

Cyanobacteria from coastal lagoons in southern Brazil: non-heterocytous filamentous organisms

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ABSTRACT – (Cyanobacteria from coastal lagoons in southern Brazil: non-heterocytous filamentous organisms). This study describes and illustrates non-heterocytous filamentous cyanobacteria found in lagoon systems on the coastal plains of Rio Grande do Sul State. Collections were carried out in different freshwater bodies along the eastern (Casamento Lake area) and western (Tapes City area) margins of the Patos Lagoon (UTM 461948-6595095 and 542910-6645535) using a plankton net (25 µm mesh) in pelagic and littoral zones as well as by squeezing submerged parts of aquatic macrophytes, during both the rainy and dry seasons, from May to December/2003. Twenty two species belonging to the families Phormidiaceae (eight taxa), Pseudanabaenaceae (seven taxa), Oscillatoriaceae (six taxa), and Spirulinaceae (one taxon) were identified. Among these species, five are reported for the first time from Rio Grande do Sul State: *Leptolyngbya cebennensis*, *Microcoleus subtorulosus*, *Oscillatoria cf. anguina*, *O. curviceps* and *Phormidium formosum*.

Key-words - Oscillatoriaceae, Phormidiaceae, Pseudanabaenaceae, Spirulinaceae, taxonomic survey

INTRODUCTION

Coastal regions are complex environmental systems because they constitute transition zones between continental and oceanic environments that respond to interactions and exchanges between terrestrial, oceanic and atmospheric factors.

The coastal plains of Rio Grande do Sul State hold an important system of coastal lagoons covering an area of approximately 33,000 km² (Tomazelli et al. 2000, Weschenfelder et al. 2005). This subtropical region comprises a mosaic of heterogeneous terrestrial ecosystems with great biological diversity.

Freshwater habitats in subtropical Brazil are relatively poorly known from a phycological perspective, although freshwater cyanobacteria from Rio Grande do Sul State have been documented by Callegaro et al. (1981), Torgan et al. (1981, 1995), Franceschini (1983, 1990), Werner (1984, 1988, 2002), Torgan & Garcia (1989), Werner & Rosa (1992), Torgan & Paula (1994), Garcia & Vélez (1995), Torgan (1997), Werner & Sant'Anna (1998, 2000, 2006), Cardoso & Motta-Marques (2003, 2004), Carvalho et al. (2008), Werner et al. (2008), and Werner & Laughinghouse (2009).

Cyanobacteria are often significant components of benthic, periphytic and floating microphyte communities, contributing to the productivity of aquatic ecosystems and, in some cases, providing most of the carbon sources that sustain aquatic food webs (Bunn et al. 2003).

Non-heterocytous filamentous cyanobacteria are known to cause livestock mortality, can adversely affect human health (Fastner et al. 1999, Baker et al. 2001, Tellez et al. 2001, Prati et al. 2002, Sant'Anna et al. 2008), and are recognized as important contributors to ecosystem degradation (or one of the consequences of that degradation) (McGregor 2007). But in spite of their ecological importance, there have been very few comprehensive regional studies of these organisms.

This paper is the second contribution to studies of the cyanobacteria flora in lagoons on the coastal plains of Rio Grande do Sul State, and specifically deals with non-heterocytous filamentous forms. The first manuscript dealt with unicellular forms (Martins et al. 2012).

MATERIAL AND METHODS

Collections were made in various freshwater bodies along the eastern (Casamento Lake area) and western (Tapes City area) margins of the Patos Lagoon (UTM 461948 – 6595095 and 542910 - 6645535) (table 1, figure 1). The study area is dominated by wetlands ecosystems; with freshwater, shallow (Burger & Ramos 2007), and slightly acidic lagoons (Bicca 2007).

The samples were collected during the period from May to December/2003 using phytoplankton nets (25 µm mesh) in pelagic and littoral zones and by squeezing submerged parts of aquatic macrophytes.

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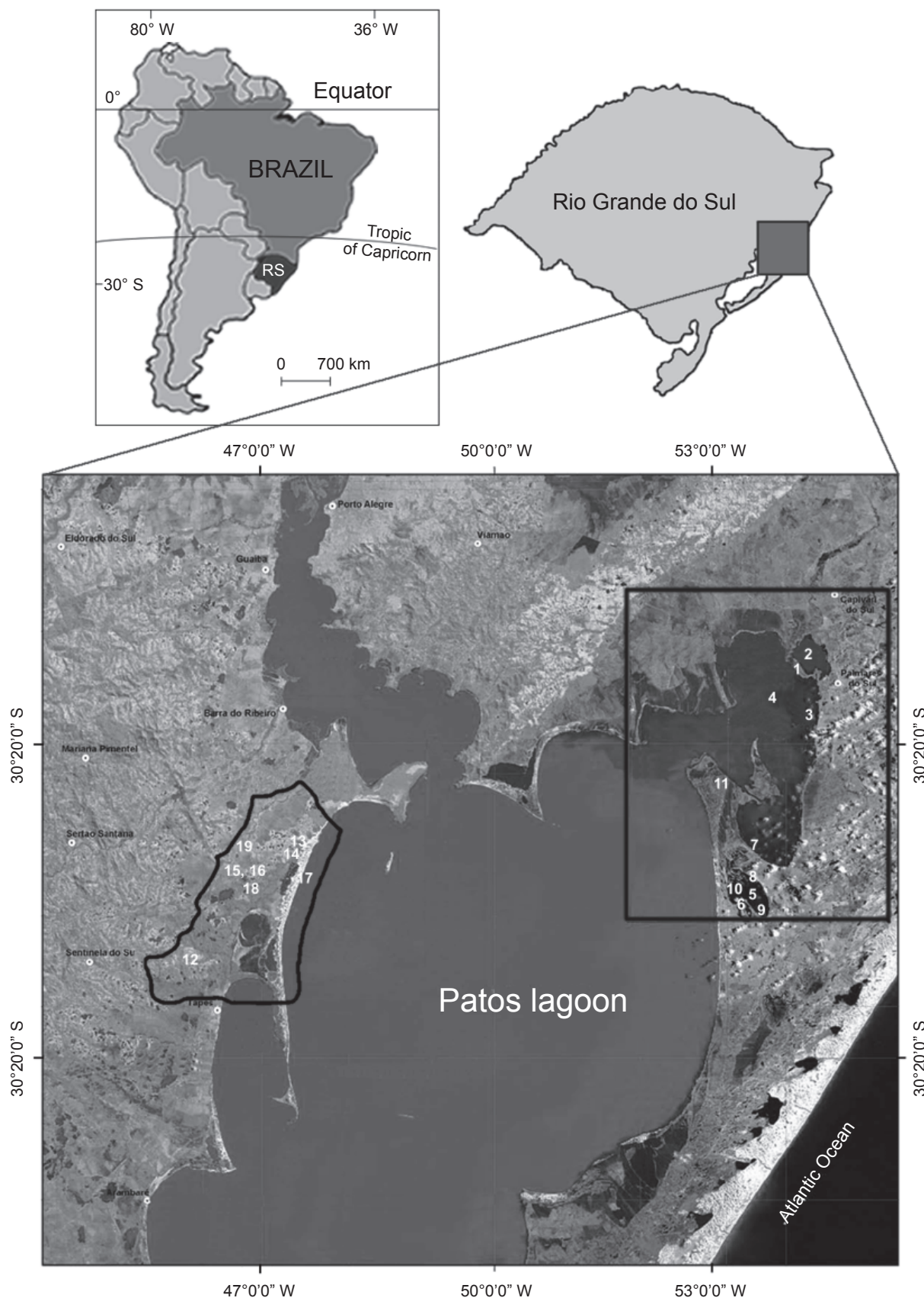


Figure 1. Map of the Casamento Lake and Tapes City areas on the coastal plains of Rio Grande do Sul State, Brazil (modified from Burger & Ramos 2007).

Table 1. Collection locations and their respective samples. (CL = Casamento Lagoon area; TC = Tapes City area; UTM = Universal Transverse Mercator coordinate system; HAS = Herbário Alarich Schultz code).

Area	UTM	HAS
CL Wetlands between Capivari and Casamento lakes	541830-6654326	HAS104092, HAS104339, HAS104340
CL Capivari Lake	542910-6655896	HAS104098, HAS104343
CL Casamento Lake – margin	541607-6654229	HAS104103, HAS104112, HAS104117, HAS104348, HAS104350, HAS104356, HAS104369, HAS104396
CL Casamento Lake – margin	541719-6654246	HAS104106, HAS104360
CL Casamento Lake – pelagic zone	542604-6650282	HAS104351, HAS104352
CL Gateados Lake – margin	532524-6621750	HAS104171, HAS104172, HAS104174, HAS104394
CL Gateados wetlands	531876-6628854	HAS104125, HAS104127, HAS104131, HAS104132, HAS104134, HAS104366, HAS104402
CL Spillway	532831-6631257	HAS104163, HAS104167, HAS104381, HAS104386, HAS104391, HAS104392
CL Gateados Lake – margin	532053-6624520	HAS104142, HAS104193
CL Gateados Lake – margin	532285-6624514	HAS104178, HAS104179, HAS104180, HAS104376, HAS104414
CL Gateados Lake – pelagic zone	533263-6624909	HAS104150, HAS104399
CL Rincão do Anastácio wetlands	530749-6639690	HAS104124, HAS104362
TC Capivaras Lake – margin	473595-6629067	HAS104209, HAS104213, HAS104435
TC <i>Sphagnum</i> wetlands	473385-6628689	HAS104223
TC Dunas Lagoon	473435-6628655	HAS104227, HAS104230, HAS104442, HAS104445
TC Dunas wetlands	473603-6628803	HAS104232, HAS104234, HAS104449
TC Charutão Lake – margin	465956-6623899	HAS104195
TC Charutão Lake – pelagic zone	465745-6623421	HAS104202, HAS104425, HAS104450, HAS104451
TC São Miguel Lagoon	464203-6623642	HAS104203, HAS104207, HAS104427, HAS103431
TC Redonda Lake	465503-6622735	HAS104235, HAS104240, HAS104455
TC Araçá	461948-6626264	HAS104242

The material was examined by bright-field microscopy using Olympus BH2 and Leica DMLB microscopes. The classification proposed by Hoffmann et al. (2005) as modified by Komárek (2006) was adopted for systematic taxonomic arrangements above the family level, and Komárek & Anagnostidis (2005) for family and lower taxonomic levels.

Taxonomic descriptions, photomicrographs, and the occurrence of each species in the aquatic environments studied are presented.

Voucher samples were deposited in the Prof. Alarich Schultz Herbarium (HAS) of the Natural Sciences Museum

of the Zoobotanical Foundation in Porto Alegre, Rio Grande do Sul State, Brazil, and their registry numbers are presented with the species descriptions.

RESULTS AND DISCUSSION

Twenty-two species of non-heterocytous filamentous cyanobacteria belonging to the orders Pseudanabaenales (seven species) and Oscillatoriales (15 species) were encountered in the aquatic environments sampled.

Order Pseudanabaenales

Key to the identification of species of Pseudanabaenales

1. Trichomes without sheaths 2
1. Trichomes with sheaths 4

- | | |
|--|---------------------------------|
| 2. Trichomes distinctly constricted | <i>Pseudanabaena catenata</i> |
| 2. Trichomes not (or only slightly) constricted | 3 |
| 3. Apex cells rounded | <i>Geitlerinema amphibium</i> |
| 3. Apex cells hooked, arcuated, long and narrow | <i>G. splendidum</i> |
| 4. Filaments entangled, cells up to 2.5 µm in length | 5 |
| 4. Filaments solitary, cells longer than 2.4 µm | 6 |
| 5. Trichomes more than 2.5 µm wide | <i>Leptolyngbya cebennensis</i> |
| 5. Trichomes up to 2.5 µm wide | <i>L. lagerheimii</i> |
| 6. Filaments in twisted coils | <i>Planktolyngbya contorta</i> |
| 6. Filaments straight | <i>P. limnetica</i> |

Pseudanabaenaceae

Geitlerinema amphibium (Agardh ex Gomont)
Anagnostidis, Pl. Syst. Evol. 164: 35, 37 1989.

Figure 2

Trichomes solitary, straight or flexuous, not constricted at the usually translucent cross-walls, not (or only very slightly) attenuated, 1.6-2.8 µm wide; cells 1.5-2.9 times longer than wide, 2.0-5.5 µm long; cell content blue-green, homogenous, 1-2 granules on either or both sides of the cross-walls; apical cell round, without calyptra or thick outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, spillway, 7-V-2003, *VR Werner s.n.* (HAS104167), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391); Gateados wetlands, 28-X-2003, *SM Alves-da-Silva s.n.* (HAS104366); Casamento Lake, 18-XI-2003, *LS Cardoso s.n.* (HAS104352), 19-XI-2003, *LS Cardoso s.n.* (HAS104356); Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104171); Tapes, Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104213); São Miguel Lagoon, 18-XI-2003, *LS Cardoso s.n.* (HAS104427); Redonda Lake, 19-XI-2003, *LS Cardoso s.n.* (HAS104455).

Comments: As discussed by Komárek & Azevedo (2000), *Geitlerinema amphibium* and *G. unigranulatum* Komárek et Azevedo are very similar species. They can be distinguished by their cell dimensions and the morphology of their apical cells and thick cross-walls. Bittencourt-Oliveira et al. (2007), however, suggested that *G. unigranulatum* was synonymous with *G. amphibium*. Bittencourt-Oliveira et al. (2009) showed that these species have overlapping morphological characteristics based on morphological and molecular data that make their taxonomic discrimination difficult. Molecular data likewise revealed a high similarity between the two species, and indicated that they could be considered synonymous.

Geitlerinema splendidum (Greville ex Gomont)
Anagnostidis, Pl. Syst. Evol. 164: 35, 1989.

Figure 3

Trichomes solitary, straight or flexuous, not constricted at cross-walls, gradually attenuated and slightly bent at apex, 2.2-3.0 µm wide; cells 1.3-2.9 times longer than wide, 3.7-6.5 µm long; cell content blue-green, homogenous, usually granulated on either or both sides of the cross-walls; apical cell hooked, slightly spherically capitate.

Material examined: BRAZIL. RIO GRANDE DO SUL: Capivari do Sul, wetlands between Capivari and Casamento Lakes, 5-V-2003, *VR Werner s.n.* (HAS104092), 27-X-2003, *SM Alves-da-Silva s.n.* (HAS104339, HAS104340); Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104112, HAS104117), 28-X-2003, *SM Alves-da-Silva s.n.* (HAS104369); Gateados wetlands, 7-V-2003, *LC Torgan s.n.* (HAS104131); Spillway, 7-V-2003, *LC Torgan s.n.* (HAS104163, HAS104167), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391), 19-XI-2003, *LS Cardoso s.n.* (HAS104386); Rincão do Anastácio wetlands, 29-X-2003, *SM Alves-da-Silva s.n.* (HAS104362); Gateados Lake, 20-XI-2003, *LS Cardoso s.n.* (HAS104399); Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104171, HAS104174, HAS104179), *LC Torgan s.n.* (HAS104180, HAS104193), 31-X-2003, *SM Alves-da-Silva s.n.* (HAS104394); Tapes, Charutão Lake, 3-VI-2003, *LC Torgan s.n.* (HAS104202); *Sphagnum* wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104223); Redonda Lake, 4-VI-2003, *VR Werner s.n.* (HAS104240); Araçá, 4-VI-2003, *VR Werner s.n.* (HAS104242); São Miguel Lagoon, 2-XII-2003, *LS Cardoso s.n.* (HAS104427).

Leptolyngbya cebennensis (Gomont) Umezaki & Watanabe, Jap. J. Phycol. 42: 203, 1994.

Figure 4

Filaments entangled, straight or flexuous, 2.5-3.5 µm in diameter; sheaths thin, homogenous, colorless;

trichomes not (or only slightly) constricted at the usually translucent cross-walls, cylindrical, not attenuated, 1.8-2.5 μm wide; cells 0.7-1.2 times longer than wide, 1.0-2.5 μm long; cell content blue-green, homogenous, without granulation, without aerotopes; apical cells rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados Lake, 8-V-2003, *VR Werner s.n.* (HAS104142), 9-V-2003, *VR Werner s.n.* (HAS104171); Palmares do Sul, Casamento Lake, 19-XI-2003, *LS Cardoso s.n.* (HAS104356, HAS104360); Tapes, São Miguel Lagoon, 2-XII-2003, *LS Cardoso s.n.* (HAS104427).

Comments: This species is known to form a subaerophytic thallus on wet rocks and moist or submerged stones. The specimens in this study were found in the metaphyton of the shallow lagoons, forming great tangles of filaments. Reported here for the first time in Rio Grande do Sul State.

Leptolyngbya lagerheimii (Gomont) Anagnostidis & Komárek, *Algolog. Stud.* 50-53: 391, 1988.

Figure 5

Filaments entangled, regularly or irregularly spiraled, or in screw-like coils, rarely flexuous, 1.5-2.5 μm in diameter; sheaths thin, homogenous, colorless; trichomes not constricted at their usually thick and translucent cross-walls, cylindrical, not attenuated, 1.5-2.0 μm wide; cells 0.9-1.5 times longer than wide, 1.5-2.5 μm long; cell content blue-green, homogenous, 1 granule on both sides of the cross-walls, without aerotopes; apical cells rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134).

Comments: Most of the populations showed regularly twisted filaments, with one granule on each side of the translucent cross-walls.

Planktolyngbya contorta (Lemmermann) Anagnostidis & Komárek, *Algolog. Stud.* 50-53: 394, 1988.

Figure 6

Filaments solitary, free-floating, regularly or irregularly spiraled, 1.6-2.0 μm wide; sheaths firm, narrow, colorless; trichomes cylindrical, not constricted at cross-walls, not attenuated, 1.3-1.7 μm wide; cells 1.7-3.5 times longer than wide, 2.8-4.5 μm long; cell content blue-green, homogenous, sometimes with 1 granule on each side of the cross-walls; apical cell without calyptra or thickened outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Capivari do Sul, Capivari Lake, 5-V-2003, *LC Torgan s.n.* (HAS104098), 18-XI-2003, *LS Cardoso s.n.* (HAS104343); Palmares do Sul, Casamento Lake, 5-V-2003, *VR Werner s.n.* (HAS104103), 27-X-2003, *SM Alves-da-Silva s.n.* (HAS104348), 18-XI-2003, *LS Cardoso s.n.* (HAS104351, HAS104352), *LC Torgan s.n.* (HAS104106), 7-V-2003, *LC Torgan s.n.* (HAS104112, HAS104117); Gateados wetlands, 7-V-2003, *VR Werner s.n.* (HAS104132); spillway, 7-V-2003, *LC Torgan s.n.* (HAS103163, HAS104167), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391), 18-XI-2003, *LS Cardoso s.n.* (HAS104381); Gateados wetlands, 28-X-2003, *SM Alves-da-Silva s.n.* (HAS104366); Rincão do Anastácio wetlands, 29-X-2003, *SM Alves-da-Silva s.n.* (HAS104362).

Comments: *Planktolyngbya contorta* can be confused with *P. circumcreta* (G.S. West) Anagnostidis et Komárek or with *P. regularis* Komárková-Legnerová et Cronberg, but *P. contorta* has longer cells than *P. circumcreta* and filaments with less regular twisting than seen in *P. regularis* (Komárková-Legnerová & Tavera 1996).

Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg, *Algolog. Stud.* 67:21, 22, 1992.

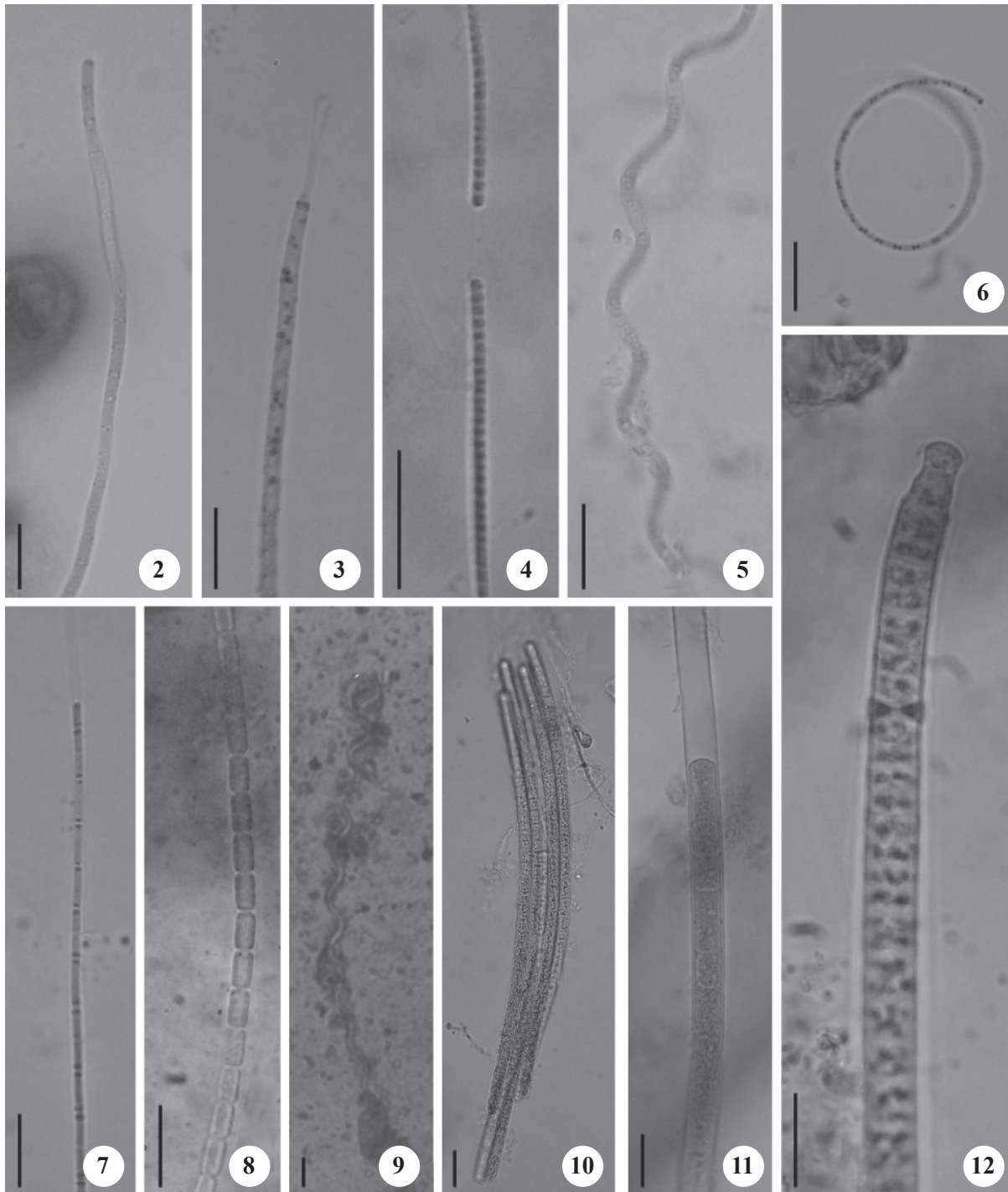
Figure 7

Filaments solitary, free-floating, straight or flexuous, 1.0-2.0 μm wide; sheaths firm, narrow, colorless; trichomes cylindrical, not constricted at cross-walls, not attenuated, 0.8-1.7 μm wide; cells 1.6-5.0 times longer than wide, 3.0-5.0 μm long; cell content blue-green, homogenous, sometimes with one granule on each side of the cross-walls; apical cell without calyptra or thickened outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Capivari do Sul, Capivari Lake, 5-V-2003, *LC Torgan s.n.* (HAS104098), 18-XI-2003, *LS Cardoso s.n.* (HAS104343); Palmares do Sul, Casamento Lake, 5-V-2003, *VR Werner s.n.* (HAS104103), *LC Torgan s.n.* (HAS104106), 7-V-2003, *LC Torgan s.n.* (HAS104112, HAS104117), 27-X-2003, *SM Alves-da-Silva s.n.* (HAS104348, HAS104350), 29-X-2003, *SM Alves-da-Silva s.n.* (HAS104396), 18-XI-2003, *LS Cardoso s.n.* (HAS104351, HAS104352), 19-XI-2003, *LS Cardoso s.n.* (HAS104356); spillway, 7-V-2003, *LC Torgan s.n.* (HAS104163, HAS104167); 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391), 19-XI-2003, *LS Cardoso s.n.* (HAS104381, HAS104386); Gateados

wetlands, 7-V-2003, *VR Werner s.n.* (HAS104127, HAS104131, HAS104132), 28-X-2003, *SM Alves-da-Silva s.n.* (HAS104366); wetlands between Capivari and Casamento Lakes, 27-X-2003, *SM Alves-da-Silva s.n.* (HAS104340); Rincão do Anastácio wetlands, 29-X-2003, *SM Alves-da-Silva s.n.* (HAS104362);

Mostardas, Gateados Lake, 8-V-2003, *VR Werner s.n.* (HAS104142), *LC Torgan s.n.* (HAS104150), 9-V-2003, *VR Werner s.n.* (HAS104174, HAS104179), *LC Torgan s.n.* (HAS104180), 19-XI-2003, *LS Cardoso s.n.* (HAS104376), 20-XI-2003, *LS Cardoso s.n.* (HAS104414).



Figures 2-12. 2. *Geitlerinema amphibium*. 3. *G. splendidum*. 4. *Leptolyngbya cebennensis*. 5. *L. lagerheimii*. 6. *Planktolyngbya contorta*. 7. *P. limnetica*. 8. *Pseudanabaena catenata*. 9. *Spirulina laxissima*. 10. *Microcoleus subtorulosus*. 11. *Phormidium aerugineo-caeruleum*. 12. *P. autumnale*. Bar = 10 μ m (2-9, 11, 12); 20 μ m (10).

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

Figure 8

Trichomes solitary, straight or flexuous, deeply constricted at the thick and translucent cross-walls, not attenuated, 1.6-2.4 μm wide; cells 1.3-3.0 times longer than wide, 2.0-6.2 μm long; cell content blue-green, homogenous or differentiated into chromate- and centropiasm; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Gateados wetlands, 7-V-2003, *VR*

Werner s.n. (HAS104125); wetlands between Capivari and Casamento Lakes, 27-X-2003, *SM Alves-da-Silva s.n.* (HAS104340); Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134); Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104171, HAS104174); Tapes, Charutão Lake, 4-VI-2003, *VR Werner s.n.* (HAS104202); Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104209); Araçá, 4-VI-2003, *VR Werner s.n.* (HAS104242); São Miguel Lagoon, 2-XII-2003, *L.S. Cardoso s.n.* (HAS104427); Dunas Lagoon, 3-XII-2003, *LS Cardoso s.n.* (HAS104442); Redonda Lagoon, 3-XII-2003, *LS Cardoso s.n.* (HAS104455).

Order Oscillatoriales

Key to the identification of species of Oscillatoriales

- | | |
|--|---------------------------------|
| 1. Trichomes up to 2.0 μm wide | <i>Spirulina laxissima</i> |
| 1. Trichomes wider than 2.0 μm | 2 |
| 2. Cells isodiametric or only slightly shorter or longer than wide | 3 |
| 2. Cells distinctly shorter than long | 10 |
| 3. Sheaths with more than one trichome | <i>Microcoleus subtorulosus</i> |
| 3. Sheaths with only one trichome, or sheath lacking | 4 |
| 4. Trichomes in microscopic fascicles | <i>Trichodesmium lacustre</i> |
| 4. Trichomes usually solitary | 5 |
| 5. Cells with aerotopes | <i>Planktothrix isothrix</i> |
| 5. Cells without aerotopes | 6 |
| 6. Trichome narrow towards apex | 7 |
| 6. Trichome not narrowed towards apex | 8 |
| 7. Apical cell with calyptra | <i>Phormidium autumnale</i> |
| 7. Apical cell without calyptra | <i>P. formosum</i> |
| 8. Trichomes with sheaths | <i>P. aerugineo-caeruleum</i> |
| 8. Trichomes without sheaths | 9 |
| 9. Trichomes up to 4.5 μm wide | <i>P. granulatum</i> |
| 9. Trichomes wider than 4.5 μm | <i>P. tergestinum</i> |
| 10. Trichomes with sheaths | <i>Lyngbya cf. martensiana</i> |
| 10. Trichomes without sheaths | 11 |
| 11. Trichomes not narrowed | 12 |
| 11. Trichomes narrowed or only slightly narrowed | 13 |
| 12. Trichome apex arcuated | <i>Oscillatoria ornata</i> |
| 12. Trichome apex straight | <i>O. tenuis</i> |
| 13. Trichomes up to 9.0 μm wide | <i>O. cf. anguina</i> |
| 13. Trichomes wider than 9.0 μm | 14 |
| 14. Trichomes 9.0-16.0 μm wide | <i>O. curviceps</i> |
| 14. Trichomes 19.0-26.5 μm wide | <i>O. princeps</i> |

Spirulinaceae

Spirulina laxissima G. S. West, Jour. Linn. Soc. Bot.: 78, 1907.

Figure 9

Trichomes solitary, loosely spiraling, not constricted at cross-walls, not attenuated, 1.4-2.0 μm wide, 5.0-6.2 μm

high, distance between coils 8.0-12.5 μm ; cell content blue-green, homogenous.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134).

Comments: The population showed trichomes wider than those cited by Komárek & Anagnostidis (2005), but

was in agreement with those observed by Desikachary (1959) and Sant'Anna & Azevedo (1995).

Phormidiaceae

Microcoleus subtorulosus Gomont ex Gomont, Ann. Sci. nat. Sér.7, 16:360, 1892.

Figure 10

Filaments solitary, flexuous, not branched; sheath homogenous, firm, colorless, containing 1-8 trichomes; trichomes arranged in parallel rows, distinctly constricted at the ungranulated cross-walls, 6.0-7.5 µm wide; cells 0.5-0.9 times longer than wide, 4.0-7.2 (8.0) µm long; cell content blue-green, granulated; apical cell rounded or rounded-conical.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104171, HAS104172).

Comments: From a morphological point of view, the specimens studied agreed well with the description provided by Gomont (1892a). *Microcoleus subtorulosus* has been recorded in lotic (Branco et al. 1999, Branco & Pereira 2002, Peres 2007) and lentic environments (Sant'Anna & Azevedo 1995) in Brazil. Although *M. subtorulosus* is known to be benthic, it was observed among the plankton in the present study. Reported here for the first time in Rio Grande do Sul State.

Phormidium aerugineo-caeruleum (Gomont) Anagnostidis & Komárek, Algolog. Stud. 50-53: 407, 1988.

Figure 11

Filaments solitary, straight or flexuous, 5.6-8.0 µm wide; sheaths thin, firm, homogenous, colorless; trichomes not attenuated, not constricted at their sometimes granulated cross-walls, 4.0-7.0 µm wide; cells 0.4-1.3 times longer than wide, 3.0-7.0 µm long; cell content blue-green, homogenous, sometimes with prominent granules; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104112), 19-XI-2003, *LS Cardoso s.n.* (HAS104369); Spillway, 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391), 19-XI-2003, *LS Cardoso s.n.* (HAS104381, HAS104386); Tapes, Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104213); Araçá, 4-VI-2003, *VR Werner s.n.* (HAS104242).

Comments: From a morphological point of view, the specimens studied agreed with the description of the type material provided by Gomont (1892b); slight differences were observed regarding the trichomes, which were

wider in the population studied. This species has an ample distribution and has been reported from a large variety of habitats (Komárek & Anagnostidis 2005).

Phormidium autumnale (Agardh) Trevisan ex Gomont, Ann. Sci. nat. Sér. 7, 16: 187, 1982.

Figure 12

Trichomes solitary, straight or flexuous, bent and strongly attenuated at apex, not (or only slightly) constricted at their granulated cross-walls, 4.5-6.0 µm wide; cells 0.5-1.0 times longer than wide, 4.0-5.5 µm long; cell content blue-green, homogenous to slightly granulated; apical cell somewhat elongated, capitated, with rounded or truncated calyptra.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Rincão do Anastácio wetlands, 7-V-2003, *VR Werner s.n.* (HAS104124); Casamento Lake, 19-XI-2003, *LS Cardoso s.n.* (HAS104356, HAS104369); Mostardas, Gateados Lake, 8-V-2003, *VR Werner s.n.* (HAS104142), 9-V-2003, *VR Werner s.n.* (HAS104171).

Comments: *Phormidium autumnale* and *P. amoenum* Kützing ex Anagnostidis et Komárek are very similar. Both have trichomes with narrow and bent apices, with apical cells calyptrate. *P. autumnale* has wider trichomes and rounded or truncated calyptra, however, while *P. amoenum* has smaller trichomes and conical calyptra.

Phormidium formosum (Bory ex Gomont) Anagnostidis & Komárek, Algolog. Stud. 50-53: 405, 1988.

Figure 13

Trichomes solitary, straight or flexuous, slightly attenuated and curved at the apex, not (or only slightly) constricted at their granulated or ungranulated cross-walls, 4.5-6.5 µm wide; cells 0.4-1.1 times longer than wide, 2.8-5.8 µm long; cell content blue-green, homogenous; apical cell rounded-conical.

Material examined: BRAZIL. RIO GRANDE DO SUL: Capivarido Sul, wetlands between Capivari and Casamento Lakes, 5-V-2003, *VR Werner s.n.* (HAS104092); Palmares do Sul, Rincão do Anastácio wetlands, 7-V-2003, *VR Werner s.n.* (HAS104124); spillway, 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391); Casamento Lake, 19-XI-2003, *LS Cardoso s.n.* (HAS104369); Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134); Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104171, HAS104174, HAS104178, HAS104179), *LC Torgan s.n.* (HAS104180), 20-XI-2003, *LS Cardoso s.n.* (HAS104399); Tapes, Dunas wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104234), 3-XI-2003, *LS Cardoso*

s.n. (HAS104449); Charutão Lake, 2-XI-2003, *LS Cardoso s.n.* (HAS104425), 3-XI-2003, *LS Cardoso s.n.* (HAS104450); São Miguel Lagoon, 2-XI-2003, *LS Cardoso s.n.* (HAS104427).

Comments: *Phormidium formosum* is a cosmopolitan species, mainly benthonic, occurring in both lotic and lentic environments. According to Komárek & Anagnostidis (2005), this species is very similar to *P. breve* (Kützing ex Gomont) Anagnostidis et Komárek but has shorter cells (1.5-3.0 µm long). Reported here for the first time in Rio Grande do Sul State.

Phormidium granulatum (Gardner) Anagnostidis, Preslia 3: 370, 2001.

Figure 14

Trichomes solitary, straight or flexuous, not attenuated, not (or only slightly) constricted at their granulated cross-walls, 3.0-4.5 µm wide; cells 0.7-1.0 times longer than wide, 2.5-5.0 µm long; cell content blue-green, homogenous, 2-4 prominent granules on both sides of the cross-walls; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, spillway, 7-V-2003, *LC Torgan s.n.* (HAS104163), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391); Casamento Lake, 19-XI-2003, *LS Cardoso s.n.* (HAS104369); Tapes, Charutão Lake, 3-VI-2003, *VR Werner s.n.* (HAS104195); Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104213); Dunas wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104234); Dunas Lagoon, 3-XII-2003, *LS Cardoso s.n.* (HAS104442); Charutão Lake, 3-XII-2003, *LS Cardoso s.n.* (HAS104451); Redonda Lake, 3-XII-2003, *LS Cardoso s.n.* (HAS104455).

Comments: The distinguishing feature of *Phormidium granulatum* is the presence of two to five prominent granules at the cross-walls (Gardner 1927, Komárek & Anagnostidis 2005).

Phormidium tergestinum (Kützing) Anagnostidis & Komárek, Algolog.Stud. 50-53: 406, 1988.

Figure 15

Trichomes solitary, straight or flexuous, not attenuated, constricted or not, 4.8-7.5 µm wide; cells 0.4-1.0 times longer than wide, 3.0-6.5 µm long; cell content blue-green, homogenous; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Capivari do Sul, wetlands between Capivari and Casamento lakes, 5-V-2003, *VR Werner s.n.* (HAS104092); Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104117), 19-XI-2003,

LS Cardoso s.n. (HAS104369); spillway, 7-V-2003, *LC Torgan s.n.* (HAS104167), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391, HAS104392); 19-XI-2003, *LS Cardoso s.n.* (HAS104381, HAS104386); Rincão do Anastácio, 7-V-2003, *VR Werner s.n.* (HAS104124); Gateados wetlands, 28-X-2003, *SM Alves-da-Silva s.n.* (HAS104366), 31-X-2003, *SM Alves-da-Silva s.n.* (HAS104402); Gateados Lake, 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104394); Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104178, HAS104179), *LC Torgan s.n.* (HAS104180); Tapes, São Miguel Lagoon, 3-VI-2003, *LC Torgan s.n.* (HAS104203); Dunas Lagoon, 4-VI-2003, *VR Werner s.n.* (HAS104227, HAS104230), 3-XII-2003, *LS Cardoso s.n.* (HAS104445); Dunas wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104232, HAS104234); Redonda Lake, 4-VI-2003, *VR Werner s.n.* (HAS104235); Charutão Lake, 3/12/2003, *LS Cardoso s.n.* (HAS104450).

Comments: This species is widely distributed and has been reported to have ample morphological variation. According to Komárek & Anagnostidis (2005), numerous morphological varieties have been described, but they probably represent a single species.

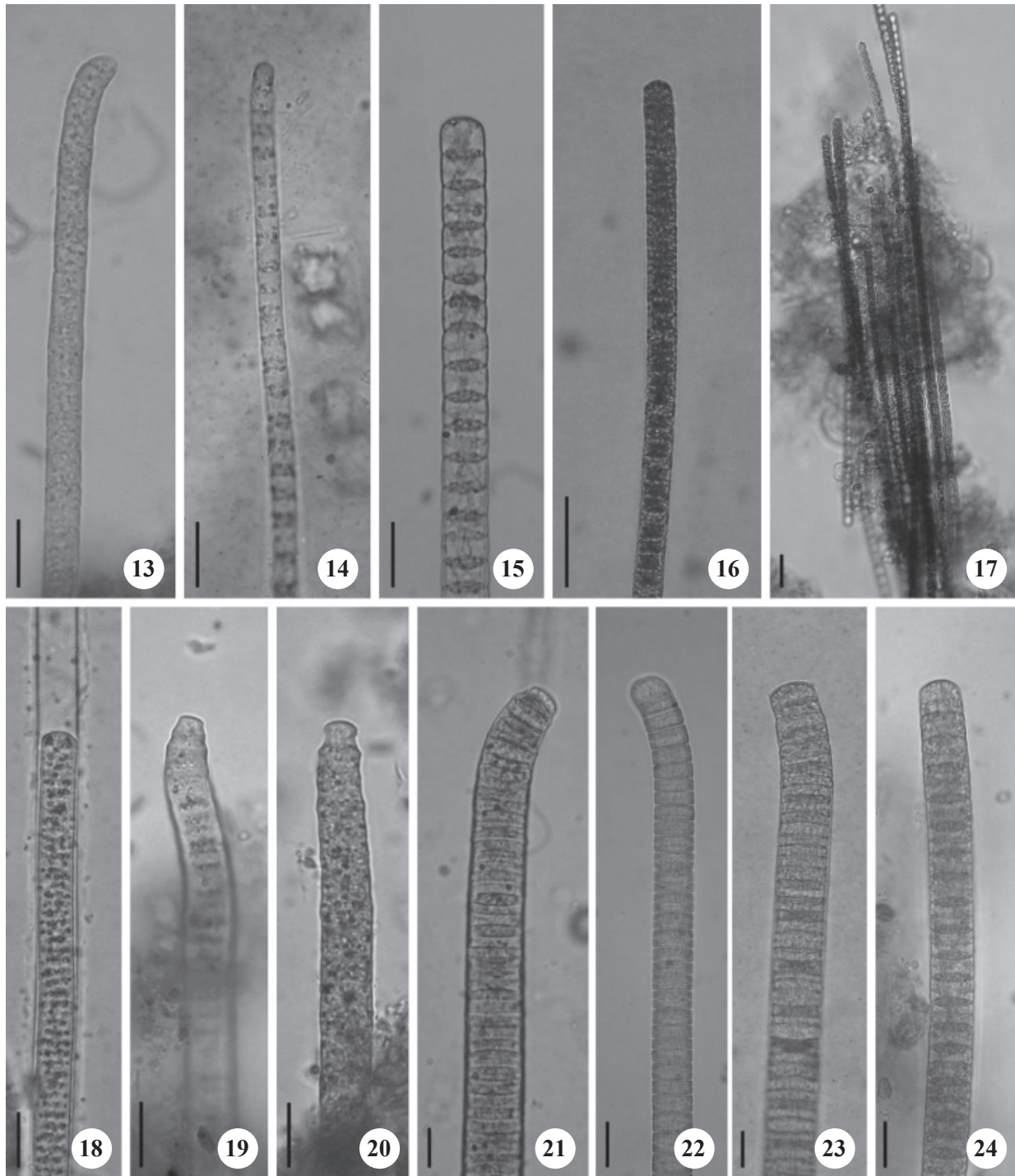
Planktothrix isothrix (Skuja) Komárek et Komárková, Czech Phycol. 4: 14, 2004.

Figure 16

Trichomes solitary, straight or flexuous, not attenuated, not constricted at their sometimes granulated cross-walls, 4.0-10.0 µm wide; cells 0.3-1.0 times longer than wide, 2.0-5.0 µm long; cell content green-brownish, numerous aerotopes; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Rincão do Anastácio wetlands, 7-V-2003, *VR Werner s.n.* (HAS104124); spillway, 7-V-2003, *LC Torgan s.n.* (HAS104163, HAS104167), 30-X-2003, *SM Alves-da-Silva s.n.* (HAS104391); Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104174, HAS104179); Tapes, Charutão Lake, 3-VI-2003, *VR Werner s.n.* (HAS104195); São Miguel Lagoon, 3-VI-2003, *LC Torgan s.n.* (HAS104203), 4-VI-2003, *VR Werner s.n.* (HAS104207); Dunas wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104234).

Comments: From a morphological point of view, the specimens studied here agreed well with the descriptions provided by Komárek & Komárková (2004). This species is primarily benthic, later forming blooms, present in eutrophic to hypertrophic stagnant bodies of water and lakes in tropical and temperate regions (Davis et al. 2003, Stefaniak et al. 2005, Pérez et al. 2009).



Figures 13-24. 13. *Phormidium formosum*. 14. *P. granulatum*. 15. *P. tergestinum*. 16. *Planktothrix isothrix*. 17. *Trichodesmium lacustre*. 18. *Lyngbya* cf. *martensiana*. 19-20. *Oscillatoria* cf. *anguina*. 21. *O. curviceps*. 22. *O. ornata*. 23. *O. princeps*. 24. *O. tenuis*. Bar = 10 μm (13-16, 18-22, 24); 20 μm (17, 23).

Trichodesmium lacustre Klebahn, Flora: 82, 1895.
Figure 17

Trichomes arranged in parallel lines, forming fascicles, straight or flexuous, 35.0-61.0 μm wide; trichomes straight,

attenuated (or not) at their apices, distinctly constricted at cross-walls, 4.5-7.0 μm wide; cells 0.7-1.3 times longer than wide, 4.5-7.0 μm long; cell content brownish-green, finely granulated, numerous aerotopes; apical cell elongated and slightly narrowed, up to 9.5 μm long.

Material examined: BRAZIL. RIO GRANDE DO SUL: Tapes, Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104209); Dunas Lagoon, 4-VI-2003, *VR Werner s.n.* (HAS104227).

Comments: This species is typically planktonic and was reported in Brazil by Sant'Anna & Azevedo (1995). Some of the trichome cells showed no aerotopes, as was also noted by Komárek & Anagnostidis (2005).

Oscillatoriaceae

Lyngbya cf. martensiana Meneghini ex Gomont, Ann. Sci. nat. Sér. 7, 16: 145, 1892.

Figure 18

Filaments solitary, straight or flexuous, 8.0-13.5 μm wide; sheaths hyaline, thick, colorless to yellowish, lamellate; trichomes not attenuated, not constricted at the granulated cross-walls, 6.5-9.0 μm wide; cells 0.2-0.5 times longer than wide, 2.0-4.0 μm long; cell content blue-green; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104112); Rincão do Anastácio, 7-V-2003, *VR Werner s.n.* (HAS104124); Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134); Tapes, Charutão Lake, 3-VI-2003, *LC Torgan s.n.* (HAS104202); Dunas wetlands, 4-VI-2003, *VR Werner s.n.* (HAS104232, HAS104234).

Comments: From a morphological point of view, the specimens studied here agreed well with the description of the type material provided by Gomont (1892b) that note the occurrence of this species in European thermal springs. Komárek & Anagnostidis (2005), in agreement with other authors, consider this species to be metaphytic and periphytic in stagnant and flowing waters, with many morphotypes, and possibly with cosmopolitan distribution; these authors recommend a taxonomic revision of the species. Thus, even though the species demonstrated morphological correspondence, the ecological delimitations of *L. martensiana* are not clear and the populations encountered were treated as cf.

Oscillatoria cf. anguina Bory ex Gomont, Ann. Sci. nat. Sér. 7, 16: 214, 1892.

Figures 19-20

Trichomes solitary, straight, curved and gradually narrowing at the apex, not constricted at the granulated cross-walls, 6.4-9.0 μm wide; cells 0.2-0.4 times longer than wide, 1.3-3.0 μm long; cell content blue-green;

apical cell capitate or rounded, with a thick outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104179), *LC Torgan s.n.* (HAS104180).

Comments: The observed specimens were morphologically similar to *Oscillatoria anguina*, however, the populations studied were identified as *O. cf. anguina* as they showed trichomes slightly wider than those described for *O. anguina* by Komárek & Anagnostidis (2005). Reported here for the first time in Rio Grande do Sul State.

Oscillatoria curviceps Agardh ex Gomont, Ann. Sci. nat. Sér. 7, 16: 213, 1892.

Figure 21

Trichomes solitary, straight, curved and gradually narrowing at the apex, not constricted at their granulated cross-walls, 9.0-16.0 μm wide; cells 0.1-0.4 times longer than wide, 1.7-3.5 μm long; cell content blue-green; apical cell capitate or rounded, with thick outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados wetlands, 8-V-2003, *V.R. Werner s.n.* (HAS104134); Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104174).

Comments: Although the specimens studied here had trichomes that were slightly smaller than those reported for *Oscillatoria curviceps*, their morphological features were in agreement with the description provided by Gomont (1892b). Reported here for the first time in Rio Grande do Sul State.

Oscillatoria ornata Kützing ex Gomont, Ann. Sci. nat. Sér. 7, 16: 214, 1892.

Figure 22

Trichomes solitary, straight or flexuous, curved at apex, not attenuated, constricted at the ungranulated or granulated cross-walls, 8.0-10.0 μm wide; cells 0.2-0.4 times longer than wide, 1.8-3.5 μm long; cell content blue-green, homogenous; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104178).

Comments: Komárek & Anagnostidis (2005) noted that *Oscillatoria ornata* has trichomes whose apices are usually coiled in a screw-like fashion. This feature was not observed by Werner (1988), Werner & Rosa (1992), Sant'Anna & Azevedo (1995), or in the present study.

Oscillatoria princeps Vaucher ex Gomont, Ann. Sci. nat. Sér.7, 16: 206, 1892.

Figure 23

Trichomes solitary, straight or curved, and slightly narrowed at apex, not (or only slightly) constricted, 19.0-26.5 μm wide; cells up to 0.4 times longer than wide, 2.5-4.0 μm long; cell content blue-green, homogenous or slightly granulated; apical cell rounded, hemispherical or truncate, with or without a thick outer cell wall.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104117); Gateados wetlands, 7-V-2003, *VR Werner s.n.* (HAS104125, HAS104131); spillway, 7-V-2003, *LC Torgan s.n.* (HAS104167); Mostardas, Gateados Lake, 9-V-2003, *VR Werner s.n.* (HAS104178); Tapes, São Miguel Lagoon, 3-VI-2003, *LC Torgan s.n.* (HAS104203); Redonda Lake, 4-VI-2003, *VR Werner s.n.* (HAS104235); Dunas Lagoon, 3-XII-2003, *LS Cardoso s.n.* (HAS104445); Charutão Lake, 3-XII-2003, *LS Cardoso s.n.* (HAS104450, HAS104451); Redonda Lake, 3-VII-2003, *LS Cardoso s.n.* (HAS104455).

Oscillatoria tenuis Agardh ex Gomont, Ann. Sci. nat. Sér. 7, 16: 220, 1892.

Figure 24

Trichomes solitary, straight or flexuous, not attenuated, not (or only slightly) constricted at the granulated or ungranulated cross-walls, 6.5-11.0 μm wide; cells up to 0.2-0.4 times longer than wide, 2.0-3.8 μm long; cell content blue-green, homogenous; apical cell rounded.

Material examined: BRAZIL. RIO GRANDE DO SUL: Palmares do Sul, Casamento Lake, 7-V-2003, *LC Torgan s.n.* (HAS104117), 19-XI-2003, *LS Cardoso s.n.* (HAS104360); Rincão do Anastácio, 7-V-2003, *VR Werner s.n.* (HAS104124); Gateados wetlands, 7-V-2003, *VR Werner s.n.* (HAS104125); Mostardas, Gateados wetlands, 8-V-2003, *VR Werner s.n.* (HAS104134), Gateados lake, 9-V-2003, *VR Werner s.n.* (HAS104174); Tapes, São Miguel Lagoon, 3-VI-2003, *LC Torgan s.n.* (HAS104203), 4-VI-2003, *VR Werner s.n.* (HAS104207), 2-XII-2003, *LS Cardoso s.n.* (HAS104431); Capivaras Lake, 4-VI-2003, *VR Werner s.n.* (HAS104213), 3-XII-2003, *LS Cardoso s.n.* (HAS104435); Dunas Lagoon, 3-XII-2003, *LS Cardoso s.n.* (HAS104442); Charutão Lake, 3-XII-2003, *LS Cardoso s.n.* (HAS104451); Redonda Lake, 3-XII-2003, *LS Cardoso s.n.* (HAS104455).

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