



Cyanobacteria from a Brazilian subtropical freshwater water body

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Abstract

Due to the undeniable importance of the role that cyanobacteria play in different ecosystems, and the new discoveries and periodic changes in their taxonomic classification, the main objective of this research was a taxonomic update of the cyanobacteria recorded in an artificial, subtropical freshwater water body. This work also aimed at the knowledge of the geographic distribution and frequency of the species throughout the study period. The analyzed pond (called Basin 7) is located in an environmental preservation area called Braskem Environmental Station (29°51'57.3"S and 51°21'54.7"W), which is part of the “green belt” that surrounds the set of companies of the Southern Petrochemical Complex of Rio Grande do Sul state (Brazil). The studied samples were taken from May 2000 to December 2015, using a plankton net (30 µm), and floating thallus of cyanobacteria were collected directly by hand. Thirty-three species were identified and distributed in the orders Oscillatoriales (14), Synechococcales (12), Chroococcales (6) and Spirulinales (1). *Phormidium* Kützing ex Gomont presented the highest species richness, with five species identified, and *P. tergestinum* (Kützing) Anagnostidis & Komárek was the one with the highest frequency of occurrence (81.3%). Among the identified species, seven are especially important for being potentially toxic. *Eucapsis pseudalpina* Komárek & Hindák also stood out for its first recorded occurrence in Brazil, and *Ancylothrix rivularis* Martins & Branco, *Arthrospira jenneri* Stizenberger ex Gomont and *Pannus* cf. *brasiliensis* Malone et al. for their first recorded occurrence in Rio Grande do Sul state. For each species, diagnoses, basionyms and synonyms when appropriate, illustrations and comments are presented.

Keywords Artificial pond · Biodiversity · Cyanoprokaryota · Petrochemical complex · Southernmost Brazil · Taxonomy

1 Introduction

Cyanobacteria are gifted with great ecological plasticity, adaptable to the most diverse environments and regions of the Earth, being found in almost every part of the world.

They resist rather drastic environmental variations, occurring from the poles to the tropics, from sea level to the highest mountains. They can grow both in the seas and in the continental waters, in clean water as well as in

polluted ones, resisting wide thermal variations. They also occur in snow, glaciers, desert sands, soil, cement and wood or tree trunks. (Werner 2002).

The group encompasses a single class of organisms (Cyanophyceae) that present an important relevance, mainly in continental waters, sometimes because of its dominance in the environment, causing public health and water supply problems, sometimes for its unequivocal importance in studies of saprobity, toxicity, nitrogen fixation and genetics. Its use as both human and other animal's food and in the pharmaceutical and textile industries have to be highlighted.

Due to the undeniable importance of the role that cyanobacteria play in different ecosystems, the increasing surface water overload, and the observation of risk situations due to the occurrence of toxic blooms in different aquatic environments, it becomes evident the need for detailed taxonomic analyzes and a greater understanding of the biodiversity and distribution of these organisms,

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providing, thus, subsidies for studies of socioeconomic interest.

The biodiversity of cyanobacteria from tropical and subtropical regions is still very little known and is certainly much larger than previously described, and only a very small percentage has been properly studied (Komárek 1985; Komárek and Komárková-Legnerová 2007). Among the taxonomic studies of the group that cover Brazilian subtropical aquatic environments, stand out Sant'Anna et al. (1978), Torgan et al. (1981), Werner (1988), Franceschini (1990), Werner and Rosa (1992), Torgan and Paula (1994), Werner and Sant'Anna (1998, 2000, 2006), Azevedo and Sant'Anna (1999), Komárková et al. (1999), Azevedo et al. (2003), Werner (2002), Sant'Anna et al. (2004), Tucci et al. (2006), Werner et al. (2008), Werner and Laughinghouse IV (2009), Martins et al. (2012a, b), Rosini et al. (2013) and Werner et al. (2015a, b).

The knowledge of the cyanobacteria of a subtropical pond in southern Brazil studied in this work is restricted to lists of taxa (microalgae and cyanobacteria) included in reports of monitoring of water quality (e.g., FZB 2014, 2016). Over the course of 16 years, 71 taxa of cyanobacteria were recorded, but 30% of the identification was not conclusive.

Due to the new discoveries and periodic changes in the taxonomic classification of cyanobacteria, the main objective of this research was a taxonomic update of the cyanobacteria found in this water body to better understand the group's biodiversity, providing diagnoses, basionyms and synonyms when there are appropriate, illustrations, comments and some environmental data. This work also aimed at the knowledge of the geographic distribution and frequency of the species throughout the study period.

2 Materials and methods

Studied area – The analyzed pond (called Basin 7) is located in an environmental preservation area in the municipality of Triunfo, in Porto Alegre Metropolitan Region, Rio Grande do Sul state, southern Brazil (Fig. 1). Triunfo belongs to a coalfield and is part of a region called Central Depression. The climate of the region, according to the Köppen system, is Cfa type, a subtropical humid climate; the average annual temperature of Triunfo is 19.6 °C and the average rainfall is 1346 mm.

Located at the banks of the Caí River, the environmental preservation area called Braskem Environmental Station (29°51'57.3"S and 51°21'54.7"W) has an area of 68 hectares and is part of the “green belt” that surrounds the set of companies of the Southern Petrochemical Complex of Rio Grande do Sul state. The station belongs to the

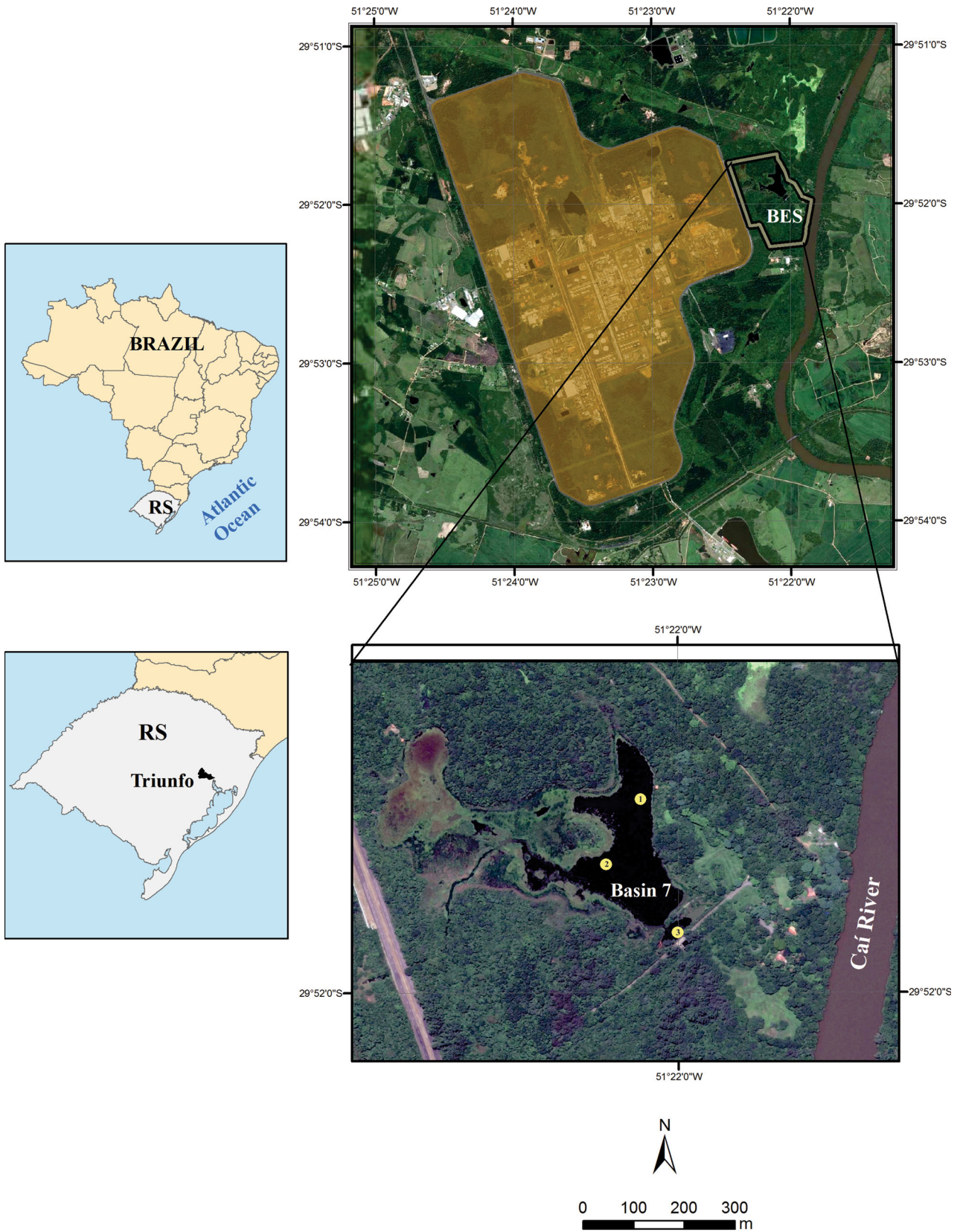
company Braskem, is located next to it and is composed of forests, damp fields, marshes and a pond (Gastal et al. 2014). With a surface of 15 hectares approximately and a maximum depth of two meters, the pond is a site for containment and accumulation of rainwater from the Industrial Park. The water in general is slightly acidic, with pH between 5.9 and 6.8, and the temperature ranges from 16 to 34 °C. This pond was created with the purpose of containing possible extravasations of residues from the companies of the Petrochemical Complex, preventing them from reaching the Caí River. It is also called Safety Basin since any waste from the Petrochemical Complex will reflect in it (Alves-da-Silva 1998). The Basin also serves as a refuge for the biota remaining after the implementation of the Southern Petrochemical Complex.

Sampling – The studied samples were taken seasonally (February, May, September and December) from May 2000 to December 2015 at two sites: one near the belvedere and the other near the central area. However, as of 2012, in the other months of the year, collections were carried out at a third place located near the bridge (Fig. 1). First, eight samples were collected each year, and from 2012 on, 16 per year.

The material was collected using a 30 µm mesh plankton net, which was dragged at least 30 times, approximately 20 cm from the water surface; floating thallus of cyanobacteria were collected directly by hand. 200 mL of each sample were preserved in formaldehyde 4% and deposited in “Prof. Dr. R Alarich RH Schultz” Herbarium (HAS) at the Natural Sciences Museum of Zoobotanical Foundation of Rio Grande do Sul (MCN–FZB/RS), Porto Alegre, Rio Grande do Sul state, Brazil.

Taxonomic studies – The samples were studied using a compound light microscope. Whenever possible, at least 15 specimens of each species were measured. They were identified by analyzing the variability of morphological and metric characteristics of vegetative and reproductive lives of natural populations. The mucilaginous structure was evidenced using Indian ink. The photographs were taken from the ocular image using a digital camera. The Komárek et al. (2014) classification system was adopted. The identifications of the specimens were based on the specialized literature for taxonomy of cyanobacteria and, whenever possible, the specimens were compared with their original descriptions. Basionyms and synonyms (when pertinent), descriptions, comments and examined material to each species are presented.

Ecological parameters – The frequency of occurrence (F) (%) of the species over the study period was calculated based on the formula: $F = [Pa/P] \times 100$, where Pa is the number of years the species was recorded and P is the total



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◀ **Fig. 1** Map of the studied area showing the Braskem Environmental Station (BES), next to Southern Petrochemical Complex of Rio Grande do Sul state and the three sampling sites in Basin 7 (1 near the belvedere, 2 near the central area and 3 near the bridge)

number of years (16). The classification of the species, according to frequency, followed the one presented by Rosini et al. (2013): very frequent ($F \geq 80\%$), frequent ($50\% \leq F < 80\%$), infrequent ($20\% \leq F < 50\%$) or rare ($F < 20\%$).

The specific richness (S) corresponds to the number of species identified.

Geographic distribution – The data referring to the geographic distribution of species in Brazil were based on Werner et al. (2015a), and complemented with the publications of Rodrigues and Bicudo (2001), Fonseca and Rodrigues (2005), Sant’Anna et al. (2011), Alcântara et al. (2011), Felisberto and Souza (2014), Werner et al. (2015b), Moura et al. (2017), Laux et al. (2018), Rangel et al. (2018).

Physicochemical variable of water – At the collections, pH data were obtained from the sampling sites with a Hach EC 10 pH Metter.

3 Results and discussion

Thirty-three species of cyanobacteria were identified and distributed in the orders Oscillatoriales (14), Synechococcales (12), Chroococcales (6) and Spirulinales (1). Some representatives of Nostocales were sporadically registered. However, because only fragments of filaments (without heterocytes or akinetes) were found, their taxonomic identifications were not possible. *Phormidium* Kützing ex Gomont presented the highest species richness, with five species identified, followed by *Merismopedia* Meyen, *Microcystis* Kützing ex Lemmermann and *Oscillatoria* Vaucher ex Gomont with three species each one.

Apart from typically planktic species, benthic and periphytic ones were also found. The expressive number of benthic cyanobacteria species (12), especially oscillatorialean (84.6%) recorded on the water surface of Basin 7, can be justified by anthropic action, namely the revolving of the mud from the bottom when floating ferns (*Salvinia* Séguier) were periodically removed, and the consequent detachment and migration of the benthic community to the surface of the water. The presence of these plants and other macrophytes may also justify the occurrence of periphytic species on the surface of this water body.

Among the identified cyanobacteria, *Microcystis aeruginosa* (Kützing) Kützing, *M. protocystis* Crow, *M. wesenbergii* (Komárek) Komárek, *Planktothrix agardhii* (Gomont) Anagnostidis and Komárek, *P. isothrix* (Skuja) Komárek and Komárková, *Radiocystis fernandoi* Komárek and Komárková-Legnerová and *Snowella lacustris* (Chodat) Komárek are especially important because they can form water blooms and produce hepatotoxin microcystins. Even though some were well represented, blooms of these species were not recorded in Basin 7 over the 16 years of study.

Eucapsis pseudalpina Komárek & Hindák also stood out for its first recorded occurrence in Brazil, and *Ancylothrix rivularis* Martins & Branco, *Arthrospira jenniferi* Stizenberger ex Gomont and *Pannus* cf. *brasiliensis* Malone et al. for their first recorded occurrence in Rio Grande do Sul state.

Phormidium tergestinum (Kützing) Anagnostidis & Komárek was the most common in Basin 7 over those 16 years of study, with frequency of occurrence of 81.3%, observed in all seasons of the year. It was the only species classified as “very frequent.” Most of the other species identified were rare (48.5%), with frequency of occurrence between 6 and 19%. They were found in three analyzed samples at most.

Generally, the species richness of cyanobacteria in Basin 7 was low ($\bar{X} = 10 \pm 4$) during the study period. The highest species richness (16) was registered in 2013, while the lowest ones (4) were in 2009 and 2010. This fact can be explained by the frequent occurrence of microalgae blooms, mainly diatoms (*Aulacoseira* Thwaites) and chrysophyceae (*Dinobryon* Ehrenberg).

Considering that numerous records for cyanobacteria in freshwater indicate that their diversity and abundance are the greatest at the higher pH values (Whitton and Potts 2000), the acidic to slightly acidic waters of Basin 7 over those 16 years ($\bar{X} = 6.5 \pm 0.2$) could also justify the low species richness of cyanobacteria.

The frequency of occurrence of cyanobacteria found in Basin 7, the species richness per year, and its mean and standard deviation are presented in Table 1.

The cyanobacteria identified in Basin 7 are presented below.

Synechococcales Hoffmann, Komárek & Kaštovský 2005

Synechococcaceae Komárek & Anagnostidis 1995

Anathece Komárek et al. 2011

Anathece smithii (Komárková-Legnerová & Cronberg) Komárek, Kaštovský & Jezberová, Eur. J. Phycol., 46(3): 322. 2011.

Basionim: *Aphanothece smithii* Komárková-Legnerová & Cronberg, Algol. Stud., 72: 25. 1994.

Table 1 Frequency of occurrence of cyanobacteria found in Basin 7 over the course of 16 years, and the species richness per year as well as its mean and standard deviation

Taxa	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	F %
<i>Anagnostidinema amphibium</i>	x	x	-	-	-	x	-	-	x	x	-	x	x	-	x	x	-	F-56
<i>Anathece smithii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	R-6
<i>Ancylothrix rivularis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	R-19
<i>Aphanocapsa delicatissima</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	R-6
<i>A. elachista</i>	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	R-6
<i>Arthrospira jemerii</i>	-	x	-	x	-	-	-	-	-	-	-	-	x	x	x	x	x	I-38
<i>Coelomonon pusillum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	R-13
<i>Chroococcus nipitanensis</i>	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	R-6
<i>C. turgidus</i>	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	R-6
<i>Eucapsis pseudalpina</i>	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	R-6
<i>Limnococcus limneticus</i>	x	-	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-	R-19
<i>Merismopedia glauca</i>	x	x	x	x	x	x	x	-	x	-	x	-	-	-	x	-	-	F-56
<i>M. punctata</i>	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	R-6
<i>M. tenuissima</i>	x	x	x	x	x	x	x	x	x	x	-	-	-	x	-	-	-	F-63
<i>Microcoleus autumnale</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	R-6
<i>Microcystis aeruginosa</i>	-	-	x	x	x	x	-	x	-	-	-	-	-	x	x	x	x	F-50
<i>M. protocystis</i>	-	-	x	x	x	x	x	x	x	x	-	-	-	x	x	-	-	F-56
<i>M. wesenbergii</i>	-	x	-	-	-	x	-	-	-	-	x	-	-	-	-	-	-	I-25
<i>Oscillatoria limosa</i>	-	x	x	-	-	x	x	x	x	x	-	-	x	-	x	-	-	F-56
<i>O. princeps</i>	-	-	x	x	x	x	x	x	x	x	-	x	-	-	-	-	-	F-56
<i>O. sancta</i>	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	I-25
<i>Pannus cf. brasiliensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	R-6
<i>Phormidium articulatum</i>	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	R-13
<i>P. chalybeum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R-13
<i>P. granulatum</i>	-	x	-	-	-	-	-	-	-	x	-	-	-	-	x	x	x	I-32
<i>P. irrigum</i>	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	R-13
<i>P. tergestinum</i>	x	-	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x	MF-81
<i>Planktothrixagardhii</i>	-	-	-	-	-	-	x	x	x	-	-	-	-	-	x	-	-	I-25
<i>P. isoethrix</i>	-	-	-	x	-	-	x	x	-	x	x	x	x	x	x	x	-	F-63
<i>Pseudanabaena catenata</i>	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	R-13
<i>Radiocystis fernandoi</i>	-	-	-	-	-	x	x	-	-	x	x	-	-	x	x	x	x	F-50
<i>Snowella lacustris</i>	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	-	-	I-25
<i>Spirulina princeps</i>	-	-	-	x	x	x	x	x	x	x	-	-	x	-	-	x	x	F-56
Species richness (S)	5	8	7	10	12	9	13	9	14	10	4	4	10	11	16	13	8	($\bar{X} = 10 \pm 4$)

F frequent, MF very frequent, I infrequent, R rare; \bar{X} mean, x present, - absent

Colonies irregular, cells more or less loosely and regularly arranged in colonial mucilage; mucilage colorless, homogenous, diffluent; cells oval to cylindrical, 1.8–2.2 μm long, 1.2–1.8 μm wide; cell content homogenous, pale blue-green, without aerotopes (Fig. 2).

According to McGregor (2013), it is a cosmopolitan species reported from meso-eutrophic reservoirs throughout the temperate zones. Although the species was originally described from planktic freshwater material of a temperate area (Börningesjön lake - Sweden), its presence has already been recorded in different aquatic biotopes of tropical and subtropical climates throughout the world (e.g., Joosten 2006; Sant'Anna et al. 2007; Delazari-Barroso et al. 2007; McGregor 2013; Werner et al. 2015b; Laux et al. 2018). According to Komárek and Anagnostidis (1998), the species was also found in bays of the Baltic Sea. In Brazil, the species was also reported in brackish

water from tropical and subtropical coastal lagoons by Azevedo et al. (1999) and Werner (2002), respectively.

The species was found in both tropical and subtropical water bodies from two Brazilian regions: southeastern (Espírito Santo, Rio de Janeiro, Minas Gerais and São Paulo states), and southern (Rio Grande do Sul state).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 5-II-2013, SM Alves-da-Silva s.n. (HAS109552).

Merismopediaceae Elenkin 1933

Aphanocapsa Nägeli 1849

Aphanocapsa delicatissima W. & G. S. West, J. Linn. Soc. Bot. 40: 431. 1912.

Colonies microscopic, spherical, oval or elongated; cells loosely arranged in colonial mucilage; mucilage homogenous, fine, colorless and diffluent; cells spherical, hemispherical after division, 0.9–1(1.2) μm diam.; cell content blue-green, homogenous (Fig. 3).

It is a planktic species of different aquatic biotopes (lakes, ponds and reservoirs) throughout the world reported mainly in temperate regions (Komárek and Anagnostidis 1998).

In Brazil, the species was found in freshwater from north (Amazonas and Pará states), central-west (Federal District and Goiás state), northeastern (Ceará and Rio Grande do Norte), southeastern (Minas Gerais, Rio de Janeiro and São Paulo states) and southern (Rio Grande do Sul state) regions.

In Basin 7 it was rare, and although the species has been observed on a single occasion (late spring 2012), it stood out in the analyzed sample due to its numerous colonies, with various morphotypes.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 3-XII-2012, SM Alves-da-Silva s.n. (HAS109455).

Aphanocapsa elachista W. & G.S. West, J. Linn. Soc. Bot. 30: 276. 1894.

Colonies microscopic, spherical, oval or elongated; cells very loosely and irregularly arranged in colonial mucilage; mucilage homogenous, fine, colorless and diffluent; cells spherical, hemispherical after division, 1.3–1.7 μm diam.; cell content pale blue-green, homogenous (Fig. 4).

It is a planktic species, common in tropical regions, rare in temperate areas (Komárek and Anagnostidis 1998).

In Brazil, the species was found in both tropical and subtropical different aquatic biotopes from central-west (Goiás state), southeastern (Rio de Janeiro and São Paulo states) and southern (Rio Grande do Sul state) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 3-II-2011, SM Alves-da-Silva s.n. (HAS108853).

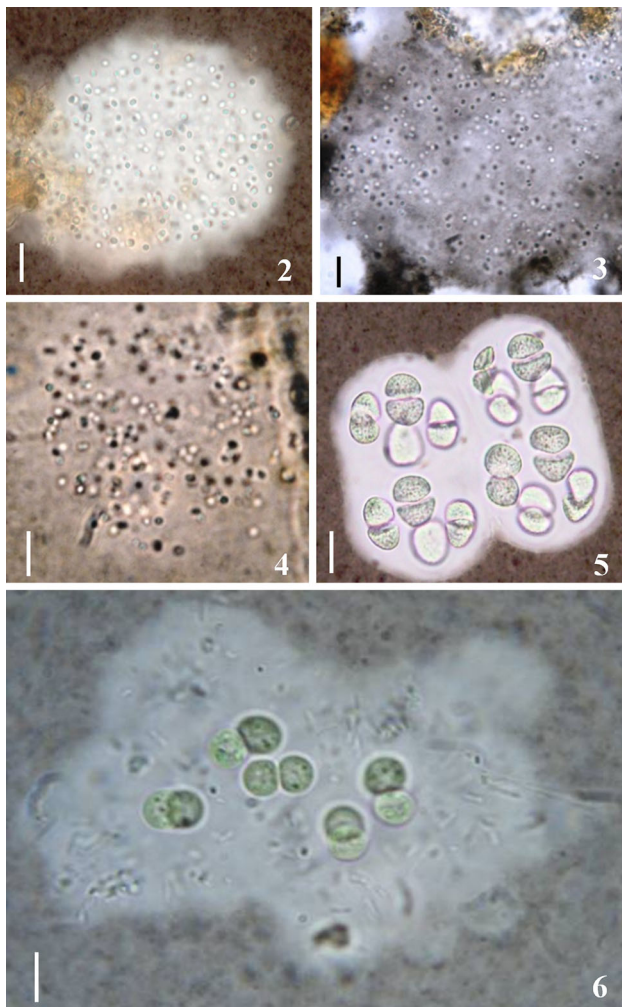


Fig. 2–6 2 *Anathece smithii*. 3 *Aphanocapsa delicatissima*. 4 *A. elachista*. 5 *Eucapsis pseudalpina*. 6 *Limnococcus limneticus*. Bar = 10 μm (2–6)

Eucapsis Clements & Shantz 1909

Eucapsis pseudalpina Komárek & Hindák, Nova Hedwigia 103 (3–4): 451. 2016.

Colonies microscopic, 15–22.2 μm diam., 20–29.3 μm long, 8–32 cells, arranged in groups of 8; mucilage colorless, homogenous, usually diffuent; cells spherical, hemispherical after division, 9–11 μm diam.; cell content blue-green, homogenous or slightly granulated (Fig. 5).

According to Komárek et al. (2016), *Eucapsis pseudalpina* occurs in swamps, peat bogs and littoral of lakes in the north part of temperate zones.

This is the first recorded occurrence of the species in Brazil.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 2-V-2007, V Juliano & G Cunha s.n. (HAS 107404).

Limnococcus Komárková et al. 2010

Limnococcus limneticus (Lemmermann) Komárková et al. Hydrobiologia 639: 79. 2010.

Basionym: *Chroococcus limneticus* Lemmermann, Bot. Zbl. 76: 153. 1898.

Colonies microscopic, oval, elongated or irregular; irregularly arranged cells, sometimes in indistinct groups (2–6 cells); mucilage colorless, firm, homogenous, diffuent; cells spherical or hemispherical after division, usually with individual envelope, 6.3–7.5 μm diam.; cell content blue-green, homogenous or slightly granulated (Fig. 6).

Limnococcus limneticus is a typically planktic species with cosmopolitan distribution, but its exact variations, distribution and ecology are not well known (Komárek and Anagnostidis 1998—described as *Chroococcus limneticus*; Komárková et al. 2010). It has already been recorded in different temperate, tropical and subtropical aquatic biotopes throughout the world.

In Brazil, until now, the species has not been recorded only in the northeastern region. It was found in Amazonas (north), and Goiás (central-west), Rio de Janeiro and São Paulo (southeastern), Paraná and Rio Grande do Sul (southern) states and Federal District (central-west).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 6-XII-2000, SM Alves-da-Silva & G Machado s.n. (HAS35364); 12-IX-2005, VR Werner & V Juliano s.n. (HAS106655); 3-II-2011, SM Alves-da-Silva s.n. (HAS108853).

Merismopedia Meyen 1839

Merismopedia glauca (Ehrenberg) Kützing, Phycol. Germ., 142. 1845.

Basionym: *Gonium glaucum* Ehrenberg, Infusions, 58. 1838.

Colonies tabular, flat, rectangular, cells distributed in regular rows, close to each other, forming groups of 16–64; mucilage homogenous, colorless, diffuent; cells spherical or oblong before division, after division hemispheric, 4.5–5 μm diam.; cell content blue-green, homogenous without aerotopes (Fig. 7).

According to Komárek and Anagnostidis (1998) *Merismopedia glauca* is metaphytic and benthic, facultatively planktic. It is a cosmopolitan species reported in different temperate, tropical and subtropical aquatic biotopes throughout the world.

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes in north (Amazonas and Pará states), central-west (Federal District), northeastern (Rio Grande do Norte and Bahia states), southeastern (Minas Gerais, Rio de Janeiro and São Paulo states) and southern (Paraná and Rio Grande do Sul states) regions. Usually it was found in freshwater, but it was also recorded in a subtropical, southernmost brackish coastal lagoon by Werner (2002).

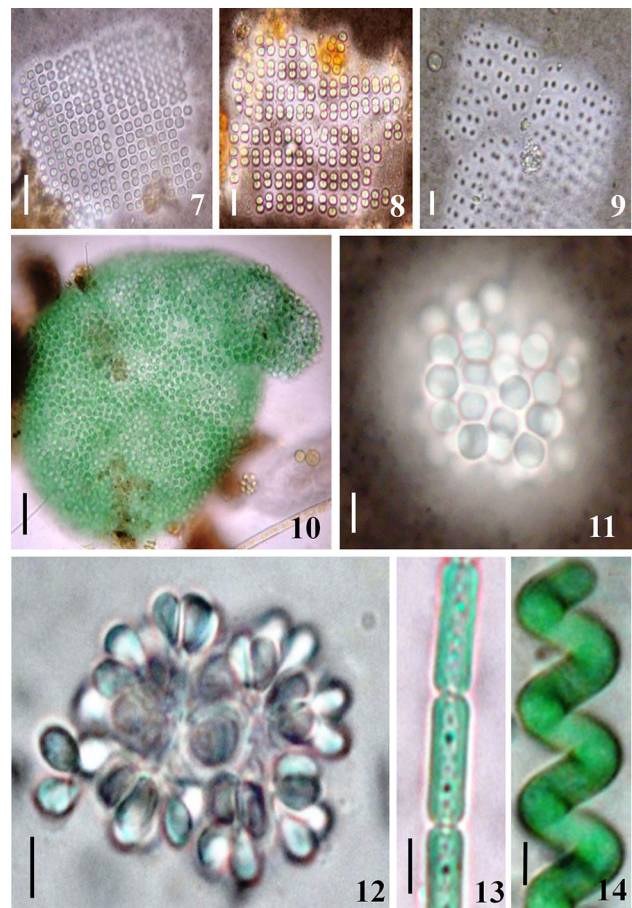


Fig. 7–14 7 *Merismopedia glauca*. 8 *M. punctata*. 9 *M. tenuissima*. 10 *Pannus* cf. *brasiliensis*. 11 *Coelomoron pusillum*. 12 *Snowella lacustris*. 13 *Pseudanabaena catenata*. 14 *Spirulina princeps*. Bar = 2.5 μm (13); 5 μm (11, 12, 14); 10 μm (8, 9); 20 μm (7); 30 μm (10)

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 11-V-2000, SM Alves-da-Silva & G Machado s.n. (HAS35211, 35213); 18-VII-2000, G Machado s.n. (HAS35274); 9-X-2000, SM Alves-da-Silva & G Machado s.n. (HAS35358, 35360); 3-VII-2002, SM Alves-da-Silva & N Bittencourt s.n. (HAS103461); 2-XII-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103595, 103597); 1-X-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104329); 1-XII-2003, VR Werner s.n. (HAS104461, 104462); 13-IX-2004, VR Werner & ML Nunes s.n. (HAS106178); 8-XI-2004, SM Alves-da-Silva s.n. (HAS106182); 6-XII-2004, ML Nunes s.n. (HAS106337); 15-II-2005, SM Alves-da-Silva & V Juliano s.n. (HAS106455); 5-XII-2005, V Juliano s.n. (HAS106726, 106728); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107308, 107310); 2-V-2007, V Juliano & G Cunha s.n. (HAS107404, 107406); 3-IX-2007, SM Alves-da-Silva & V Juliano s.n. (HAS107462); 5-V-2009, SM Alves-da-Silva s.n. (HAS108095); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552, 109554); 7-V-2013, SM Alves-da-Silva s.n. (HAS109598); 10-XII-2013, SM Alves-da-Silva s.n. (HAS109805, 109807).

Merismopedia punctata Meyen, Neues Syst. Pfl.—Physiol. 3: 440. 1839.

Colonies microscopic, flat, tabular, rectangular, cells disposed more or less loosely in regular rows, forming groups of 16–64; mucilage homogenous, fine, colorless, diffuent; cells spherical, hemispherical after division, 2.8–3 µm diam.; cell content blue-green, homogenous, without aerotopes (Fig. 8).

The species can be both planktic and metaphytic in fresh or brackish water throughout the world; cosmopolitan but most common in tropical and other warm areas (Komárek and Anagnostidis 1998).

According to Sant'Anna et al. (2004), *M. punctata* is a common species in tropical and subtropical regions, but sometimes mistaken for *M. glauca* or *M. hyalina* (Ehrenberg) Kützing. The species differs from *M. glauca* and *M. hyalina* by their cellular dimensions, which are smaller than the first and larger than the second. In addition, *M. punctata* cell-to-cell distance is bigger, while cells are arranged closer to each other in the other two species. *M. hyalina* also differs from *M. punctata* due to a smaller number of cells in the colony (generally up to 16) and a somewhat irregular cell arrangement.

In Brazil, the species was recorded in different tropical and subtropical fresh and brackish water biotopes, both in plankton and in metaphyton. Its presence has already been registered in all Brazilian regions: north (Amazonas state), northeastern (Pernambuco state), central-west (Federal District and Mato Grosso state), southeastern (Espírito

Santo, Rio de Janeiro and São Paulo states) and southern (Paraná and Rio Grande do Sul states).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 12-V-2005, VR Werner s.n. (HAS106568); 5-XII-2005, V Juliano s.n. (HAS106728).

Merismopedia tenuissima Lemmermann, Bot. Zbl. 76: 154. 1898.

Colonies microscopic, flat, tabular, rectangular, cells disposed more or less densely in perpendicular rows, mucilage homogenous, fine, colorless, diffuent; cells spherical, hemispherical after division, 1.5–2 µm diam.; cell content blue-green, homogenous, without aerotopes (Fig. 9).

Species commonly found in plankton. According to Komárek and Anagnostidis (1998), it is common in stagnant eutrophic freshwater, also in brackish water, particularly in the warm season of the year, probably cosmopolitan.

In Brazil, the species was recorded in different tropical and subtropical fresh and brackish water biotopes, both in plankton and in metaphyton. It has already been registered in all Brazilian regions: north (Amazonas and Pará states), northeastern (Pernambuco state), central-west (Federal District and Goiás state), southeastern (Espírito Santo, Rio de Janeiro, Minas Gerais and São Paulo states) and southern (Paraná and Rio Grande do Sul states).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 11-V-2000, SM Alves-da-Silva & G Machado s.n. (HAS35211); 9-X-2000, SM Alves-da-Silva & G Machado s.n. (HAS35358, 35360); 6-XII-2000, SM Alves-da-Silva & G Machado s.n. (HAS35364, 35366); 6-II-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103233); 14-VI-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103441); 2-XII-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103593, 103597); 4-VIII-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104088); 1-XII-2003, VR Werner s.n. (HAS104461); 6-XII-2004, ML Nunes s.n. (HAS106337); 5-XII-2005, V Juliano s. n. (HAS106726); 8-II-2006, VR Werner & V Juliano s.n. (HAS106790, 106792); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 12-XII-2006, VR Werner s.n. (HAS107214); 2-V-2007, HAS107404; 7-II-2008, SM Alves-da-Silva (HAS107635); 6-V-2008, VR Werner s.n. (HAS107689); 3-XII-2012, SM Alves-da-Silva s.n. (HAS109453).

Pannus Hickel 1991

Pannus cf. *brasiliensis* Malone et al. Nova Hedwigia 99: 511–524. 2014

Colonies microscopic, hollow, clathrate, elongated, with lobes; cells densely arranged, in one layer in the colonial

periphery; mucilage fine, homogenous, colorless, diffuent; cells rounded or hemispherical after division, 3.1–4.3(4.5) μm diam.; cell content bright blue-green, homogenous, without aerotopes or individual mucilage (Fig. 10).

The colonies observed resemble *Pannus brasiliensis*, described by Malone et al. (2014) from a Brazilian tropical wetland area, in a combined approach of morphological, ultrastructural and genetic analyses. Due to their morphological similarities, the population analyzed was labeled *P. cf. brasiliensis*, and a polyphasic approach would be necessary to define the correct circumscription of this taxon.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 3-XII-2012, SM Alves-da-Silva s.n. (HAS109455).

Coelosphaeriaceae Elenkin 1933

Coelomoron Buell 1938

Coelomoron pusillum (Van Goor) Komárek & Hindák, *Algol. Stud.* 50–53: 210, 1988.

Basionym: *Coelosphaerium pusillum* Van Goor, *Recueil Trav. Bot. Néerl.* 22: 318. 1924.

Colonies microscopic, spherical or slightly oval, 22.2–26 μm diam., sometimes composed of subcolonies; cells more or less radially arranged in the colonial periphery; mucilage homogenous, colorless, diffuent; cells oval, 3–3.5 μm diam., 3.5–4.5 μm long; cell content blue-green, homogenous, without aerotopes (Fig. 11).

The two closest species, *Coelomoron microcystoides* Komárek and *C. tropicalis* Senna, Peres and Komárek, differ from *C. pusillum*, basically, by the dimensions of the colonies and by the thickness of the mucilaginous envelope of the colonies. The colonies of *C. pusillum* are smaller than those of *C. microcystoides* [– 50 (– 80) μm diam] and larger than those of *C. tropicalis* [(9.8–) 10.7–13.7 (– 16.8) μm diam] (Senna et al. 1998). Although in the three species the mucilage is diffuent, colorless and perceptible only with dye, in *C. pusillum* it is wide, whereas in the other two it is very fine. Regarding the size and morphology of the cells and their arrangement in the colony, there are no strong distinctive elements among the three species. *C. pusillum* was originally found in a temperate region and the other two species in tropical ones. The three species were found in both plankton and metaphyton in different environments characterized by the presence of large amounts of macrophytes.

This is the second recorded occurrence of the species in Brazil. The first was recorded by Martins et al. (2012a) from populations found in a subtropical marsh in southernmost Brazil.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 3-XII-2012, SM Alves-da-Silva s.n. (HAS109453); 7-IV-2014, VR Werner s.n. (HAS109991).

Snowella Elenkin 1938

Snowella lacustris (Chodat) Komárek & Hindák, *Algol. Stud.*, 50–53: 212. 1988.

Basionym: *Gomphosphaeria lacustris* Chodat *Bull. Herb. Bossier*, 6: 180. 1898.

Colonies solitary, rounded; mucilage thin, colorless, diffuent; cells pyriform, 2.1–3 μm long, 2–2.5 μm wide, joined to the end of a mucilaginous stalk system, radiating from the colonial center; cell content blue-green, without aerotopes (Fig. 12).

Planktic species found in different aquatic biotopes, including the eastern Baltic Sea; common but never in masses; probably cosmopolitan (Komárek and Anagnostidis 1998). Its presence has already been observed in temperate, tropical and subtropical regions of the world.

In Brazil, the species was found mainly in subtropical water bodies of the south region of the country, in both fresh and brackish water, but it was also recorded in tropical zones from north (Amazonas and Pará states), central-west (Federal District and Goiás state), southeastern (São Paulo state) and southern (Rio Grande do Sul state) regions.

In Basin 7, it was infrequent and was well represented in samples collected in the summer (February), especially those obtained in 2010 and 2015 due to its numerous colonies, but it never formed blooms.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 9-II-2010, SM Alves-da-Silva & s.n. (HAS108309); 7-II-2012, SM Alves-da-Silva s.n. (HAS109128, 109201); 10-XII-2013, SM Alves-da-Silva s.n. (HAS109807); 4-II-2015, SM Alves-da-Silva s.n. (HAS110202, 110203); 9-VI-2015, SM Alves-da-Silva s.n. (HAS110333).

Pseudanabaenaceae Anagnostidis & Komárek 1988

Pseudanabaena Lauterborn 1916

Pseudanabaena catenata Lauterborn, *Verh. Naturh.-med. Ver. Heidelb.*, 13(2): 437. 1916.

Trichomes solitary, straight or flexuous, deeply constricted at the thickened, translucent cross-walls, not attenuated, 1–2.2 μm wide; cells cylindrical, truncate-rounded at the extremity, 2.5–5.5 μm times longer than wide, 5–6.5 μm long; cell content blue-green, homogenous, without aerotopes; apical cell rounded, without thickened outer cell wall (Fig. 13).

It is a cosmopolitan species, found in different environments throughout the world; it can be benthic, epipelagic, sapropelagic or periphytic, secondarily planktic (tychoplanktic) in fresh, brackish, thermal and salt water bodies (Komárek and Anagnostidis 2005). Its presence has already been observed in temperate and tropical regions of the world.

In Brazil, the species was recorded in both tropical and subtropical water bodies from north (Amazonas state), northeastern (Pernambuco, Paraíba, and Bahia states), central-west Distrito Federal and Goiás state), southeastern (Rio de Janeiro and São Paulo states) and southern (Rio Grande do Sul state) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, açude (Basin 7), 10-III-2014, VR Werner s.n. (HAS109966); 8-XII-2014, VR Werner s.n. (HAS110190).

Spirulinales Komárek, Kaštovský, Mareš, Johansen 2014
Spirulinaceae (Gomont) Hoffmann, Komárek, Kaštovský 2005

Spirulina Turpin ex Gomont 1892

Spirulina princeps W. & G. S. West, Trans. Linn. Soc., 2. ser. Bot., 6: 205. 1902.

Trichomes solitary or forming fluctuating mass, coiled, not constricted, not attenuated, 4–5 µm wide, coils regular, (8.5) 9.5–12 µm wide, distance between coils (7.5) 8–12 µm; cell content bright blue-green, homogenous, without aerotopes; apical cell rounded, without thickened outer cell wall (Fig. 14).

Spirulina princeps is known from tropical and subtropical areas throughout the world (Komárek and Anagnostidis 2005, McGregor 2007). According to Komárek and Anagnostidis (2005), it is rare, living solitary among other algae in stagnant water. McGregor (2007) found it on benthos of a wetland.

In Brazil, until now, the species had only been recorded in a tropical floodplain in Paraná state by Rodrigues and Bicudo (2001) and Fonseca and Rodrigues (2005), and in a subtropical marsh in Rio Grande do Sul state by Werner et al. (2015b), two states in the southern region.

In Basin 7 it was frequent, and normally, the trichomes were solitary, living among other filamentous cyanobacteria but were also found in floating, macroscopic, dark green thallus formed mainly by *Ancylothrix rivularis*.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 1-X-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104329); 6-XII-2004, ML Nunes s.n. (HAS106337); 5-XII-2005, V Juliano s.n. ((HAS106726); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 12-XII-2006, VR Werner s.n. (HAS107215); 2-V-2007, V Juliano & G Cunha s.n. (HAS107406); 6-V-2008, VR Werner s.n. (HAS107689); 2-V-2011, V. Juliano s.n. (HAS108997); 6-XI-2014, VR Werner s.n. (HAS110082); 8-XII-2014, DM Talgatti s.n. (HAS110190); 4-II-2015, SM Alves-da-Silva s.n. (HAS110202); 7-IV-2015, VR Werner s.n. (HAS110223); 6-V-2015, SM Alves-da-Silva s.n. (HAS110331, 110332).

Chroococcales Wettst 1924

Microcystaceae Elenkin 1933

Microcystis Kützing ex Lemmermann 1907

Microcystis aeruginosa (Kützing) Kützing, Tab. Phycol., 1: 6. 1846.

Basionym: *Micaloa aeruginosa* Kützing, Linnaea, 8: 371. 1833.

Colonies mucilaginous, more or less spherical to irregular; sometimes net-like clathrate with holes; irregularly distributed cells, usually densely aggregated in the center of colonies; mucilage wide, homogeneous, colorless, diffuent; cells spherical, 5–6 µm diam.; cell content blue-green, with aerotopes (Fig. 15).

Among the species of the genus, *Microcystis aeruginosa* is the most commonly cited. It is a cosmopolitan species and has not been recorded yet only in polar and subpolar regions. This planktic species sometimes forms dense toxic blooms in fresh or brackish water (Komárek and Anagnostidis 1998). In eutrophic water bodies, *M. aeruginosa* is the most frequent species in cyanobacterial blooms and, even when occurring together with other species, it is frequently the dominant species (Sant'Anna et al. 2004).

In Brazil, *M. aeruginosa* is widely spread, recorded from the North to the South of the country. However, its wide

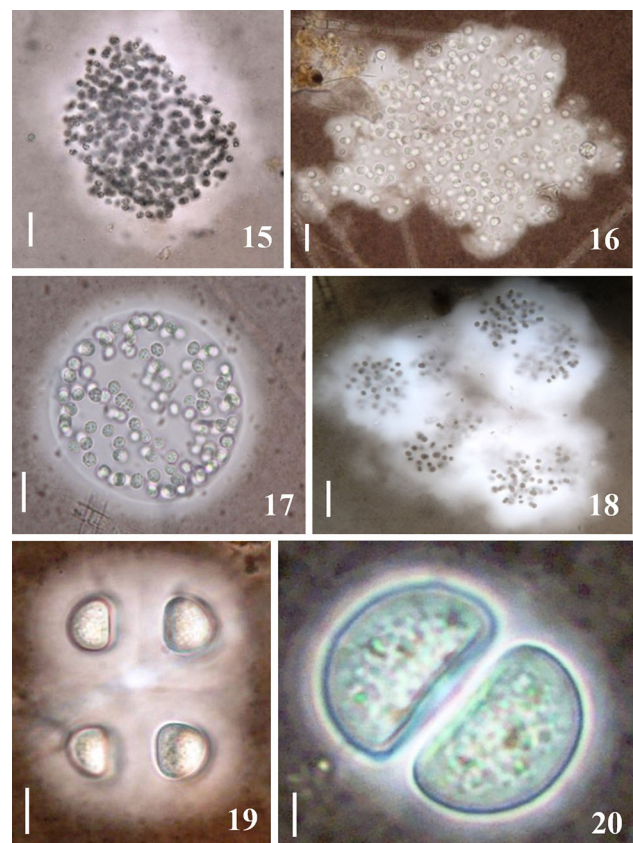


Fig. 15–20 15 *Microcystis aeruginosa*. 16 *Microcystis protocystis*. 17 *M. wesenbergii*. 18 *Radiocystis fernandoi*. 19 *Chroococcus mipitanensis*. 20 *C. turgidus*. Bar = 5 µm (20); 10 µm (19); 20 µm (17); 30 µm (15, 16); 50 µm (18)

distribution may be related to identification mistakes (Sant'Anna et al. 2004). The taxonomic misinterpretations and confusions in the precise identification of the species are due, in great part, to the fact that *M. aeruginosa* presents numerous morphotypes in its different stages of development.

In Basin 7, *M. aeruginosa* was frequent, occurred in different seasons of the year, but never forming blooms.

Examined material: BRAZIL. Rio Grande do Sul, Triunfo: pond (Basin 7), 14-VI-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103441); 3-VII-2002, SM Alves-da-Silva & N Bittencourt s.n. (HAS103461); 4-II-2003, SM Alves-da-Silva & G Cunha s.n. (HAS103908, 103910); 2-VI-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104084); 1-X-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104329, 104332); 1-XII-2003, VR Werner s.n. (HAS104461, 104462); 3-II-2004, SM Alves-da-Silva & G Cunha s.n. (HAS104591, 104593); 11-IX-2006, V.R. Werner & V. Juliano (HAS107142); 3-IX-2012, SM Alves-da-Silva s.n. (HAS109370); 10-XII-2013, SM Alves-da-Silva s.n. (HAS109807); 8-XII-2014, VR Werner s.n. (HAS110190); 4-II-2015, SM Alves-da-Silva s.n. (HAS110203); 9-VI-2015, SM Alves-da-Silva s.n. (HAS110333); 9-IX-2015, SM Alves-da-Silva s.n. (HAS110516); 3-XI-2015, V Juliano s.n. (HAS110536).

Microcystis protocystis Crow, New Phytol. 22(2): 62, 1923.

Colonies mucilaginous, irregular, spherical or elongate, irregular in outline, without lobes or holes; irregularly and sparsely arranged cells in all colonial mucilage; mucilage homogeneous, colorless, diffluent; cells spherical, sometimes with their own colorless gelatinous envelopes, 3.6–6.5 µm diam.; cell content blue-green, with aerotopes (Fig. 16).

This is a typical tropical species, originally described from the plankton in Sri Lanka, and considered to have a pantropical distribution, forming often heavy water blooms (Komárek and Anagnostidis 1998; Komárek et al. 2001).

According to Komárek et al. (2002), *Microcystis protocystis* is very common in plankton of Brazilian water bodies. However, its recorded occurrence in Brazil is scarce, for having been misinterpreted probably with *M. aeruginosa*. Young stages of *M. protocystis* and *M. aeruginosa* are particularly similar (Komárek et al. 2001). Besides, Sant'Anna et al. (2004) mentioned that the sparse cell disposition gives *M. protocystis* the aspect of old or senescent colonies of different *Microcystis* species. Therefore, its distribution must be wider than usually mentioned in the literature.

Microcystis protocystis was recorded in both tropical and subtropical Brazilian freshwater (usually in blooms), especially in water bodies of São Paulo state (southeastern

region) by Komárek et al. (2002), Sant'Anna et al. (2004, 2007), Rosini et al. (2013). The species also occurs commonly in aquatic biotopes of the southern region of Brazil (VR Werner personal communication), where it was already reported in lakes by Carvalho et al. (2008) and Martins et al. (2012a), and in ponds by Domingues and Torgan (2011) and Werner et al. (2015b). It was also registered in other regions of the country: north (Amazonas state), northeastern (Rio Grande do Norte, Paraíba and Pernambuco states), central-west (Goiás state) and southeastern (Rio de Janeiro, Minas Gerais and São Paulo states). Toxic blooms were documented in the northeastern region (Pernambuco state) by Komárek et al. (2001).

In Basin 7, it was frequent, standing out in late spring 2012 (December) due to its numerous colonies, with various morphotypes, but did not form blooms.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 14-VI-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103441); 3-VII-2002, SM Alves-da-Silva & N Bittencourt s.n. (HAS103461); 2-IX-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103591); 2-XII-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103597); 4-II-2003, SM Alves-da-Silva & G Cunha s.n. (HAS103908); 2-VI-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104084); 4-VIII-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104090); 2-IX-2003, VR Werner s.n. (HAS104327, 104328); 3-II-2004, SM Alves-da-Silva & G Cunha s.n. (HAS104591); 12-IX-2005, VR Werner & V Juliano s.n. (HAS106655); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 3-IX-2007, SM Alves-da-Silva & V Juliano s.n. (HAS107460); 6-V-2008, VR Werner s.n. (HAS107689); 3-XII-2012, SM Alves-da-Silva s.n. (HAS109453); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552, 109554); 7-V-2013, SM Alves-da-Silva s.n. (HAS109598).

Microcystis wesenbergii (Komárek) Komárek in Kondratieva, Cvetenie vody, 13. 1968.

Basionym: *Diplocystis wesenbergii* Komárek in Komárek & Ettl, Algologische Studien, 68. 1958.

Colonies rounded, oval, elongated, irregular, lobate and clathrate, with holes, sometimes composed of subcolonies; cells irregularly distributed in the mucilage; internal mucilaginous envelope distinctly delimited, firm, colorless, with refractive outline, sometimes with external diffluent, hyaline mucilage; cells rounded, 5–6.3 µm diam.; cell content blue-green, with aerotopes (Fig. 17).

Microcystis wesenbergii is easily distinguished from other species of the genus by the distinctive outline of its colonies: internal mucilaginous firm, homogeneous and evident (refractive). Although it is easily recognized, the species presented numerous morphotypes.

This planktic species is cosmopolitan and has not been recorded only in polar and subpolar regions (Komárek and Anagnostidis 1998). It is common in eutrophic water bodies and may form toxic or non-toxic water blooms.

In Brazil, the species was recorded in both tropical and subtropical Brazilian water bodies, in both fresh and brackish water. It was found in north (Amazonas and Pará states), central-west (Goiás state), southeastern (Minas Gerais, Rio de Janeiro and São Paulo states) and southern (Rio Grande do Sul and Santa Catarina states).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 3-II-2004, SM Alves-da-Silva & G Cunha s.n. (HAS104591, 104593); 3-II-2009, SM Alves-da-Silva s.n. (HAS108024); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552).

Radiocystis Skuja 1948

Radiocystis fernandoi Komárek & Komárková-Legnerová, Preslia, Praha, 65: 355–357. 1993.

Colonies rounded or irregular, formed by one or more groups of cells disposed more or less in rows arranged from the center to the periphery; mucilage homogeneous, colorless, diffuent; cells rounded or oval, 5–7 µm diam. 6–6.8 µm long.; cell content blue-green, with aerotopes (Fig. 18).

Radiocystis fernandoi is typically tropical originally described from the plankton of a mesotrophic reservoir located in São Paulo state. It also occurs in Indonesia, Sri Lanka and Southern Africa (Komárek and Komárková-Legnerová 1993; Komárek and Anagnostidis 1998).

The species was recorded in both tropical and subtropical Brazilian freshwater, especially in water bodies of the southeastern region of the country (São Paulo state). It was also recorded in north (Amazonas, Pará states) and in central-west region (Goiás state) regions. It is relatively common in water bodies in Rio Grande do Sul state, mainly in water blooms (VR Werner personal communication).

In Basin 7, the species was frequent, observed in different seasons of the year, never forming water blooms.

Examined material: BRAZIL. Rio Grande do Sul, Triunfo: pond (Basin 7), 3-II-2004, SM Alves-da-Silva & G Cunha s.n. (HAS104593); 7-VI-2004, SM Alves-da-Silva & G Cunha s.n. (HAS106174); 15-II-2005, SM Alves-da-Silva & V Juliano s.n. (HAS106453); 6-V-2008, VR Werner s.n. (HAS107691); 3-II-2009, SM Alves-da-Silva s.n. (HAS108024); 3-IX-2012, SM Alves-da-Silva s.n. (HAS109370); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552, 109554); 7-V-2014, SM Alves-da-Silva s.n. (HAS110005); 11-VIII-2014, SM Alves-da-Silva s.n. (HAS110059); 7-IV-2015, VR Werner s.n. (HAS110224); 4-III-2015, SM Alves-da-Silva s.n. (HAS110214); 3-XI-2015, V Juliano s.n. (HAS110536).

Chroococcaceae Nägeli 1849

Chroococcus Nägeli 1849

Chroococcus mipitanensis (Woloszynska) Geitler, in Pascher, Süßwasser-Flora, 12: 79. 72. 1925.

Basionym: *Chroococcus turgidus* var. *mipitanensis* Woloszynska, Bull. int. Acad. Sci. Lett. Cracovie, ser. B, 1912: 692. 1913.

Colonies oval or elliptic, or doubled (biscuit-like) when in division, formed by groups of 2–8 cells; mucilage colorless, usually firm, homogenous or lamellate, delimited; cells spherical or oval, hemispherical after division, usually arranged in pairs, 8.5–17 µm diam.; cell content pale blue-green, slightly granulated, without aerotopes (Fig. 19).

According to Komárek and Novelo (1994), *Chroococcus mipitanensis* is a well-defined species and is easily recognized by its characteristic doubled (biscuit-like) colonies when in division. The species grows mainly in the periphyton (metaphyton and firmly adhered to the substrate), occurring occasionally in the plankton, is widely distributed in tropical regions, thus a pantropical species.

In Brazil, until now, it had been recorded only in a subtropical freshwater coastal lagoon of southern region of the country (Rio Grande do Sul state) by Werner (2002). This is the second registered occurrence of the species in Brazilian biotopes.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 2-V-2007, V Juliano & G Cunha s.n. (HAS107404).

Chroococcus turgidus (Kützinger) Nägeli, Gatt. einz. Algen. 46. 1849.

Basionym: *Protococcus turgidus* Kützinger, Tab. phycol. 1: 5. 1846.

Colonies usually elliptical, formed by 2–4 cells; mucilage colorless, firm, homogenous or lamellate, usually delimited; cells spherical or hemispherical after division, 12.5–17.5 µm diam.; cell content blue-green, homogenous or granular, without aerotopes (Fig. 20).

According to Komárek and Anagnostidis (1998), *Chroococcus turgidus*, a benthic/metaphytic species, can occur in littoral of stagnant water, ponds and lakes, preferring slightly acidic environments. It is common in temperate regions, but probably cosmopolitan.

The species was recorded in both tropical and subtropical Brazilian fresh and brackish water biotopes, in benthos, periphyton and plankton, from north (Pará state), central-west (Federal District and Goiás state), southeastern (Rio de Janeiro, Minas Gerais and São Paulo states) and southern (Santa Catarina and Rio Grande do Sul states) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, açude (Basin 7), 2-V-2007, V Juliano & G Cunha s.n. (HAS107404).

Oscillatoriales Elenkin1934

Coleofasciculaceae Komárek, Kaštovský, Mareš & Johansen 2014

Anagnostidinema Strunecký et al. 2017

Anagnostidinema amphibium (Agardh ex Gomont) Strunecký, Bohunická, Johansen, Komárek, Fottea 17(1): 119–121. 2017.

Basionym: *Oscillatoria amphibia* Agardh ex Gomont, Ann. Sci. Nat.–Bot. 16: 221, pl. VII, Fig. 6. 1892.

Synonym: *Phormidium amphibium* (Agardh ex Gomont) Anagnostidis & Komárek, Arch. Hydrobiol. Suppl./Algol. Stud. 50–53: 404, 1988; *Geitlerinema amphibium* (Agardh ex Gomont) Anagnostidis, Plant. Syst. Evol. 164: 38. 1989.

Trichomes solitary, straight or flexuous, not or very slightly attenuated, not constricted at the usually translucent cross-walls, (1–1.2)1.5–2.5 μm wide; cells 1.7–3.3(–5) times longer than wide, 3–7.5 μm long; cell content blue-green, homogenous, without aerotopes; 1–2 granules on either or both sides of the cross-walls; apical cell rounded or truncated, without calyptra or thickened outer cell wall (Fig. 21).

A freshwater, benthic, usually periphytic species in stagnant waters; it can also occur in streams, in greenhouses, on wet soils. It is distributed throughout the world, probably cosmopolitan (Komárek and Anagnostidis 2005, Strunecký et al. 2017).

Anagnostidinema amphibium is commonly distributed in Brazilian tropical and subtropical regions, designated *Geitlerinema amphibium* (e.g., Torgan and Paula 1994, Nogueira 1999, Werner 2002, Sant'Anna et al. 2007, Martins et al. 2012b, and Rosini 2013) or *Oscillatoria amphibia* (e.g., Sant'Anna et al. 1978, Senna and Ferreira 1986, Senna 1996, Werner and Rosa 1992, Azevedo et al. 1996, and Torgan 1997). It was found in fresh and brackish water aquatic biotopes (plankton and periphyton), and also on moist soil, in north (Pernambuco state), central-west (Federal District and Goiás state), southeastern (Rio de Janeiro, São Paulo states) and southern (Rio Grande do Sul state) regions.

In Basin 7, it was frequent, observed in different seasons of the year.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, açude (Basin 7), 9-X-2000, SM Alves-da-Silva & G Cunha s.n. (HAS35360); 6-XII-2000, SM Alves-da-Silva & G Machado s.n. (HAS35364); 7-VI-2004, SM Alves-da-Silva & G Cunha s.n. (HAS106174); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107310); 2-V-2007, V

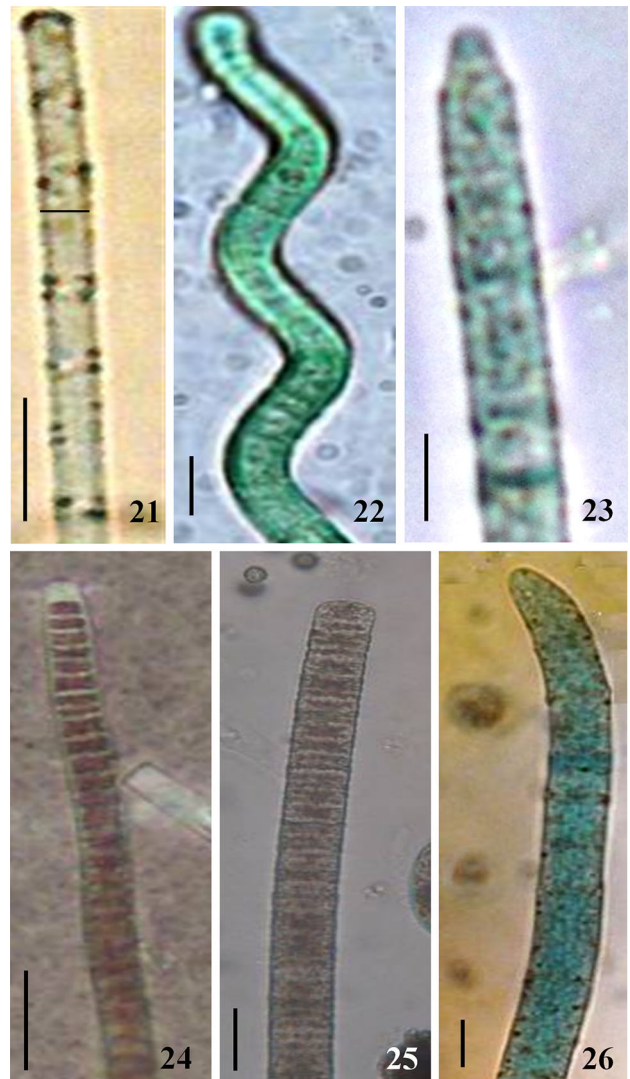


Fig. 21–26 21 *Anagnostidinema amphibium*. 22 *Arthrospira jenneri*. 23 *Microcoleus autumnale*. 24 *Planktothrix agardhii*. 25 *P. isoethrix*. 26 *Ancylothrix rivularis*. Bar = 5 μm (21, 23, 26); 10 μm (22, 24, 25)

Juliano & G Cunha s.n. (HAS107404); 3-IX-2007, SM Alves-da-Silva & V Juliano s.n. (HAS107460); 7-II-2008, SM Alves-da-Silva s.n. (HAS107635); 9-II-2010, SM Alves-da-Silva & V Juliano s.n. (HAS108309); 10-V-2010, VR Werner s.n. (HAS108552); 3-II-2011, SM Alves-da-Silva s.n. (HAS108853); 12-IX-2011, V Juliano s.n. (HAS109112, 109114); 8-XII-2011, SM Alves-da-Silva s.n. (HAS109157); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552); 7-V-2013, SM Alves-da-Silva s.n. (HAS109600); 10-III-2014, VR Werner s.n. (HAS109966); 7-IV-2014, VR Werner s.n. (HAS109991).

Microcoleaceae Komárek, Kaštovský, Mareš & Johansen 2014

Arthrospira Stizenberger ex Gomont 1892

Arthrospira jenniferi Stizenberger ex Gomont, Ann. Sci. nat., Sér.7. Bot. 16: 247. 1892.

Trichomes solitary or forming fluctuating mass, coiled, not constricted, not attenuated, 4–5 µm wide, coils regular, 8–11.3 µm wide, distance between coils 13.7–23 µm; cells almost isodiametric or shorter than wide, 0.5–1.1(1,3) times longer than wide, 2.5–5 µm long; cell content blue-green, homogenous, cross-walls granulated, without aerotopes; apical cell rounded, without thickened cell wall (Fig. 22).

This freshwater species can be periphytic, epiphytic or benthic, widely distributed throughout temperate and tropical regions (Komárek and Anagnostidis 2005).

In Brazil, until now, the species had been recorded only in tropical water bodies in the southeastern region of the country by Magrin et al. 1997 (Minas Gerais state) and by Sant'Anna et al. 2011 (São Paulo state), and in the central-west region (Goiás state) by Nogueira et al. (2008). This is the first registered occurrence of the species in a Brazilian subtropical area.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 1-XII-2003, VR Werner s.n. (HAS104461, 104462); 2-V-2011, V Juliano s.n. (HAS108997, 108999); 7-V-2012, SM Alves-da-Silva s.n. (HAS109337, 109600); 3-IX-2012, SM Alves-da-Silva s.n. (HAS109370); 8-XII-2014, VR Werner s.n. (HAS110190); 4-III-2015, SM Alves-da-Silva s.n. (HAS110214); 4-II-2015, SM Alves-da-Silva s.n. (HAS110202, 110203); 6-V-2015, SM Alves-da-Silva s.n. (HAS110331, 110332).

Microcoleus Desmazières ex Gomont 1892

Microcoleus autumnale (Trevisan ex Gomont) Strunecký, Komárek & Johansen, J. Phycol. 49: 1176. 2013. Basionym: *Phormidium autumnale* Trevisan ex Gomont, Ann. Sci. nat., Sér. 7, Bot. 16: 187. 1892.

Trichomes entangled, straight or flexuous, not or slightly constricted, attenuated at the ends, 4.5–5 µm wide; cells isodiametric or shorter than wide, 0.6–0.8 times longer than wide, 2.5–4(4.5) µm long; cell content blue-green, homogenous to slightly granulated (cross-walls granulated), without aerotopes; apical cells somewhat elongated, capitated, without calyptra or thickened cell wall (Fig. 23).

According to Anagnostidis and Komárek (2005), the trichomes of the species are mostly abruptly and strongly attenuated at the ends. However, in the analyzed population the trichomes were only attenuated, similar to Fig. 707d (*Phormidium autumnale*), presented in the aforementioned publication, corroborating the present identification.

This cosmopolitan, freshwater species can occur in the periphyton on submersed substrates and in benthos of different aquatic biotopes (Anagnostidis and Komárek 2005), and also in wet soils (Strunecký et al. 2012).

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes in north (Pará state) and northeastern (Bahia state) regions by Drouet (1937), in southeastern region (São Paulo state) by Sant'Anna et al. (2011) and southern region (Rio Grande do Sul state) by Martins et al. (2012b).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 7-I-2014, VR Werner s.n. (HAS109889).

Planktothrix Anagnostides & Komárek 1988

Planktothrix agardhii (Gomont) Anagnostidis & Komárek, Algolog. Stud. 50–53: 416. 1988.

Basionym: *Oscillatoria agardhii* Gomont, Ann. Sci. nat. Sér. 7, 16: 205. 1892.

Trichomes solitary, straight or flexuous, slight attenuated, not constricted at the sometimes granulated cross-walls, 4–5 µm wide; cells shorter than wide, 0.5–0.7 time longer than wide, (2)2.5–3.3 µm long; cell content blue-green, numerous aerotopes; apical cell convex, sometimes conical, sometimes capitated, sometimes with calyptra or thickened cell wall (Fig. 24).

This freshwater, planktic species is widely distributed throughout temperate regions and is less common in tropics and subtropics (Anagnostidis and Komárek 2005; McGregor 2007).

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes (usually in water blooms) in north (Amazonas and Roraima states), northeastern (Ceará, Rio Grande do Norte, Paraíba, Pernambuco and Bahia states), central-west (Goiás and Mato Grosso do Sul states), in southeastern (São Paulo state) and southern (Rio Grande do Sul state) regions.

In Basin 7, it was infrequent, and it was never found in water blooms.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 5-XII-2005, V Juliano s.n. (HAS106728); 8-II-2006, VR Werner & V Juliano s.n. (HAS106790); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107308, 107310); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552).

Planktothrix isothrix (Skuja) Komárek & Komárková, Czech Phycol. 4: 14. 2004.

Basionym: *Oscillatoria mougeotii* Bory ex Gomont, Ann. Sci. Nat. Bot., sér. 7, 16: 230. 1892.

Synonym: *Oscillatoria agardhii* var. *isothrix* Skuja, Symbol. Bot. Upsal 9:49. 1948. *Planktothrix mougeotii* (Bory ex Gomont) Anagnostidis & Komárek, Anagnostidis & Komárek, Arch. Hydrobiol./Suppl., 80(1–4), Algolog. Stud. 50–53: 416. 1988.

Trichomes solitary, straight or flexuous, not attenuated, not constricted at the sometimes granulated cross-walls,

5–9.5 (10) μm wide; cells shorter than wide, (0.3)0.4–0.8 time longer than wide, (1.5)2.5–5 μm long; cell content blue-green, numerous aerotopes; apical cell rounded, not capitated, without calyptra or thickened cell wall (Fig. 25).

This cosmopolitan, freshwater species is at first benthic, epipelic on mud, later planktic and can form water blooms, distributed worldwide in eutrophic to hypertrophic waters (Komárek and Anagnostidis 2005, McGregor 2007).

In Brazil, *Planktothrix isoethrix* occurs from the north to the south of the country, usually in dense blooms, adding a greenish color, and earthy taste and odor to the waters. It was recorded in north (Amazonas state), northeastern (Ceará, Rio Grande do Norte and Pernambuco states), central-west (Mato Grosso do Sul states), southeastern (São Paulo state) and southern (Rio Grande do Sul state) regions.

In Basin 7, it was frequent, observed in different seasons of the year but never in blooms.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 14-VI-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103439); 10-III-2003, SM Alves-da-Silva & G Cunha s.n. (HAS103912); 1-XII-2003, VR Werner s.n. (HAS104461, 104462); 12-V-2005, V.R. Werner (HAS106570); 12-IX-2005, VR Werner & V Juliano s.n. (HAS106655); 8-II-2006, VR Werner & V Juliano s.n. (HAS106790); 7-II-2008, SM Alves-da-Silva s.n. (HAS107635); 5-V-2009, SM Alves-da-Silva s.n. (HAS108095, 108097); 9-II-2010, SM Alves-da-Silva & V Juliano s.n. (HAS108309); 8-IX-2010, SM Alves-da-Silva s.n. (HAS108575); 2-V-2011, V Juliano (HAS108997); 3-IX-2012, SM Alves-da-Silva s.n. (HAS109370); 5-II-2013, SM Alves-da-Silva s.n. (HAS109554); 10-III-2014, VR Werner s.n. (HAS109966); 7-IV-2014, VR Werner s.n. (HAS109991); 7-V-2014, SM Alves-da-Silva s.n. (HAS110005).

Oscillatoriaceae (S.F. Gray) Harvey ex Kirchner 1898

Ancyllothrix Martins & Branco 2016

Ancyllothrix rivularis Martins & Branco, Int. J. Syst. Evol. Microbiol. 66: 2396–2405. Martins et al. 2016.

Trichomes entangled, straight or flexuous, not or slightly constricted, attenuated and bent at the ends, (4–4.8)5.5–6.4 μm wide; cells cylindrical, shorter than wide to isodiametric, 0.4–1 times longer than wide, 2.5–5.6 long; cell content blue-green, usually granulated at the cross-walls, without aerotopes; apical cells conical-rounded and narrowed, without calyptra or thickened outer cell wall, 3.2–4.8 μm wide, (2.8)3.2–4.8 μm long (Fig. 26).

Ancyllothrix rivularis and *Kamptonema formosum* (Bory de Gomon) Strunecký et al. are morphologically similar but differ genetically, according to Martins et al. (2016).

Trichomes with sheath were not registered in the analyzed populations, which, although rare, were observed in

the type material. Moreover, among the specimens studied rare trichomes narrower than those originally described (5.5–7 μm) were reported. Despite these slight differences, the phylogenetic position of the studied populations, presented by Martins et al. (2016)—(7PC strain), ensures the current identification. So, the specimens studied allow broadening the inferior limit of the trichomes of *Ancyllothrix rivularis* to 4 μm wide.

The species occurred along with *Spirulina princeps*, forming macroscopic, dark green thallus, floating in high water temperature (32 °C), pH 6.2 and conductivity 117.2 $\mu\text{S cm}^{-1}$. Solitary trichomes were also observed sporadically.

One of the strains (7PC) of *Ancyllothrix rivularis*, originally submitted to polyphasic evaluation (morphological, ecological and molecular studies), was obtained from a population of Basin 7 (HAS110191). The other two analyzed strains were from tropical environments of São Paulo state: Barra Funda (8PC—holotype) and Jacaré (9PC) streams (Martins et al. 2016). Thus, this is the first recorded occurrence of the genus and species in Rio Grande do Sul state.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7). 5-II-2013, SM Alves-da-Silva s.n. (HAS109552); 8-XII-2014, DM Talgatti s.n. (HAS110191); 6-V-2015, SM Alves-da-Silva s.n. (HAS110331, HAS 110332).

Oscillatoria Vaucher ex Gomont 1892

Oscillatoria limosa Agardh ex Gomont, Ann. Sci. Nat. Bot., sér. 7, 16: 210. 1892.

Trichomes straight, sometime somewhat curved, not or slightly attenuated, not constricted, 10–15 μm wide; cells 0.2–0.4 time longer than wide, 2.3–3.8(4.5) μm long, apical cells rounded-truncate, not capitate, frequently with slightly thickened cell wall; cell content bright blue-green, usually finely granulated, granulated or not at the cross-walls, without aerotopes (Figs. 27, 28).

Oscillatoria limosa is initially benthic on various substrata, occasionally in free-floating tufts or in solitary trichomes among other cyanobacteria, algae and macrophytes; later free-floating, forming mats in fresh or brackish water. It is distributed worldwide and cosmopolitan (Komárek and Anagnostidis 2005; McGregor 2007).

The species was recorded in both tropical and subtropical Brazilian fresh and brackish water biotopes, in north (Amazonas and Pará states), central-west (Goiás, Mato Grosso and Mato Grosso do Sul states), in southeastern (Rio de Janeiro and São Paulo state) and southern (Paraná and Rio Grande do Sul states) regions.

In Basin 7, it was frequent, and only solitary trichomes were observed in different seasons of the year.

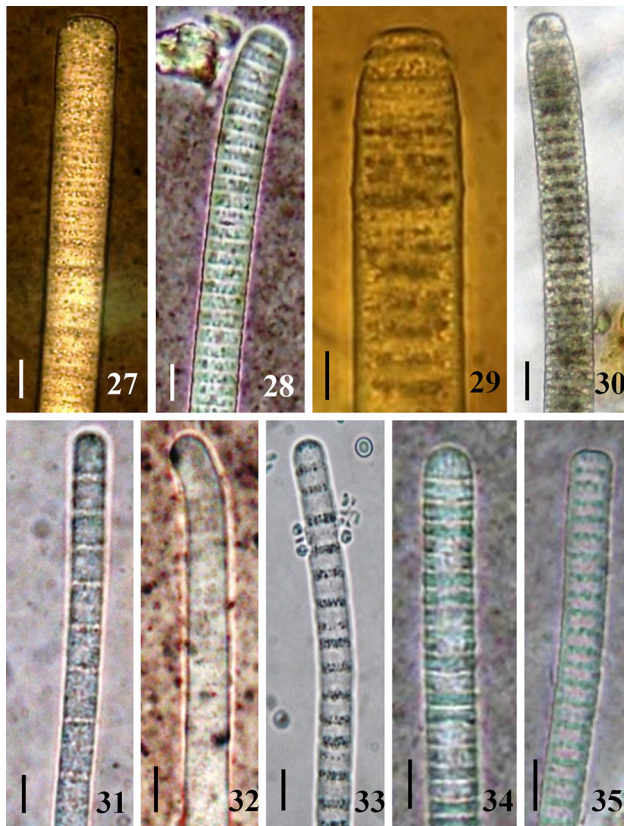


Fig. 27–35 27, 28 *Oscillatoria limosa*. 29 *O. princeps*. 30 *O. sancta*. 31 *Phormidium articulatum*. 32 *P. chalybeum*. 33 *P. granulatum*. 34 *P. irrigum*. 35 *P. tergestinum*. Bar = 5 μm (31, 33); 10 μm (27–30, 32, 34, 35)

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 6-II-2002, SM Alves-da-Silva s.n. (HAS103231); 3-VII-2002, SM Alves-da-Silva & N Bitencourt s.n. (HAS103461); 5-VIII-2002, SM Alves-da-Silva s.n. (HAS103481); 2-XII-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103597); 3-II-2004, SM Alves-da-Silva & G Cunha s.n. (HAS104593); 11-V-2004, SM Alves-da-Silva & G Cunha s.n. (HAS106173); 6-XII-2004, ML Nunes s.n. (HAS106337); 12-IX-2005, VR Werner & V Juliano s.n. (HAS106655); 5-XII-2005, V Juliano s.n. (HAS106726, 106728); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107308); 2.V.2007, V Juliano & G Cunha s.n. (HAS107406); 7-II-2008, SM Alves-da-Silva s.n. (HAS107637); 3-II-2011, SM Alves-da-Silva s.n. (HAS108853); 2-V-2011, V Juliano s.n. (HAS108999); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552); 7-V-2013, SM Alves-da-Silva s.n. (HAS109600).

Oscillatoria princeps Vaucher ex Gomont, Ann. Sci. Nat. Bot., sér. 7, 16: 206. 1892.

Trichomes straight or slightly curved in the apex, slightly attenuated, not or slightly constricted, 17.5–25 (50)

μm wide; (0.1)0.2–0.4 time longer than wide, 2.5–6.3 (7.5) μm long; apical cells rounded, hemispherical or rounded-truncate, sometimes subcapitate, without or with slightly thickened cell wall; cell content blue-green, homogeneous or slightly granulated, not granulated at the cross-walls, without aerotopes (Fig. 29).

Oscillatoria princeps is a benthic, secondarily free-floating (tychoplanktic) species. It is common and widespread, often forming thick mats that can float free from the substratum into the water column. Originally described from temperate freshwater, but it was also recorded in tropical and subtropical regions (Komárek and Anagnostidis 2005; McGregor 2007; Nguyen et al. 2007).

In Brazil, the species occurs in different aquatic biotopes, from the north to the south of the country, in benthos, periphyton and plankton. It was also found forming mats on moist soil (Werner 2002; Werner et al. 2015a, b). It was recorded in north (Amazonas and Pará states), northeastern (Ceará state), central-west (Goiás, Mato Grosso and Mato Grosso do Sul states, and Federal District), southeastern (Rio de Janeiro and São Paulo states) and southern (Paraná and Rio Grande do Sul states) regions.

In Basin 7, it was frequent, observed in different seasons of the year, especially in summer.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 2-XII-2002, SM Alves-da-Silva & G Cunha s.n. (HAS 103595); 4-II-2003, SM Alves-da-Silva & G Cunha s.n. (HAS 103908); 1-XII-2003, VR Werner s.n. (HAS 104461, 104462); 11-V-2004, SM Alves-da-Silva & G Cunha s.n. (HAS 106173); 6-XII-2004, ML Nunes s.n. (HAS 106337); 15-II-2005, SM Alves-da-Silva & V Juliano s.n. (HAS 106455); 12-IX-2005, VR Werner & V Juliano s.n. (HAS 106655); 8-II-2006, VR Werner & V Juliano s.n. (HAS 106790); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS 106851); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS 107310); 2-V-2007, V Juliano & G Cunha s.n. (107404); 3-IX-2007, SM Alves-da-Silva & V Juliano s.n. (HAS 107460, 107462); 7-II-2008, SM Alves-da-Silva s.n. (HAS 107635); 2-IX-2008, SM Alves-da-Silva s.n. (HAS 107871); 9-II-2010, SM Alves-da-Silva & V Juliano s.n. (HAS 108309); 3-II-2011, SM Alves-da-Silva & ML Nunes s.n. (HAS 108853).

Oscillatoria sancta Kützing ex Gomont, Ann. Sci. nat. Sér. 7, 16: 209. 1892.

Trichomes straight, sometimes slightly bent and slightly attenuated at the ends, slightly constricted at the granulated cross-walls, (7.5–8)8.5–13.8 μm wide; cells 0.2–0.4(0.5) time longer than wide, 2–4 μm long; apical cell rounded or truncate, usually slightly capitate, with thickened cell wall; cell content blue-green, homogenous, granulated, without aerotopes (Fig. 30).

According to Komárek and Anagnostidis (2005), *Oscillatoria sancta* can grow in both aquatic (benthic or free-floating) and terrestrial environments (on moist rocks or soils, and greenhouses). It is a cosmopolitan species and can occur in fresh, brackish and salt waters, possibly also in thermal springs.

The species was recorded in both tropical and subtropical Brazilian fresh and brackish water biotopes (planktic and metaphytic), from north (Amazonas and Pará states), central-west (Federal District), in southeastern (São Paulo state) and southern (Paraná and Rio Grande do Sul states) regions.

In Basin 7, only solitary, free-floating trichomes were observed.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7). 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107308, 107310); 2-V-2007, V Juliano & G Cunha s.n. (HAS107404); 2-V-2011, V Juliano s.n. (HAS108999); 10-XII-2013, SM Alves-da-Silva s.n. (HAS109805); 7-V-2014, SM Alves-da-Silva s.n. (HAS110005); 8-XII-2014, V.R.Werner (HAS110191).

Phormidium Kützing ex Gomont 1892

Phormidium articulatum (Gardner) Anagnostidis & Komárek, Arch. Hydrobiol./Suppl., 80(1–4), Algol. Stud. 50–53: 404. 1988.

Basionym: *Oscillatoria articulata* Gardner, Mem. New York Bot. Gard. 7: 34. 1927.

Trichome straight, not attenuated, not or slightly constricted, 3.5–4 µm wide; cells almost isodiametric or shorter than wide, (0.7)0.8–1.1 times shorter than wide, (2.5)3–4 µm long, apical cell rounded, without thickened cell wall; cell content blue-green, without aerotopes (Fig. 31).

According to Komárek and Anagnostidis (2005), the trichomes of *Phormidium articulatum* can be straight or circinate. However, only straight trichomes in the analyzed populations were observed. Similar trichomes were found in a subtropical marsh from southernmost Brazil by Werner and Rosa (1992).

This is a freshwater, benthic, later tychoplanktic species, in stagnant waters; it can occur also on moist rocks. It is known mainly from tropical region but it can occur in other climates (Komárek and Anagnostidis 2005).

In Brazil, until now, the species was recorded only in a tropical biotope from the northeastern region (Ceará state) by Drouet (1937)—as *Oscillatoria grunowiana* Gomont var. *articulata* (Gardner) Drouet, and in a subtropical marsh (Rio Grande do Sul state) by Werner and Rosa (1992)—as *Oscillatoria articulate* Gardner. Thus, this is the third occurrence record of the species in Brazil.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 2-V-2007, V Juliano & G Cunha s.n.

(HAS107404); 7-V-2013, SM Alves-da-Silva s.n. (HAS109600).

Phormidium chalybeum (Mertens ex Gomont) Anagnostidis & Komárek, Arch. Hydrobiol./Suppl., 80(1–4), Algol. Stud. 50–53: 405. 1988.

Basionym: *Oscillatoria chalybea* Mertens ex Gomont, Ann. Sci. Nat. sér. 7, 16: 232. 1892.

Trichomes straight or flexuous, slightly attenuated and curved at the ends, slightly constricted, 7.5–8.0 (10) µm wide; cells usually shorter than wide, rarely almost isodiametric, 0.4–0.7 time shorter than wide, 3.5–5(7) µm long; apical cell rounded-conical, not capitated, without thickened outer cell wall; cell content blue-green, granulated, ungranulated or somewhat granulated cross-walls, without aerotopes (Fig. 32).

According to Komárek and Anagnostidis (2005), *Phormidium chalybeum* can be found in periphyton and benthos, occasionally in tychoplankton. It is distributed worldwide and cosmopolitan.

In Brazil, the species was found in different aquatic biotopes, from the north to the south of the country. It was recorded (as *Oscillatoria chalybea*) in north (Amazonas state), northeastern (Ceará state), central-west (Federal District), southeastern (Minas Gerais, Rio de Janeiro and São Paulo states) and southern (Rio Grande do Sul state) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 1-XII-2003, VR Werner s.n. (HAS104462); 7-V-2012, SM Alves-da-Silva s.n. (HAS109337).

Phormidium granulatum (Gardner) Anagnostidis, Preslia 73: 370. 2001.

Basionym: *Oscillatoria granulata* Gardner, Mem. New York Bot. Gard. 7: 37. 1927.

Trichome straight or flexuous, not attenuated, not constricted, 3.5–4 µm wide; cells almost isodiametric or shorter than wide, 0.8–1.3 times shorter than wide, 2.5–4.5 µm long, apical cell rounded, not capitated, without thickened outer cell wall; cell content blue-green, homogeneous, cross-walls distinctly granulated, without aerotopes (Fig. 33).

According to Komárek and Anagnostidis (2005), *Phormidium granulatum* can compose mats in the shape of small, slimy flakes (clusters), expanded plant mass or in solitary trichomes, rarely scattered among algae, in stagnant, rarely in slowly flowing waters. It is widely distributed in tropical and temperate zones.

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes, from northeastern (Ceará and Paraíba states), central-west (Federal District),

southeastern (Minas Gerais and São Paulo states) and southern (Paraná and Rio Grande do Sul states) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7). 7-II-2008, SM Alves-da-Silva s.n. (HAS107635); 7-V-2013, SM Alves-da-Silva s.n. (HAS109598); 7-IV-2014 VR Werner s.n. (HAS109991); 7-V-2014, SM Alves-da-Silva s.n. (HAS110005); 8-XII-2014, VR Werner s.n. (HAS110190); 4-II-2015, SM Alves-da-Silva s.n. (HAS110203); 7-IV-2015, VR Werner s.n. (HAS110224).

Phormidium irrigum (Kützing ex Gomont) Anagnostidis & Komárek, Arch. Hydrobiol./Suppl., 80(1–4), Algol. Stud. 50–53: 405. 1988.

Basionym: *Oscillatoria irrigua* (Kützing ex Gomont), Ann. Sci. Nat. sér. 7, 16: 216. 1892.

Trichome straight, not attenuated, not or slightly constricted, 6–12.5 (13.5) μm wide, cells almost isodiametric or shorter than wide, 0.5–0.8 times shorter than wide, 4–7.5 μm long, apical cell convex, slightly capitated, with thickened outer cell wall; cell content blue-green, homogeneous, cross-walls sometimes granulated, without aerotopes (Fig. 34).

According to Komárek and Anagnostidis (2005), *Phormidium irrigum* forms blackish to dark blue-green or grayish thallus in stagnant and flowing waters and is also found on moist rocks. It is widely distributed and possibly cosmopolitan (McGregor 2007).

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes, from central-west (Goiás and Mato Grosso do Sul states) and southeastern (São Paulo state) regions.

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 8-XI-2004, SM Alves-da-Silva s.n. (HAS106182); 6-XII-2004, ML Nunes s. n. (HAS106337); 5-XII-2005, V Juliano s.n. (HAS106726, 106728).

Phormidium tergestinum (Kützing) Anagnostidis & Komárek, Arch. Hydrobiol./Suppl., 80(1–4), Algol. Stud. 50–53: 406. 1988.

Basionym: *Oscillatoria tergestina* Kützing, Alg. Aq. Dulc. Germ., 13: 123. 1836.

Trichomes straight, sometimes slightly and irregularly curved, sometimes bent at the ends, not attenuated, not or slightly constricted, 5–9 μm wide; cells usually shorter than wide, 0.3–0.9(1) times shorter than wide, 2.5–5(6) μm long, apical cell rounded, not capitated, without thickened outer cell wall; cell content blue-green, homogeneous, cross-walls granulated (Fig. 35).

This is a freshwater, benthic species, common on mud and other substrates in different aquatic biotopes. Probably, it is cosmopolitan, except in polar regions (Komárek and Anagnostidis 2005).

The species was recorded in both tropical and subtropical Brazilian freshwater biotopes, from central-west (Goiás and Mato Grosso do Sul states), southeastern (São Paulo state) and southern (Rio Grande do Sul state) regions.

In Basin 7, only free-floating solitary trichomes were observed, which differs from the literature that mentions *P. tergetinum* forming thin, mucilaginous bright blue-green to olive-green, sometimes black-green thallus (Komárek and Anagnostidis 2005, McGregor 2007). Nonetheless, populations with only solitary trichomes were also found in a tropical water body of the Brazilian Pantanal by Santos and Sant’Anna (2010).

Examined material: BRAZIL. Rio Grande do Sul: Triunfo, pond (Basin 7), 11-V-2000, SM Alves-da-Silva & G Machado s.n. (HAS35213); 9-X-2000, SM Alves-da-Silva & G Machado s.n. (HAS35358, 35360); 6-II-2002, SM Alves-da-Silva s.n. (HAS103233); 14-VI-2002, SM Alves-da-Silva & G Cunha s.n. (HAS103439, 103441); 2-IX-2003, VR Werner s.n. (HAS104328); 1-X-2003, SM Alves-da-Silva & G Cunha s.n. (HAS104329, 104332); 1-XII-2003, VR Werner s.n. (HAS104461, 104462); 7-VI-2004, SM Alves-da-Silva & G Cunha s.n. (HAS106176); 15-II-2005, SM Alves-da-Silva & V Juliano s.n. (HAS106453); 5-XII-2005, V Juliano s.n. (HAS106726, 106728); 8-II-2006, VR Werner & V Juliano s.n. (HAS106792); 9-V-2006, SM Alves-da-Silva & ML Nunes s.n. (HAS106851); 12-XII-2006, VR Werner s.n. (HAS107215); 5-II-2007, SM Alves-da-Silva & ML Nunes s.n. (HAS107308, HAS107310); 2-V-2007, V Juliano & ML Nunes s.n. (HAS107404); 7-XII-2007, V Juliano & G Cunha s.n. (HAS107404); 7-II-2008, SM Alves-da-Silva s.n. (HAS107635); 2-V-2011, V Juliano s.n. (HAS109337); 7-V-2012, SM Alves-da-Silva s.n. (HAS109337); 3-IX-2012, SM Alves-da-Silva s.n. (HAS109370); 3-XII-2012, SM Alves-da-Silva s.n. (HAS109453); 5-II-2013, SM Alves-da-Silva s.n. (HAS109552); 7-V-2013, SM Alves-da-Silva s.n. (HAS109600); 10-XII-2013, SM Alves-da-Silva s.n. (HAS109807); 4-II-2014, SM Alves-da-Silva s.n. (HAS109962); 7-IV-2014, VR Werner s.n. (HAS109991); 6-XI-2014, DM Talgatti s.n. (HAS110082); 8-IX-2014, VR Werner s.n. (HAS110060, 110061); 8-XI-2014, VR Werner s.n. (HAS110191); 4-II-2015, SM Alves-da-Silva s.n. (HAS110202, 110203); 4-III-2015, SM Alves-da-Silva s.n. (HAS110214); 6-V-2015, SM Alves-da-Silva s.n. (HAS110331, 110332).

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