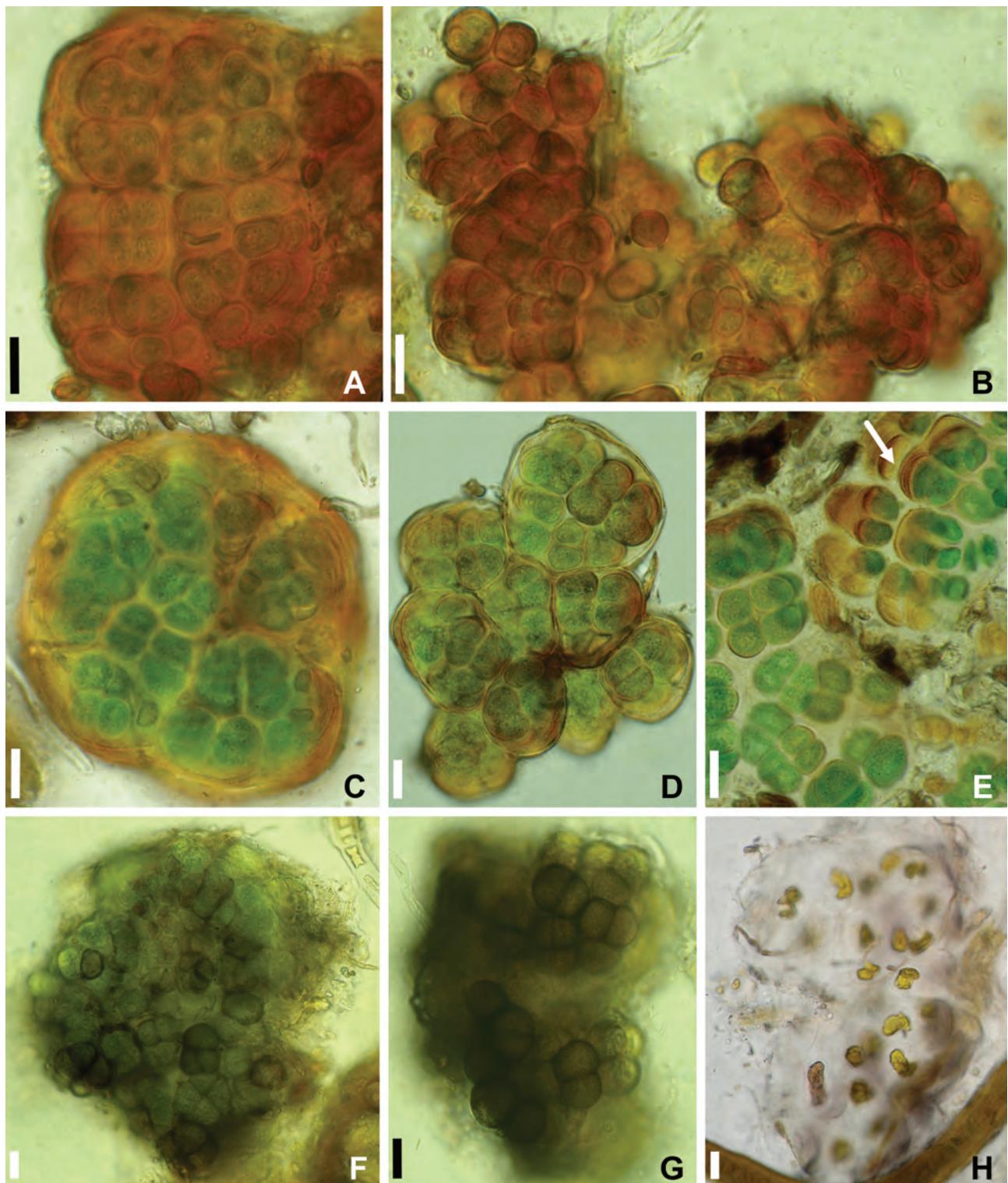
Gloeocapsopsis sp. 2 (Figs. 7F–7H).

Sarcinoid, round, elongated to irregular colonies, 71.7–123.2 µm diam., sub-colonies present, overlapping. Sheath firm, hyaline (rare) to dark-brown, conspicuous, non-lamellate, smooth. Cells irregularly spherical, ellipsoid, hemispherical, 6.7–10.6 µm diam. Cell content hardly granulated, olive-green.

Habitat:—Wet rocks.

Notes:—The population found was distinguishable from other *Gloeocapsopsis* species by the colonial arrangement, cell shape, and sheath color. Moreover, the cells were not polygonal and their content was intensely granulated, which is not seen in the other *Gloeocapsopsis*.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 12" S, 47° 55' 27" W, 26 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 427336).



FIGURES 6L–7B. *Gloeocapsopsis dvorakii*. **6L.** Colony collected from a rock. **7A.** Colony collected from a rope. **7B.** Colony collected from a roof.

FIGURES 7C–7E. *Gloeocapsopsis* sp. 1. General colony habit and detail of lamellate sheaths.

FIGURES 7F–7H. *Gloeocapsopsis* sp. 2. **7H.** Colony with hyaline sheath and dry cells.

Nephrococcus shilinensis Tian in Tian *et al.* (2001: 280) (Figs. 8A–8C).

Sarcinoid, round to elongated colonies to irregular, 25.4–340.0 µm diam., sub-colonies present, 2–4–8–16 celled, overlapping. Sheath firm, orange to red, more intense in inner layers, conspicuous, lamellate, finely granulated. Cells reniform to ellipsoid, (3.3)8.1–10.4(15.5) µm diam. Cell content finely granulated, blue-green to olive green.

Habitat:—Wet rocks.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401418).

Pseudocapsa dubia Ercegović (1925: 95) (Figs. 8D–8E).

Round to irregular colonies, 8.0–33.0 µm diam., sub-colonies present. Sheath firm, hyaline to brown, conspicuous, non-lamellate, smooth. Cells spherical, hemispherical to irregular, 2.0–4.0 µm diam., radially arranged in mature colonies. Cell content homogeneous, blue-green to yellow.

Habitat:—Wet walls in a cave.

Studied material:—BRAZIL. São Paulo: Ubatuba, “Sununga” Beach (Gruta-que-chora), 23° 31' S, 45° 8' W, 12 April 2003, M.T. Fujii et al. (SP 401448).

Pseudocapsa sp. (Figs. 8F–8G).

Isolated or composed colonies formed by round to irregular sub-colonies, 6.4–12.5 µm diam. Sheath firm, hyaline to dark brown, conspicuous, non-lamellate, smooth. Cells hemispherical to irregular, 2.9–4.4 µm diam., radially arranged in mature colonies. Cell content homogeneous, pale blue-green.

Habitat:—Dry wood.

Notes:—This population resembles *P. dubia* differing mainly by habitat, which is a wet cave wall for *P. dubia* and dry wood for *Pseudocapsa* sp.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 12" S, 45° 8' 44" W, 23 February 2010, W.A. Gama-Jr. (SP 401421).

Family Microcystaceae Elenkin (1933: 19).

Chondrocystis dermochroa (Nägeli) Komárek & Anagnostidis (1995: 17) (Fig. 8H).

Basionym: *Gloeocapsa dermochroa* Nägeli (1849: 51).

Sarcinoid colonies to irregular, 26.5–64.3 µm diam., sub-colonies densely packed. Sheath firm, hyaline, conspicuous, homogeneous, smooth. Cells spherical to hemispherical, 1.8–2.4 µm diam. Cell content homogeneous, blue-green.

Habitat:—Rocks covered by a water slide near a waterfall.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401419).

Gloeocapsa compacta Kützing (1845: 24) (Figs. 8I–9A)

Round, elliptical to irregular colonies, 7.3–168.8 µm diam., 2–4–8 celled, rarely more. Sheath firm in outer layer, diffused in inner, brown to purple, conspicuous, rarely lamellate, smooth to slightly granulated. Cells spherical to hemispherical, 4.3–5.4 µm diam. Cell content homogenous to sparsely granulated, blue-green. Spores dark orange, solitary or in groups after released, 3.3–4.0 µm diam.

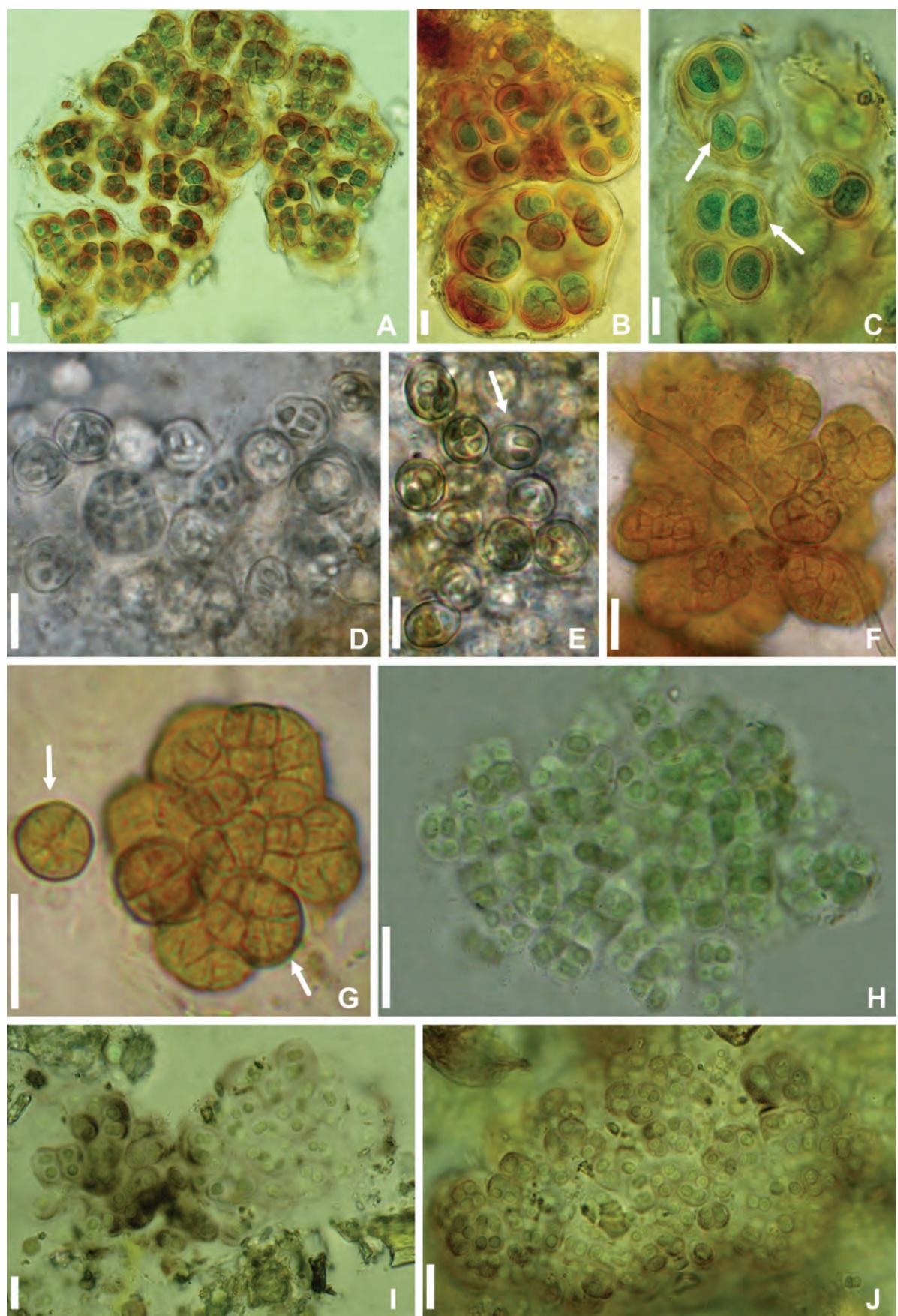
Habitat:—Tree bark and dry rocks.

Studied material:—BRAZIL. São Paulo: Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401447); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.018' S, 47° 4.847' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427326).

Gloeocapsa nigrescens Nägeli in Rabenhorst (1857: 629) (Figs. 9B–9D).

Round colonies, rarely elongated, 7.3–44.8 µm diam., 2–4–8–16 celled, rarely more. Sheath firm, hyaline to bluish or blackish, conspicuous, rarely lamellate, granulated. Cells spherical to slightly elongated, 3.2–5.4 µm diam. Cell content homogenous to sparsely granulated, blue-green to olive green. Spores elongated to irregular, dark-grey, roughly granulated, solitary or in pairs, 5.8–7.7 µm diam.

Habitat:—Dry and wet concrete walls.



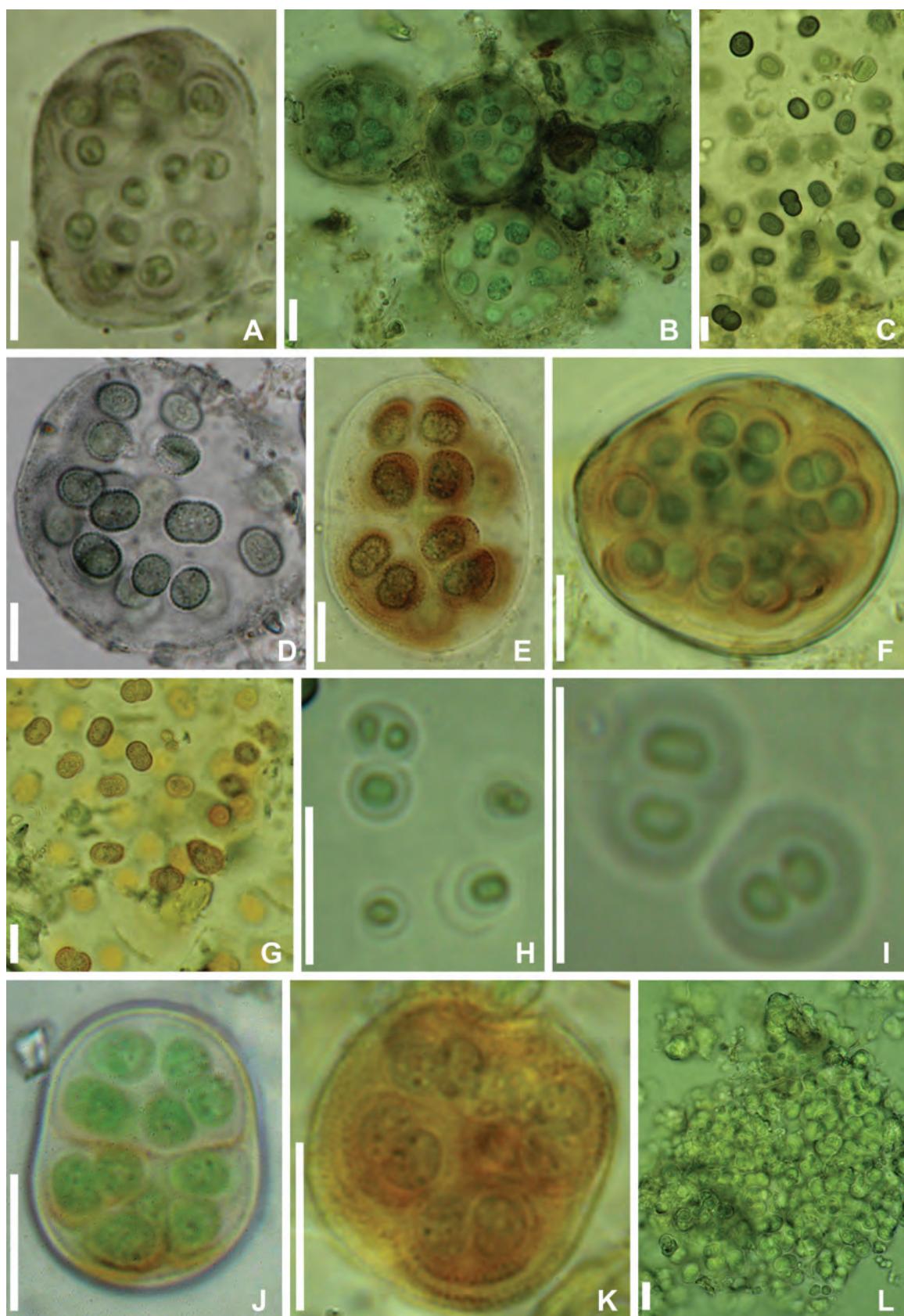
FIGURES 8A–8C. *Nephrococcus shilinensis*. General colony habit and detail of reniform cells (arrows).

FIGURES 8D–8E. *Pseudocapsa dubia*. General colony habit with colonies showing brown sheaths (arrow).

FIGURES 8F–8G. *Pseudocapsa* sp. General colony habit and cells in fan disposition, which is typical from *Pseudocapsa* (arrow).

FIGURE 8H. *Chondrocystis dermochroa*.

FIGURES 8I–8J. *Gloeocapsa compacta*. **8I.** Colony collected from a rock. **8J.** Colony collected from tree bark.



FIGURES 9A. *Gloeocapsa compacta*. Colony collected from a tree bark.

FIGURES 9B–9D. *Gloeocapsa nigrescens*. **9B.** General mature colony habit. **9C.** Released spores. **9D.** Spores inside the colony.

FIGURES 9E–9G. *Gloeocapsa novacekii*. **9E–9F.** Variability of colonial morphology. **9G.** Released spores.

FIGURES 9H–9I. *Gloeocapsa punctata*.

FIGURES 9J–9K. *Gloeocapsa stegophila*. **9J.** General aspect of colonies found on rocks. **9K.** General aspect of colonies found on tree barks.

FIGURES 9L. *Gloeocapsa* sp. 1.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401425); 23° 20' 10" S, 45° 8' 44" W, 24 February 2010 W.A. Gama-Jr. (SP 401435); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401438); 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401437); 25° 4' 08" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401440) 25° 5' 8" S, 47° 55' 30" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401445); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 26.420' S, 47° 4.588' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427305); 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324) 24° 22.739' S, 47° 4.719' W, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427333).

***Gloeocapsa novacekii* Komárek & Anagnostidis (1995: 19) (Figs. 9E–9G).**

Round colonies, rarely elongated, 9.6–174.4 µm diam. Sheath firm, hyaline to rosy or dark red, conspicuous, lamellate or non-lamellate, finely granulated. Cells spherical to slightly elongated, 2.7–5.2(6.4) µm diam. Cell content granulated, pale blue-green to blue-green. Spores elongated to irregular, dark red, roughly granulated, solitary or in pairs, 4.6–5.8 µm diam.

Habitat:—Dry and wet concrete walls.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401418); 23° 20' 10" S, 45° 8' 44" W, 24 February 2010 W.A. Gama-Jr. (SP 401435); Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401438); 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401440); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 26.420' S, 47° 4.588' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427305); 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427310); 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324); 24° 22.739' S, 47° 4.719' W, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427333).

***Gloeocapsa punctata* Nägeli (1849: 51) (Figs. 9H–9I).**

Round, elliptical to irregular colonies, 3.8–13.8 µm diam., 2–4–8 celled, rarely more. Sheath firm to diffused, hyaline, conspicuous, rarely lamellate, smooth. Cells spherical to hemispherical, 1.4–2.2 µm diam. Cell content homogenous, blue-green. Spores not observed.

Habitat:—Dry concrete wall.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.013' S, 47° 4.836' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427324).

***Gloeocapsa stegophila* (Itzigsohn) Rabenhorst (1863: 72) (Figs. 9J–9K).**

Basionym: *Monocapsa stegophila* Itzigsohn in Rabenhorst (1853: 263a).

Round to elongated colonies, 7.2–32.8(57.7) µm diam., 2–4–8 celled, rarely more. Sheath firm, hyaline to dark orange, conspicuous, rarely lamellate, smooth to slightly granulated. Cells spherical to hemispherical, (2.8)3.2–3.9(4.2) µm diam. Cell content homogenous to sparsely granulated, blue-green. Spores not observed.

Habitat:—Tree bark and dry rocks.

Notes:—This species differs from *Gloeocapsa rupicola* Kützing (1849: 221) by the pattern of colonial coloration, which is dark reddish in the inner part and almost hyaline at the edge of the colonies (Komárek & Anagnostidis 1998). The cell diameter is also smaller in *G. rupicola*.

Studied material:—BRAZIL. São Paulo: Cananéia, “Recanto do Mar” Inn, 25° 1' 16" S, 47° 55' 31" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401447); Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.018' S, 47° 4.847' W, 17 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427326).

Gloeocapsa sp. 1 (Figs. 9L–10B).

Round, elliptical to irregular colonies, 3.7–18.3(107.8) μm diam., 2–4–8 celled, rarely more. Sheath firm, hyaline to slightly navy-blue, conspicuous, lamellate or not, smooth. Cells spherical to hemispherical, elongated after division, 1.2–2.2 μm diam. Cell content homogenous, olive-green. Spores not observed.

Habitat:—Tree bark.

Notes:—The population from the Atlantic Rainforest was similar to *Gloeocapsa punctata* Nägeli (1849: 51), due to the morphometry of colonies and cells. However, it differs from *G. punctata* by habitat (rocks/concrete), cell content color, and that the sheaths are always hyaline. *Gloeocapsa atrata* Kützing (1843: 174) is another morphologically similar species, though *Gloeocapsa* sp. 1 differs by having smaller cells and a different habitat, since *G. atrata* occurs on wet rocks (Komárek & Anagnostidis 1998).

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 5' 8" S, 47° 55' 30" W, 30 November 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401442).

Gloeocapsa sp. 2 (Fig. 10C).

Elliptical to irregular colonies, 7.8–73.2 μm diam., 2–4 celled, rarely more. Sheath firm to diffused, hyaline to brown and purple, conspicuous, lamellate or not, smooth to slightly granulated. Cells spherical to hemispherical, elongated after division, (2.6)3.1–3.8 μm diam. Cell content homogenous or with disperse little granules, blue-green. Spores not observed.

Habitat:—Tree bark.

Notes:—*Gloeocapsa* sp. 2 most resembles *Gloeocapsa lignicola* Rabenhorst (1865: 41) and *Gloeocapsa compacta* Kützing (1847: 24), differing by the bluish color of colonies in the former, and the smaller cell diameter in the latter.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401426).

Family Entophysalidaceae Geitler (1925: 235).

Chlorogloea cf. *novacekii* Komárek & Montejano (1994: 6) (Figs. 10D–10E).

Polarized, elongated colonies, 58.3–95.0 μm length. Sheath firm to diffused, hyaline, conspicuous, non-lamellate, smooth. Cells spherical, 2.6–3.2 μm diam., to cylindrical 1.3–1.9 × 2.7–3.3 μm , arranged in rows. Cell content homogenous or 2–4 granules per cell, pale blue-green.

Habitat:—Wet rocks.

Notes:—*Chlorogloea novacekii* was described from a wet cave with a mean temperature lower than 20 °C (Komárek & Montejano 1994), different than the environmental conditions found in the Atlantic Rainforest.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 16" S, 45° 9' 1" W, 22 February 2010, W.A. Gama-Jr. (SP 401418).

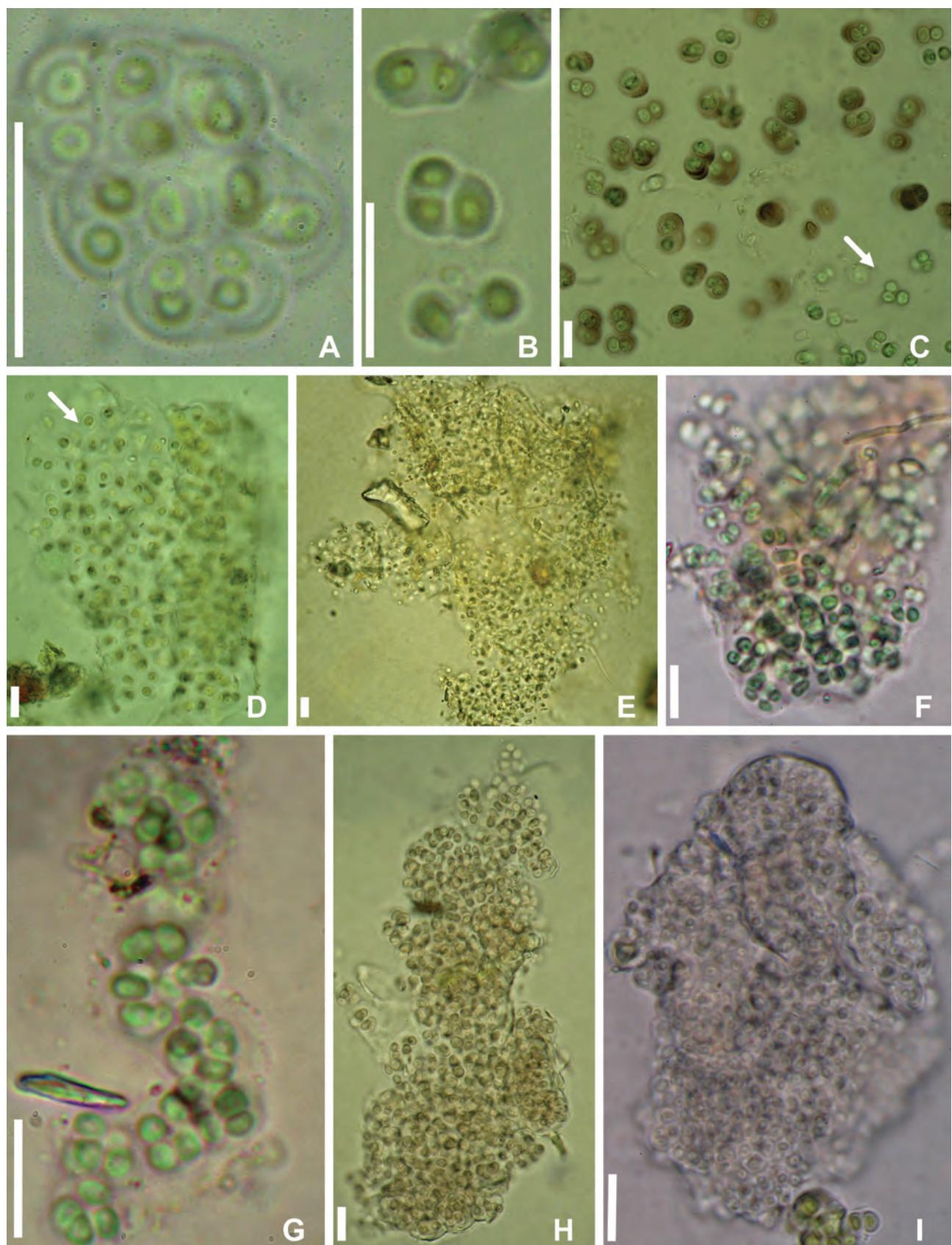
Chlorogloea sp. 1 (Figs. 10F–10G).

Polarized, elongated colonies, 27.0–83.0 μm length. Sheath firm to diffused, hyaline, conspicuous, non-lamellate, smooth. Cells spherical to elongated, 1.7–2.6 μm diam., arranged in rows, without an individual envelopes. Cell content homogenous, pale blue-green.

Habitat:—Tree bark.

Notes:—The corticolous habitat, cell content color, cell dimensions, and the absence of individual cell envelopes are the diacritical features that distinguish this morphotype from other *Chlorogloea* Wille (1900: 5) species.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401427).



FIGURES 10A–10B. *Gloeocapsa* sp. 1

FIGURE 10C. *Gloeocapsa* sp. 2. General colony habit with cells with color sheath and also hyaline (arrow).

FIGURES 10D–10E. *Chlorogloea* cf. *novacekii*. General colony habit showing cells with individual envelopes (arrow).

FIGURES 10F–10G. *Chlorogloea* sp. 1

FIGURES 10H–10I. *Chlorogloea* sp. 2

***Chlorogloea* sp. 2 (Figs. 10H–10I).**

Polarized, round to elongated colonies, 19.1–154.4 µm length. Sheath firm to diffluent, hyaline, conspicuous, non-lamellate, smooth. Cells spherical to elliptical, 1.0–1.9(2.8) µm diam., arranged in rows, without individual envelopes. Cell content homogenous, pale purple.

Habitat:—Tree bark.

Notes:—The color of the cell content is one of the diagnostic features of *Chlorogloea* sp. 2, in which it resembles *Chlorogloea purpurea* Geitler (1928b: 98). However, this species is described as benthic on rocks in alpine lakes, a distinct habitat from the Atlantic Rainforest population.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 5' 8" S, 47° 55' 30" W, 30 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401443).

***Chlorogloea* sp. 3 (Figs. 11A–11C).**

Polarized, round to elongated colonies, 16.4–133.2 µm length. Sheath firm, hyaline to reddish, conspicuous, lamellate, and finely granulated. Cells spherical to elliptical, 3.0–4.6 µm diam., arranged in rows, with individual envelopes. Cell content homogenous to slightly granulated, blue-green.

Habitat:—Dry rope and roof.

Notes:—*Chlorogloea* sp. 3 is morphometrically similar to *Aphanocasa richteriana* var. *major* Gardner (1927: 4), differing by the honey color of sheaths and presence of envelopes only in peripheral cells. In spite of *Aphanocapsa* being different to *Chlorogloea*, this variety has cells surrounded by individual and colored sheath, not typical in *Aphanocapsa*. Besides, Komárek & Komárková-Legnerová (2007) comment on the relationship of *A. richteriana* var. *major* with *Chlorogloea* species.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 10" S, 45° 8' 44" W, W.A. Gama-Jr. (SP 401433); 23° 20' 10" S, 45° 8' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401434).

***Cyanoarbor* aff. *himalayensis* M.Watanabe & Komárek in Branco *et al.* (2006: 373) (Figs. 11D–11E).**

Polarized, elongated and lobed colonies, 79.8–157.6 µm diam. Sheath firm, hyaline to brown, conspicuous, non-lamellate, smooth. Cells spherical to slightly elongated, 2.3–3.2 µm diam., arranged in rows. Cell content homogenous, blue-green.

Habitat:—Dry concrete wall.

Notes:—The genus *Cyanoarbor* Wang (1989: 129) was rediscovered and revised by Branco *et al.* (2006), 17 years after its original description. In this paper, the authors also published the species *Cyanoarbor himalayensis*, which resembles the Atlantic Rainforest population by the similar color of the colonies and cell dimensions. However, *C. himalayensis* was described from mountains in Nepal, growing on wet rocks, and only rarely has cells organized in rows (Branco *et al.* 2006). Our population was found on a dry wall surrounded by a preserved Atlantic Rainforest area, with cells always organized in a linear fashion.

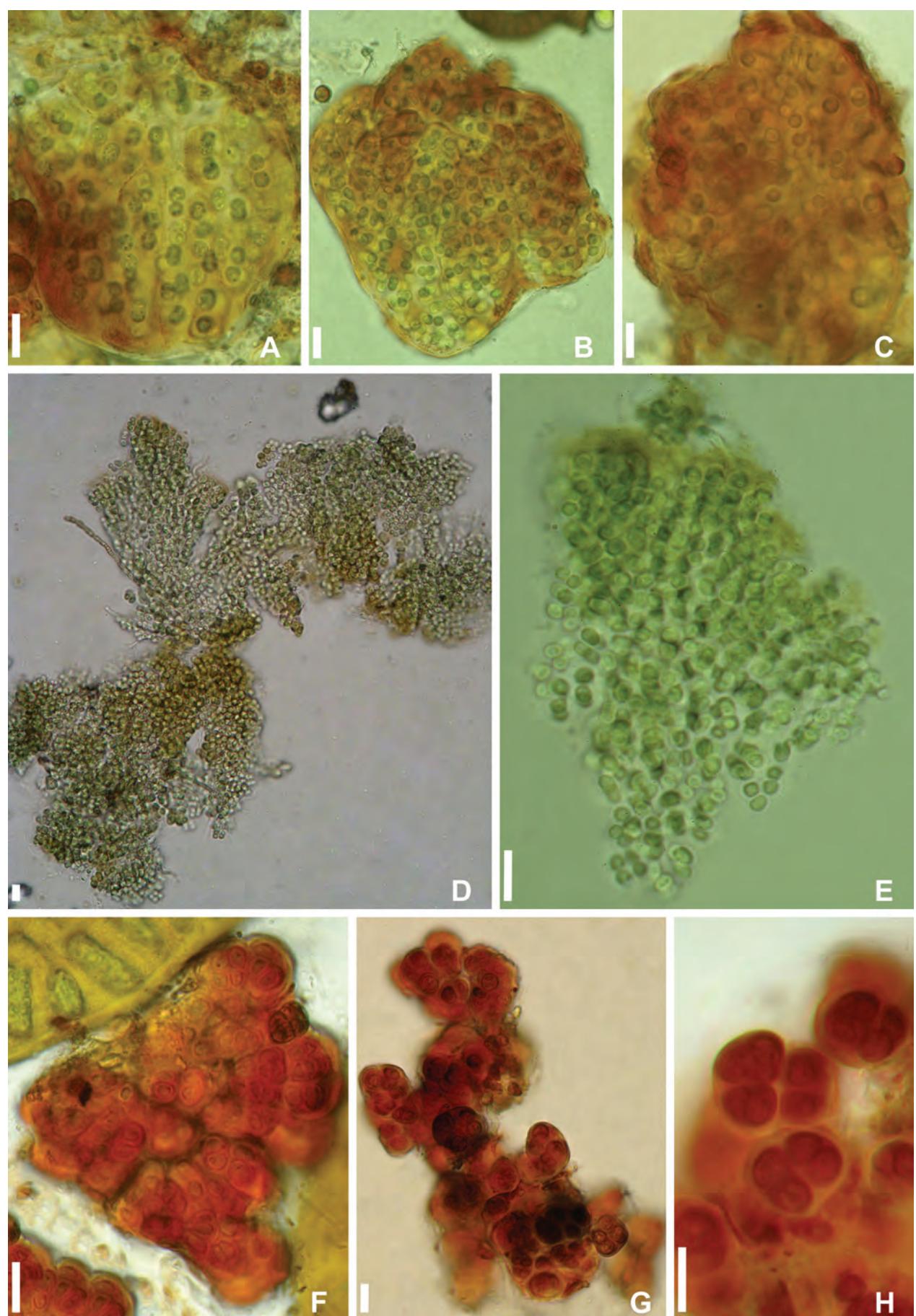
Studied material:—BRAZIL. São Paulo: São Paulo, Institute of Botany, 23° 38' 32" S, 46° 37' 21" W, 29 November 2011, W.A. Gama-Jr. (SP 427335).

***Entophysalis arboriformis* Kaštovský, Fučíková, Hauer & Bohunická (2011: 174) (Figs. 11F–11H).**

Polarized, arboriform colonies, 11.0–134.4 µm diam., composed by sub-colonies. Sheath firm, hyaline to intensely rusty red, conspicuous, lamellate, smooth. Cells spherical to polygonal, 3.2–7.1(11.9) µm diam. Cell content granulated, blue-green.

Habitat:—Dry rocks.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401430).



FIGURES 11A–11C. *Chlorogloea* sp. 3

FIGURES 11D–11E. *Cyanoarbor* aff. *himalayensis*

FIGURES 11F–11H. *Entophysalis arboriformis*

Entophysalis granulosa Kützing (1843: 177) (Figs. 12A–12C).

Polarized, arboriform to irregular colonies, 29.5–118.7 µm length. Sheath firm, hyaline to red-brownish or purple-brownish, conspicuous, lamellate, smooth to finely granulated. Cells spherical, hemispherical to ellipsoid, 2.1–3.7(4.2) µm diam. Cell content granulated, blue-green.

Habitat:—Rocks in tidal zone.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 24.146' S, 47° 3.648' W, 15 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427310); 24° 22.783' S, 47° 1.287' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427312); 24° 22.796' S, 47° 1.231' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427313).

Entophysalis cf. samoensis Wille (1913: 144) (Figs. 12D–12E).

Polarized, fasciculate colonies, 21.0–115.3 × 8.4–85.1 µm. Sheath firm, hyaline to slightly yellow, conspicuous, non-lamellate, smooth. Cells elliptical, hemispherical, rarely spherical, 2.4–3.4 × 1.0–2.5 µm. Cell content homogenous to granulated, intensely blue-green.

Habitat:—Dry concrete.

Notes:—*Entophysalis samoensis* and the material found in the Atlantic Rainforest are similar in color and in the ‘coral shape’ of colonies. However, they differ by *E. samoensis* having a larger cell diameter (3–4 µm) and lamellate sheaths.

Studied material:—BRAZIL. São Paulo: Cananéia, State Park of “Ilha do Cardoso” (Perequê), 25° 4' 8" S, 47° 55' 12.24" W, 29 June 2010, W.A. Gama-Jr. & C.F.S. Malone (SP 401437).

Entophysalis sp. 1 (Figs. 12F–12G).

Polarized, arboriform to irregular colonies, 57.8–125.2 µm length. Sheath firm, hyaline, conspicuous, homogeneous, smooth, with holes. Cells spherical, hemispherical to polygonal, 3.2–8.0 µm diam. Cell content granulated, gray.

Habitat:—Wet rock.

Notes:—Empty ‘holes’ throughout the mucilage were found. The cell dimensions and the color content also differs this morphotype from the other *Entophysalis* species.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Jureia-Itatins”, 24° 23.311' S, 47° 0.940' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427316).

Entophysalis sp. 2 (Figs. 13A–13B).

Polarized, lobate to irregular dense colonies, 38.6–125.4 µm length. Sheath firm, hyaline to yellowish, conspicuous, homogeneous, smooth. Cells spherical, hemispherical to polygonal, 3.6–7.6 µm diam. Cell content granulated, vacuole-like, green to olive green.

Habitat:—Wet concrete covered with plants.

Notes:—This morphotype is distinguishable by its dense celled colonies, surrounded by a rigid and wide sheath, in addition to the cell content color and vacuole-like structures.

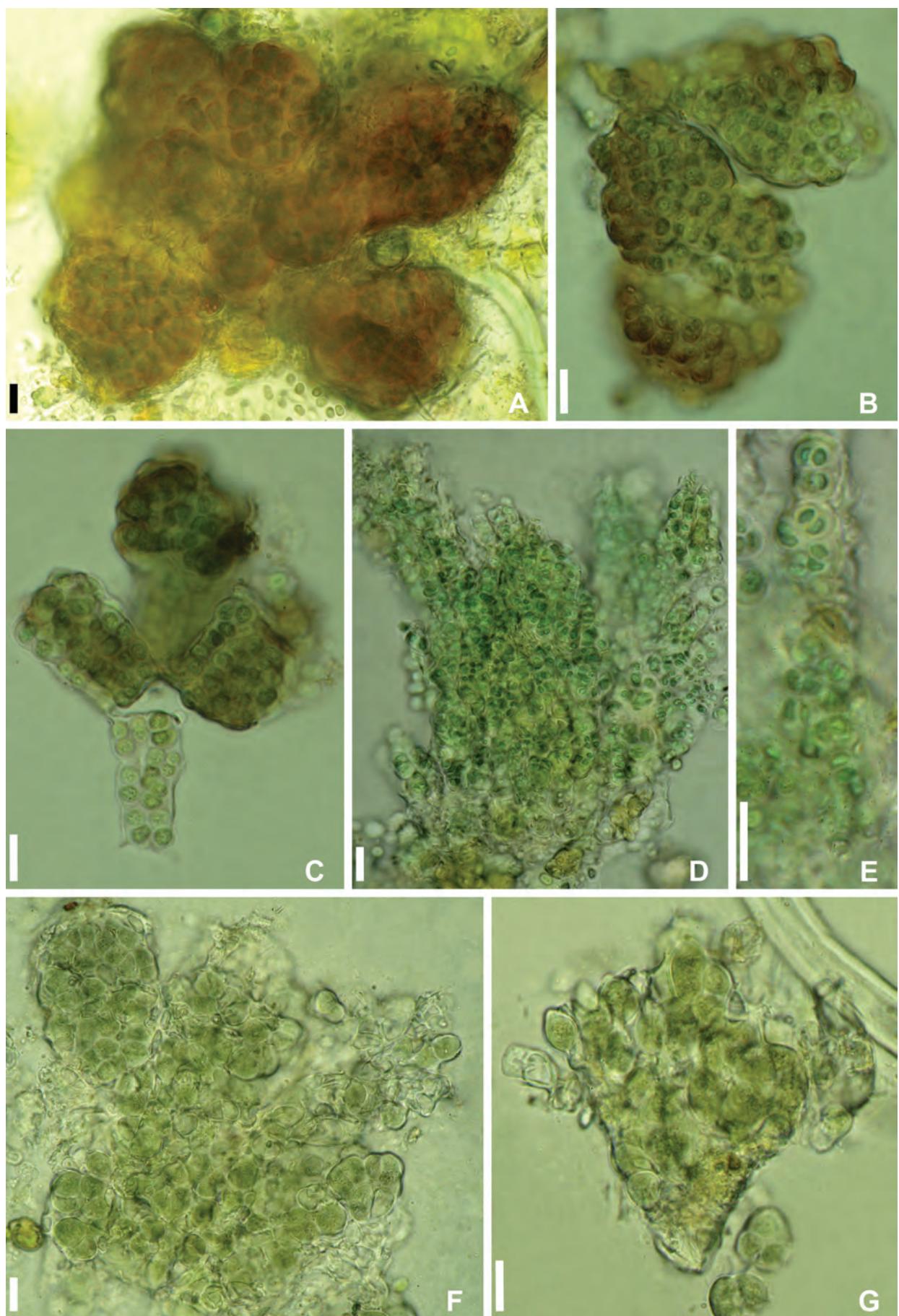
Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 401422, SP 401423).

Unidentified Entophysalidaceae (Figs. 13C–13E).

Polarized, arboriform, lobed, round to irregular colonies, 43.4–277.0 µm length, with cells agglomerated at the periphery (lobes) and sparse inside. Sheath firm, hyaline inside the colonies to intensely violet to orange brown at the colonies’ edge, conspicuous, lamellate, smooth to finely granulated, with holes. Cells spherical, hemispherical to ellipsoidal, 3.4–6.1 µm diam. Cell content granulated, vacuole-like, green to blue-green.

Habitat:—Wet rocks.

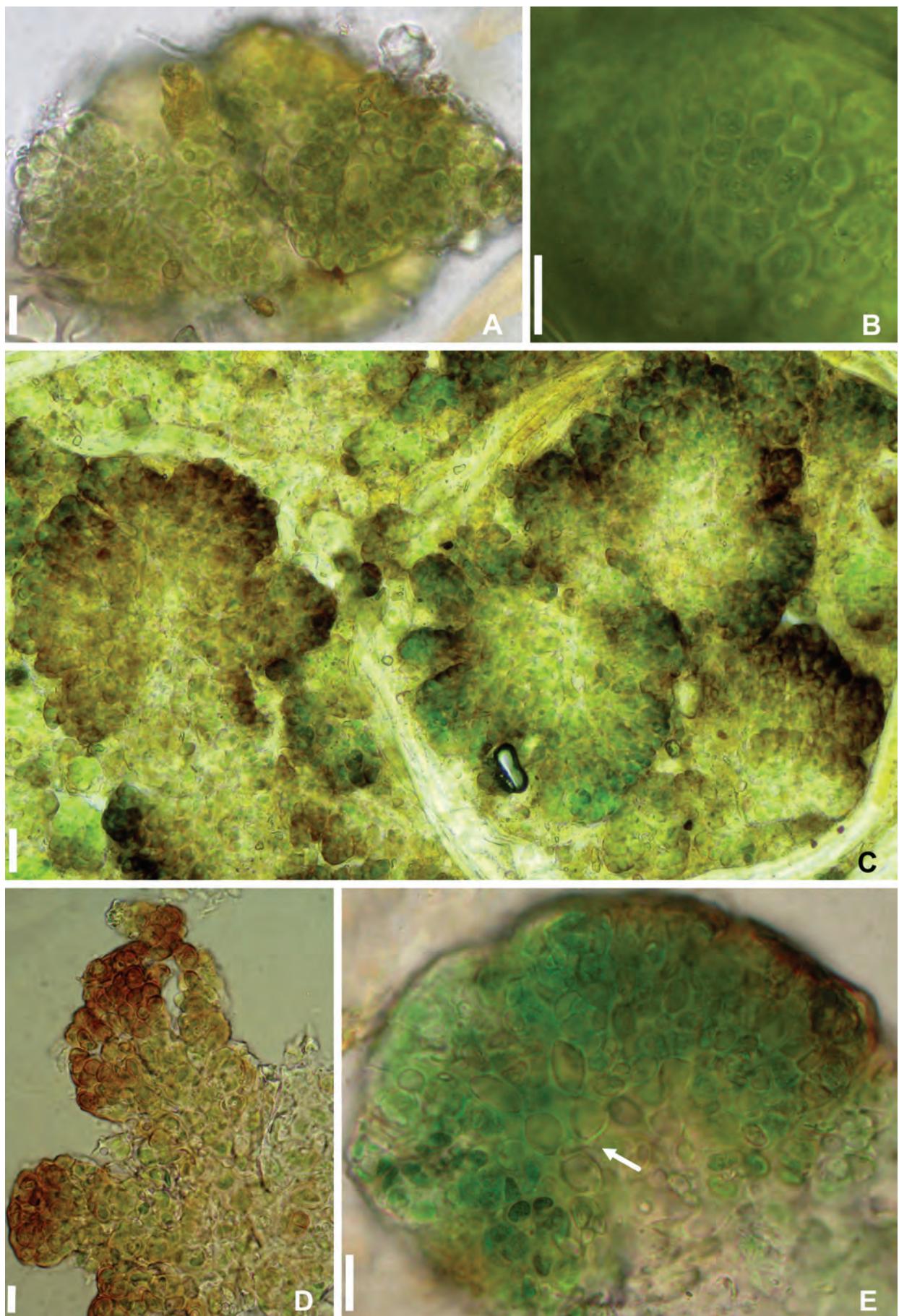
Notes:—The morphotype found has a colonial structure very similar to *Placoma regulare* Broady & Ingerfeld (1991: 548). This species was described for New Zealand and despite being in the genus *Placoma* Schousboe ex Bornet & Thuret (1876: 4), it differs substantially from *P. vesiculosum* Schousboe in Bornet & Thuret (1876: 4), the type-species of the genus. We believe that *P. regulare* and the Atlantic Rainforest population are a putative new genus, characterized by the lobed colonies with cells disposed mainly at the edge, being surrounded by firm and perforated sheaths. According to the erect thalli, this new genus should belong to the family Entophysalidaceae.



FIGURES 12A–12C. *Entophysalis granulosa*

FIGURES 12D–12E. *Entophysalis* cf. *samoensis*

FIGURES 12F–12G. *Entophysalis* sp. 1



FIGURES 13A–13B. *Entophysalis* sp. 2

FIGURES 13C–13E. Unidentified Entophysalidaceae. 13C–13D. General colony habit showing the color variation. 13E. Detail of the perforated mucilage (arrow).

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 35" S, 45° 8' 17" W, 24 February 2010, W.A. Gama-Jr. (SP 401431), Peruíbe, Ecological Station “Juréia-Itatins”, 24° 22.783' S, 47° 1.287' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427312).

Family Chamaesiphonaceae Borzì (1878: 238).

Chamaesiphon stratosus Sant’Anna, Gama-Jr., Azevedo & Komárek (2011c: 26) (Figs. 14A–14B).

Colonies shrub-like, fan-shaped. Cells club-shaped, rounded at both ends, organized in one layer or at most two, 9.3–20.6(26.8) × 2.3–4(6.5) µm. Sheath U-shaped, distinct, colorless to intensely yellowish-green or brownish, slightly lamellate and frayed when old. Exocytes 1.5–2.6 µm diam., singularly liberated or forming variable number of rows and layers. Cell content brownish or olive-green, slightly granular.

Habitat:—Rocks near a river splash zone.

Studied material:—BRAZIL. São Paulo: Campos do Jordão, Horto Florestal, 22° 41' 26.3" S, 45° 28' 51.4" W, 8 November 2002, C.L. Sant’Anna, M.T.P. Azevedo & J. Komárek (SP 400963).

Family Hyellaceae Borzì (1914: 359).

Hyella cf. caespitosa var. *arbuscula* Al-Thukair & Golubić (1996: 84) (Figs. 14C–14D).

Main thallus with polygonal cells, 4.4–5.2 µm diam. Pseudofilaments radiating into substrate, 30.8–78.0 µm length, branched, uniseriate. Sheath firm, hyaline, conspicuous, non-lamellate, smooth. Middle cells of pseudofilaments quadratic to rectangular, 1.9–3.6 × 3.3–9.0 µm. Apical cells of pseudofilaments tortuous, round ends, 1.9–2.8 × 10.6–17.0 µm. Baeocytes produced by the main thallus, more than 20 per cell, 1.2–1.6 µm diam. Cell content homogenous, rosy to purple-brown.

Habitat:—Rocks in tidal zone.

Notes:—The habitat and morphology of the colonies and cells of the Brazilian population are similar to those described for *Hyella caespitosa* var. *arbuscula* Al-Thukair & Golubić (1996: 84). However, the dimensions of all structures were smaller.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 23.368' S, 47° 0.671' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427318).

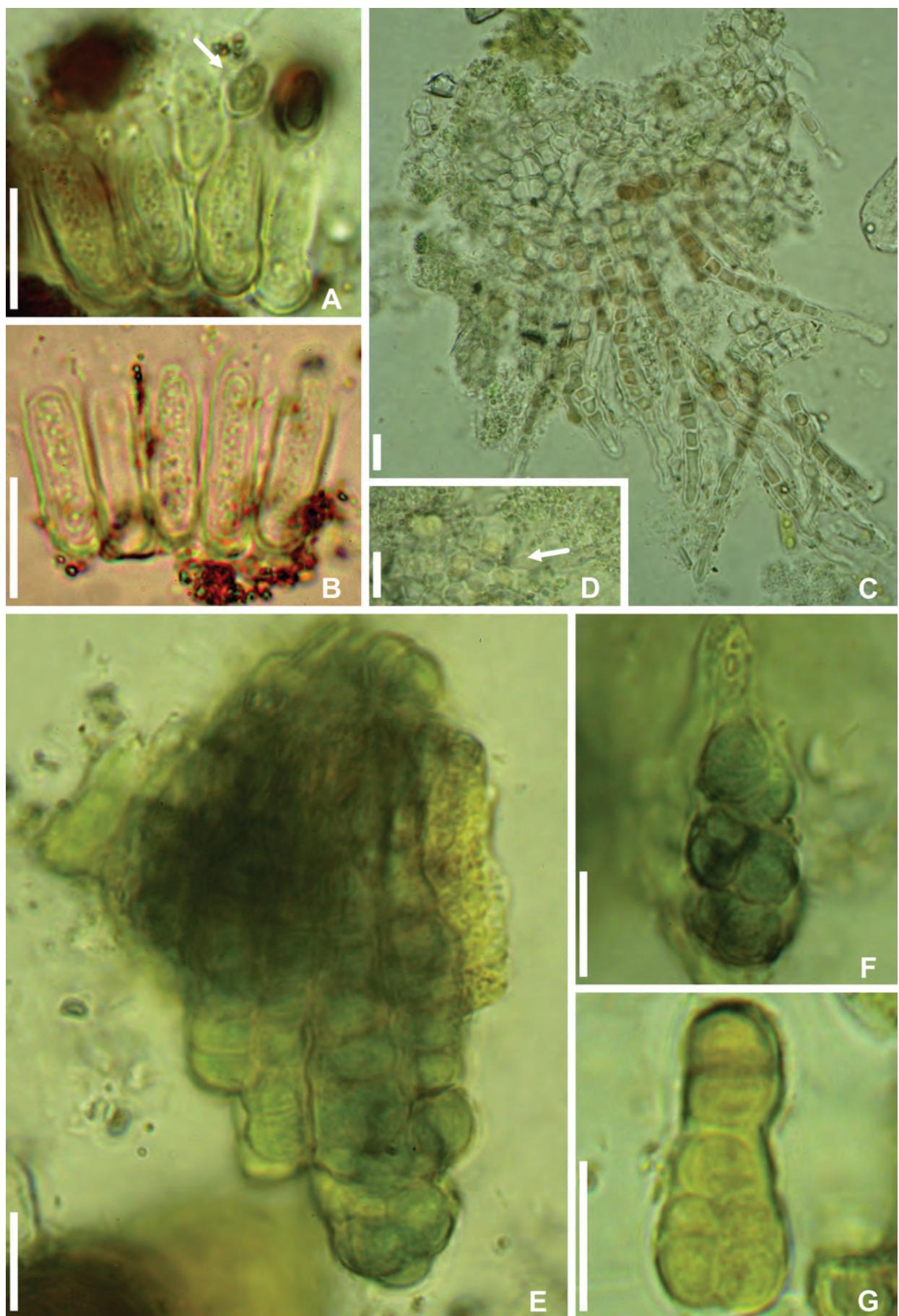
Pleurocapsa cf. aurantiaca Geitler (1932: 354) (Figs. 14E–14G).

Polarized, fasciculate colonies, with cells densely packed. Cells hemispherical to elliptical, 3.8–6.8 µm diam. Pseudofilaments dichotomous, biseriate, 5–17 celled, 20.2–59.2 × 8.4–13.4 µm. Sheath firm, yellow to dark brown, conspicuous, non-lamellate, smooth. Baeocytes not observed. Cell content homogenous, blue-green to green brownish.

Habitat:—Rocks covered by a water slide.

Notes:—Despite baeocytes not being found, colonial arrangement was typical of *Pleurocapsa*. The population described resembles *Pleurocapsa aurantiaca* in relation to habitat and colonial morphology. However, this species has larger cell diameter and orange/red sheaths.

Studied material:—BRAZIL. São Paulo: Peruíbe, Ecological Station “Juréia-Itatins”, 24° 22.783' S, 47° 1.287' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427312).



FIGURES 14A–14B. *Chamaesiphon stratosus*. Cell arrangement and initial stage after exospore germination (arrow).

FIGURES 14C–14D. *Hyella cf. caespitosa* var. *arbuscula*. General thallus aspect and detail of baeocytes in mothers' sheath (arrow).

FIGURES 14E–14G. *Pleurocapsa cf. aurantiaca*

Pleurocapsa sp. (Figs. 15A–15D).

Round, elliptical, club-shaped cells, 4.1–22.4 µm diam., isolated or forming dense colonies. Pseudofilaments simple or dichotomous, uniserial, 3–8 celled, 20.2–59.2 × 6.4–8.7 µm. Sheath firm, hyaline to blackish, conspicuous, non-lamellate, smooth. Baeocytes (many, >20 per cell) spherical, 2.4–2.8 µm diam. Cell content homogenous, green brownish to brown-purplish.

Habitat:—Dry concrete covered by dry soil.

Notes:—This morphotype was only found in culture. The morphological analyses showed that this population has the same life cycle of *Pleurocapsa* group I described by Waterbury & Stanier (1978). Most species of *Pleurocapsa* are originally described to marine environments, being *Pleurocapsa muralis* Lagerheim in Wittrock & Nordstedt (1893: 195) the only species described to a terrestrial environment. However, we could not access the original description of this species to confirm its resemblance with the Atlantic Rainforest population.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 427340).

Family Xenococcaceae Ercegović (1932).

Chroococcidiopsis sp. (Figs. 15E–15G).

Round, elliptical, elongated cells, (3.5)4.6–13.7 µm diam., isolated or forming colonies. Sheath firm, hyaline, conspicuous, non-lamellate, smooth. Baeocytes (many, >15 per cell) spherical to irregular, 2.0–2.9 µm diam. Cell content homogenous to slightly granulated, green brownish to brown-purplish.

Habitat:—Wet concrete.

Notes:—This morphotype was only found in culture. Cell content color, cell dimensions, including baeocytes, and the habitat, cause this morphotype to be different from other *Chroococcidiopsis* species.

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 10" S, 45° 8' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 427348).

Myxosarcina sp. Printz (1921: 35) (Figs. 15H–15K).

Sarcinoid colonies, 20.3–48.4 µm diam., isolated or agglomerated. Sheath firm, hyaline, conspicuous, non-lamellate, smooth. Cells spherical, elliptical to polygonal, 6.3–13.0 µm diam. Baeocytes (many, >20 per cell) spherical to irregular, 2.7–3.7 µm diam. Cell content granulated, dark green to olive-green.

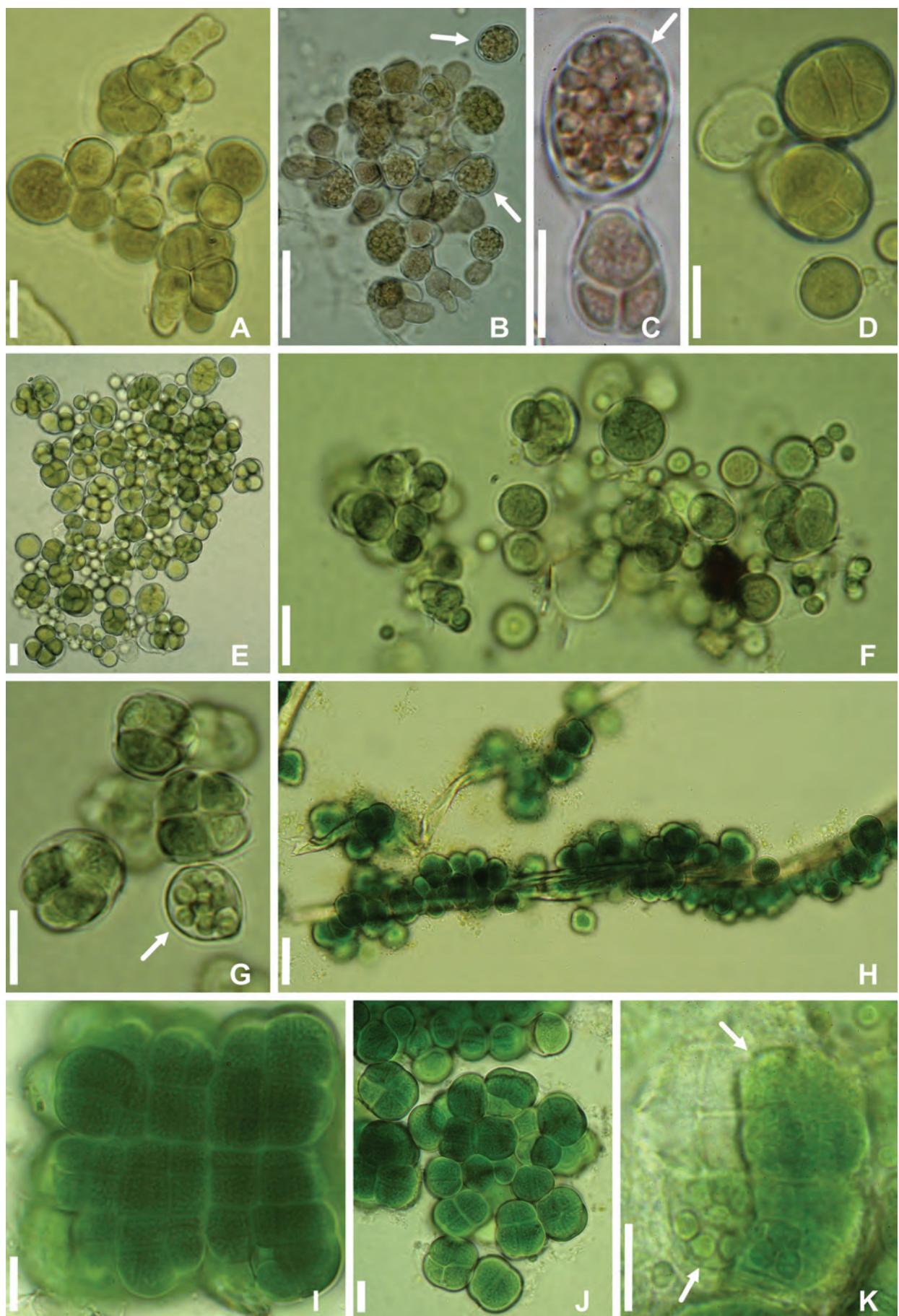
Habitat:—Wet rocks and concrete covered with plants.

Notes:—This morphotype was only found in culture. The studied population is similar to *Myxosarcina decolorata* (Varma & Mitra 1962: 356) Komárek & Anagnostidis (1995: 21). However they differ since *M. decolorata* has round cells, wider and wrinkled sheaths, and in the number of baeocytes (*M. decolorata* having 1–8).

Studied material:—BRAZIL. São Paulo: São Luís do Paraitinga, State Park of “Serra do Mar” (Santa Virgínia), 23° 20' 36" S, 45° 7' 44" W, 24 February 2010, W.A. Gama-Jr. (SP 427338); Peruíbe, Ecological Station “Jureia-Itatins”, 24° 23.311' S, 47° 0.940' W, 16 August 2011, W.A. Gama-Jr., G.S. Hentschke, C.F.S. Malone & C.L. Sant’Anna (SP 427303).

Discussion

In regards to new citations, the present study found seven species which are putative first reports for South America (i.e. *Asterocapsa aerophytica*, *Chroococcus subviolaceus*, *Gloeocapsopsis chroococcoides*, *Nephrococcus shilinensis* Tian in Tian *et al.* 2001: 280, *Chondrocystis dermochroa*, *Gloeocapsa novacekii*, and *G. stegophila*). Most of them had been described in literature for a long time, but have never been found in South America. We believe this is related to the focus of previous studies, which were scarcely concentrated on the floristics of tropical terrestrial habitats. In addition to these new occurrences, four species currently reported were never found after their original descriptions: 1) *Nephrococcus shilinensis* was the second species described for *Nephrococcus* Li (1984: 191), and to date this genus had only been found in China (Tian *et al.* 2001); 2) *Entophysalis arboriformis* was described from Mt. Roraima (Venezuela)



FIGURES 15A–15D. *Pleurocapsa* sp. General colony habit and details of baeocytes (arrows).

FIGURES 15E–15G. *Chroococcidiopsis* sp. General colony habit and details of baeocytes (arrows).

FIGURES 15H–15K. *Myxosarcina* sp. General colony habit and details of baeocytes (arrows).

as endemic (Kašťovský *et al.* 2011); 3) *Asterocapsa aerophytica* is the only species of this genus described from Europe (Lederer 2000); however, we have found all its life cycle which, together with the habitat, confirms the identification of the Atlantic Rainforest population; and 4) *Endospora rubra*, which is a morphologically complex species (see the notes under *E. rubra*), but was also found in the Atlantic Rainforest after being described and reported from Puerto Rico. Documenting these species is important for understanding their geographical distribution and better characterizing their morphology, contributing to the true biodiversity by recovering these rarely cited species, and will facilitate identifying them in future studies.

We found that the species of cyanobacteria were more associated to habitat conditions than to geographical location, implying that the ‘environment selects’. This pattern has been reported several times in literature (e.g. Bahl *et al.* 2011), and is exemplified by finding a continental European species in our study (e.g. *Gloeocapsopsis dvorakii*, *G. chroococcoides* or *Asterocapsa aerophytica*). All material found in the Atlantic Rainforest matched described species morphologically and ecologically, and they probably respond to a similar local microclimate found for the European type, which justifies their occurrence in a tropical region. Specific floristic studies on tropical coccoid cyanobacteria are rare, but high species diversity is common among those undertaken in this habitat. McGregor (2013) recently published the flora of freshwater coccoid cyanobacteria from northeastern Australia, and found 112 taxa, with 25 of them identified to generic level. These results attest that these organisms are not well known in tropical/subtropical zones, even in aquatic environments. As terrestrial cyanobacteria are mostly unexplored, studies on their biodiversity show a very promising field for new discoveries.

Nabout *et al.* (2013) estimate that 3,582 species of cyanobacteria (57% of the total estimated number) worldwide have yet to be described, demonstrating how their diversity is still undiscovered. These authors used different statistical models to achieve this number and pointed this elevated value as a consequence of the lack of biodiversity studies, mainly those related to poorly known environments, such as tropical/subtropical and terrestrial.

The present study is an example of these assumptions, since it reports 40 species of coccoid cyanobacteria in the terrestrial habitats of the Atlantic Rainforest. Moreover, 21 coccoid taxa unidentified at the specific-level were also found in this environment, which represent a putative new genus and 20 new species, with two already described (*Chamaesiphon stratosus* and *Lemmermanniella terrestris*). Considering the whole dataset, 61 taxa of coccoid cyanobacteria were found in the Atlantic Rainforest, 34.4% probably corresponding to new taxa. These numbers are much higher than those found in cyanobacterial floras on terrestrial habitats from this ecosystem, which found 14, 12, and six coccoid species (Branco *et al.* 1996, 2009, Büdel *et al.* 2002) respectively, reinforcing the idea that studies focusing on specific taxonomic groups enhance the possibility of discovering new or little known taxa. Thus, the results confirm a high biodiversity of coccoids in terrestrial environments of the Atlantic Rainforest, while highlighting the importance of studying this group of cyanobacteria.

Conclusions

Due to the high number of coccoid cyanobacterial species, we believe that the diversity of this group is much greater than previously thought and that these taxa need more in depth floristic studies. Their biodiversity data will most likely increase with directed studies to unknown environments, focusing on this specific cyanobacterial group and on terrestrial habitats from tropical/subtropical zones. We think that the Brazilian Atlantic Rainforest has a great part of this cyanobacterial richness, since it has a huge variability of habitats, which enhances the possibilities for different species to survive. However, due to the dearth of studies in this biome and to its large deforested areas, this diversity is substantially and continuously threatened.

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