New additions of coccoid green algae to the phycoflora of Brazil and the Neotropics

Geraldo José Peixoto Ramos²⁴, Carlos Eduardo de Mattos Bicudo¹, Aristóteles Góes-Neto¹ and Carlos Wallace do Nascimento Moura²

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ABSTRACT

The present study presents 11 new additions of coccoid green algae to the phycoflora of Brazil, including the first record of the genus *Westellopsis* for the neotropical region. Samples of periphyton and plankton were collected in two areas of the Marimbus Wetlands (the Marimbus do Baiano and Marimbus do Remanso, within the Marimbus-IRAQUARA Environmentally Protected Area), in the Chapada Diamantina Region of the state of Bahia, Brazil. Sample collection occurred during dry periods (April-June and August 2011) and rainy periods (October-December 2011 and February 2012). Here, we describe the taxa identified from the 56 samples collected.

Key words: Chlorophyta, Chlorophyceae, Trebouxiophyceae, caatinga, Marimbus Wetlands

Introduction

Coccoid green algae include unicellular taxa without flagella during their vegetative phases, with solitary or colonial habits, covered (or not) by mucilage and growing principally in shallow lentic ecosystems. Their occurrence is influenced by factors such as the illumination regime, temperature, and trophic levels (Komárek & Fott 1983; Comas 1996; Menezes et al. 2011). Most of the representatives of this group are cosmopolitan, although some are endemic to tropical or temperate regions (Komárek 1983; Komárek & Jankovská 2001; Coesel & Krienitz 2008).

Although coccoid green algae have been studied in Brazil since the end of the 19th century (Moseley 1875; Bohlin 1897), it was only in the 1970s that research focusing on these algae became more common, with studies concentrated in the southeast (Sant’Anna 1984; Nogueira 1991, 1994, 1996; Fernandes & Bicudo 2009; Rosini et al. 2012), south (Felisberto et al. 2001; MoreSCO & Bueno 2007; Torgan & Hentschke 2011; Domingues & Torgan 2012; Hentschke & Prado 2012), central-west (De-Lamonica-Freire & Sant’Anna 1993; Nogueira & Oliveira 2009; Bertolini et al. 2010), and north (Sant’Anna & Martins 1982; Bittencourt-Oliveira 1993). Little is currently known about these algae in the northeastern region of Brazil, especially in the caatinga (shrublands). The Caatinga Biome, which is the only exclusively Brazilian biome, is characterized by an arid environment with considerable biodiversity (Mares et al. 1985; Sampaio 1995; Giulietti et al. 2002). Among the major studies focusing on these algae within the Caatinga Biome are those conducted by Ramos et al. (2012) and Ramos (2013).

The present study reports 11 coccoid green algae that represent new records for Brazil, including one new record for the Neotropics, identified from samples collected in the Marimbus Wetlands at the eastern border of the Chapada Diamantina mountain range, a well-defined ecoregion within the Caatinga Biome.

Material and methods

The Marimbus Wetlands study area is situated on the eastern border of Chapada Diamantina National Park, in the state of Bahia, Brazil. It is a flat, swampy area flooded by the Santo Antônio, Utinga and São José Rivers, which collectively drain a large portion of the region (Lima & Nolasco 1997; Funch 2002). Due to the rich biodiversity of the local flora and fauna, the swamplands not included in the national park were incorporated into the Marimbus-Iraquara Environmentally Protected Area by Gubernatorial Decree no. 2216, on June 14, 1993 (Ramos et al. 2012).

The Marimbus Wetlands (12°39’13” to 12°46’48”S; 41°17’00” to 41°21’25”W) can be subdivided into four areas (França et al. 2010), all of which are interconnected by the Santo Antônio River (Fig. 1): the Marimbus do Remanso (located in the north, in the municipality of Lençóis);
Marimbus da Fazenda Velha; the Marimbus do Ferreira; and the Marimbus do Baiano (the southernmost area, in the municipality of Andaraí).

The regional climate oscillates from subhumid to dry, with an average annual temperature of 22.4°C, and an average annual rainfall of 1049 mm (Bahia 2013); maximum water flow occurs from December to March, the lowest flow rates occurring from May through September (Moura & Marques 2007).

The present study was conducted in two areas of the Marimbus Wetlands (the Marimbus do Remanso and Marimbus do Baiano). The Marimbus do Remanso (41°20'W; 12°40'S) is located within the municipality of Lençóis, near the village of Remanso, and is characterized by calm waters (in most of its zones), with a pH 6.6-7.6 and moderate transparency (2.1 m). The Santo Antonio River has a notable influence on the dynamics of the environment, especially in its narrower parts, in which flow rates are higher. The Marimbus do Baiano (41°18'W; 12°45'S), located in the municipality of Andaraí, consists of several interconnected lakes, including the Lagoa do Baiano, Lagoa da Isca, Lagoa dos Paus and Olho D'Água do Peri. Those lakes are most often used by local fishermen during the dry season, when the water level of the Santo Antonio River is well below normal and the lakes are not interconnected. In the present study, most of the samples collected in the Marimbus do Baiano

Figure 1. Map of the Marimbus Wetlands area, (Marimbus-Iraquara Environmentally Protected Area), Chapada Diamantina region, state of Bahia, Brazil.
were taken from the Lagoa do Baiano. The Marimbus do Baiano is also characterized by calm waters, with a pH 6.0-7.2 and moderate transparency (0.9 m). In the Marimbus Wetlands, various macrophytes have been identified (Ramos et al. 2012); *Utricularia foliosa* L., *Cabomba haynesii* Wiersema, *Eichhornia azurea* (Sw.) Kunth., *Nymphea ampla* (Salisb.) DC, *Salvinia auriculata* Aubl. and *Hydrocleys nymphaoides* (Humb. & Bonpl. ex Willd.).

Phycological material was collected during the dry season (April-June-August/2011) and the rainy season (October-December/2011 and February/2012). From randomly chosen sites within the Marimbus do Baiano and Marimbus do Remanso, we collected a total of 56 samples. The samples of periphytic material were obtained by pressing macrophytes and capturing the planktonic material with a plankton net (20-μm mesh). All collections were made using standard techniques for taxonomic studies of freshwater microalgae (Bicudo & Menezes 2006).

We measured the physical dimensions of the taxa using an ocular micrometer, and macro photographs were taken with a digital camera coupled to an optical microscope. The taxa were identified based on the specialized literature; the classification system used follows Krienitz & Bock (2012). We made use of descriptions and illustrations presented by those authors. Although they were otherwise in full agreement with the findings of Komárek & Fott (1983), although those authors also presented illustrations of individuals with both apices oriented in the same direction. Only individuals with cell apices turned in opposite directions were observed during the present study.

Monoraphidium obtusum (Korsikov) Komárk.-Legn., although species of the latter genus have evident pyrenoids.

The specimens examined coincided, in terms of their measurements, description and illustrations, with the findings of Komárek & Fott (1983), although those authors presented illustrations of individuals with both apices orientated in the same direction. Only individuals with cell apices turned in opposite directions were observed during the present study.


**Fig. 2B**

Isolated cells, fusiform, strongly arched, apices gradually tapering, occupying distinct planes, a single chloroplast, parietal, without pyrenoids. Cells 75-85 μm long by 2.5-3.5 μm wide.


Habitat: plankton, periphyton

The cells of the specimens collected in the Marimbus Wetlands had dimensions that were smaller than those reported by Komárek & Fott (1983) and Hindák (1977), although they were otherwise in full agreement with the descriptions and illustrations presented by those authors. According to Hindák (1977), *M. indicum* differs from other species of the genus by having larger cells, but its distinguishing characteristics, such as sigmoidal cells with apices directed toward distinct planes, are well defined.

According to Bazan et al. (2011), this species is commonly encountered in alkaline waters and is usually associated with aquatic macrophytes.


**Fig. 2C**

Isolated cells, cylindrical, fusiform, tapering gradually toward the cell extremities, apices slightly rounded; a single chloroplast, parietal, without pyrenoids. Cells 31.5-35 μm long by 3.7-4.5 μm wide.

**Results and discussion**

In the present study, 11 taxa were identified for the first time for Brazil. In addition, we provide the first report of the genus *Westellopsis* for the Neotropics.

Class: CHLOROPHYCEAE
Order: SPHAEROPLEALES
Family: SELENASTRACEAE


**Fig. 2A**

Isolated cells, sigmoidal, apices slightly tapering and curved in opposite directions, occupying the same plane; a single chloroplast, parietal, without pyrenoids. Cells 42.5-55 μm long by 2.5-3.7 μm wide.


Habitat: periphyton

*Monoraphidium fontinale* is similar to *M. litorale* Hindák, but differs by having smaller dimensions and straight cells. This species can also be confused with representatives of *Chlorobium*, although species of the latter genus have evident pyrenoids.

The specimens examined coincided, in terms of their measurements, description and illustrations, with the findings of Komárek & Fott (1983), although those authors also presented illustrations of individuals with both apices orientated in the same direction. Only individuals with cell apices turned in opposite directions were observed during the present study.


**Fig. 2B**

Isolated cells, fusiform, strongly arched, apices gradually tapering, occupying distinct planes, a single chloroplast, parietal, without pyrenoids. Cells 75-85 μm long by 2.5-3.5 μm wide.


Habitat: plankton, periphyton

The cells of the specimens collected in the Marimbus Wetlands had dimensions that were smaller than those reported by Komárek & Fott (1983) and Hindák (1977), although they were otherwise in full agreement with the descriptions and illustrations presented by those authors. According to Hindák (1977), *M. indicum* differs from other species of the genus by having larger cells, but its distinguishing characteristics, such as sigmoidal cells with apices directed toward distinct planes, are well defined.

According to Bazan et al. (2011), this species is commonly encountered in alkaline waters and is usually associated with aquatic macrophytes.


**Fig. 2C**

Isolated cells, cylindrical, fusiform, tapering gradually toward the cell extremities, apices slightly rounded; a single chloroplast, parietal, without pyrenoids. Cells 31.5-35 μm long by 3.7-4.5 μm wide.


Habitat: periphyton

Morphologically, *Monoraphidium obtusum* can be confused with *M. griffithii* (Berkeley) Komárk.-Legn., although
the latter differs by having larger cell dimensions and distinctly tapering apices.

The dimensions of the material collected in the Marimbus Wetlands were slightly smaller than those of the material described by Koršík (1953, as *Ankistrodesmus obtusus*), who reported cell dimensions of 40–61 μm long by 4.5–5 μm wide. However, the specimens examined coincided with the measurements, illustrations, and descriptions provided by Komárek & Fott (1983) and Kormáková-Legnerová (1969).


Fig. 2D

Isolated cells, lunate, tapering gradually toward the extremities, apices tapering to points; a single chloroplast, parietal, without pyrenoids. Cells 12.5–22.2 μm long by 3.7–5 μm wide.


Habitat: plankton, periphyton

According to Komárek & Fott (1983), this species demonstrates considerable phenotypic plasticity, with cells varying from fusiform to lunate or, more rarely, sigmoidal. However, only lunate cells were encountered during the present study.

The principal morphological variations encountered during the present analyses were related to the cell apices, which were sometimes more and sometimes less tapered and pointed.

Morphologically, *M. subclavatum* is similar to *M. caribeum* Hindák, although the latter differs by having thinner and more strongly arched cells.


Fig. 2E

Colonial, with 4, 8 or 16 cells arranged irregularly in a single mucilaginous sleeve; cells lunate or horseshoe-shaped, poles rounded; a single chloroplast, parietal, without pyrenoids. Cells 5–6.5 μm long by 1.2–2 μm wide.


Habitat: periphyton

Morphologically, the specimens of *Raphidocelis danubiana* were similar to those of *Raphidocelis contorta* (Schmidle) Marvan, Komárek & Comas, although the former differed by having lunate or horseshoe-shaped cells.

The specimens from the Marimbus Wetlands agreed with the descriptions, measurements, and illustrations of *Raphidocelis danubiana* presented by Komárek & Fott (1983) and Tsarenko & John (2011).


Fig. 2F–G

Colonial, with 4–16 cells disposed parallel to each other in a sheath of hyaline mucilage; cells fusiform, straight or slightly curved, apices gradually tapering; chloroplast parietal, pyrenoids not seen. Cells 12.5–31.2 μm long by 1.2–2 μm wide.


Habitat: plankton, periphyton

*Quadrigula closterioides* is similar to *Ankistrodesmus falcatus* (Corda) Ralfs, although the latter differs by having larger, arched cells. In addition, *Q. closterioides* has cells that are slightly separated, not tangential.

The specimens collected in the Marimbus Wetlands coincided with the measurements, descriptions, and illustrations presented by Koršík (1953) and Hindák (1977). According to Tsarenko & John (2011), this is probably a cosmopolitan species, occurring in the plankton as well as in the periphyton.

Family: SCENEDESMACEAE


Fig. 3A–B

Colonies spherical, with 8 or 16 cells united by five processes; cells spherical in lateral and apical views, intercellular spaces small, irregularly shaped; cell wall ornamented with small, free conical outgrowths (verrucae), distributed irregularly; a single chloroplast, parietal, with only one pyrenoid. Dimensions: coenobium 30–36.5 μm diam.; cells 11.5–13.5 μm diam.

Based on cultivation data, Hajdu et al. (1976) classified *Coelastrum verrucosum* and various other species of *Coelastrum* (including *C. morus* West & G.S.West) as heterotypic (taxonomic) synonyms of *C. sphaericum* Nägeli, because of their very similar morphologies. Hindák (1992) also undertook a detailed study of *C. verrucosum* based on cultivation data and demonstrated that this species shows considerable phenotypic plasticity, with spherical, hemispherical, and quadrangular coenobia. However, only spherical coenobia were observed in the material examined here.

The present study followed the considerations of Hindák (1992) and Tsarenko & John (2011) in recognizing *Coelastrum verrucosum* as a distinct species, in addition to constituting a currently valid name.

Comas (1996) considered *C. morus* to be a rare tropical form of *C. verrucosum*, although new records have been made in other countries in the northern hemisphere (Tsarenko & John 2011) indicating that *C. verrucosum* is more cosmopolitan than endemic.


Fig. 3C

Colonies flat, composed of 4 cells arranged in two alternating rows, without intercellular spaces; cells elliptical to fusiform, cell walls with longitudinal lines; poles with papilliform thickenings; a single chloroplast, parietal, with only one pyrenoid. Cells 16–18 μm long by 2.5–3.5 μm wide.

New additions of coccoid green algae to the phycocflora of Brazil and the Neotropics

♂ Ramos, G.J.P. s.n. (HUEFS 185353); Lençóis, Marimbus do Remanso, 20/VIII/2011, Moura, C.W.N. & Ramos, G.J.P. s.n. (HUEFS 185365).

Habitat: periphyton

The genus *Enallax* was proposed by Pascher (1943) based on material collected in the Stubai Alps, southwest of Innsbruck, Austria. The author of that work proposed the species *Enallax alpina* Pascher and transferred *Scenedesmus costatus* Schmidle to the new genus as *E. costatus* (Schmidle) Pascher. Subsequently, Skuja (1964) proposed, in a study of the algae of Laponia, Sweden, *E. coelastroides* (Bohlin) Skuja from *Scenedesmus costatus* Schmidle var. *coelastroides* Bohlin.

Kalina & Punčochařova (1977) transferred *Enallax costatus* back to the genus *Scenedesmus*, based on transmission electron microscope studies showing that the cell wall was composed of two layers, with an internal layer of cellulose and an external layer of sporopollenin.

The presence of intermediary morphotypes between *Enallax alpinus*, *E. coelastroides*, and *E. costatus* allowed Hindák (1990) to unite these three species into just one, *E. costatus* (Schmidle) Pascher.

Up until the 1980s, the genus *Enallax* appeared to be restricted to Europe (Komárek & Fott 1983), being found there on humid rocks, in peat bogs, or as planktonic material. Specimens of this genus were later reported from Cuba (Comas 1996), Pakistan (Mehwish & Aliya 2005), China (Hu & Wei 2006) and New Zealand (Broady et al. 2012). Comas (1996) believes that the genus has an amble distribution, although it appears to prefer oligotrophic environments.

In Brazil, the genus *Enallax* was previously restricted to the southeastern state of São Paulo, being represented by *E. acutiformis* (Schröd.) Hindák (Godinho 2009). This species differs from *E. costatus* by having rib-like ridges on the cell walls and cell poles that are notably acuminate, similar to spines.


Fig. 3D-E

Colonies with 8 cells, composed of 2 subcolonies of 4 cells each, united by the inconspicuous remains of the mother-cell wall; cells spherical, subtrapeziform or subtriangular, arranged in the shape of a cross in apical view, and in a slightly curved form in lateral view; a single chloroplast, parietal. Cells 3.5-4 μm diam.


Habitat: periphyton

In terms of its morphology, *Westellopsis linearis* is similar to *Westella botryoides* (West) De Wildemann, although the latter differs by having mucilaginous interconnections between the subcolonies.

During the examinations of the material collected in the Marimbus Wetlands, significant morphological variations were observed in terms of the shapes of the cells in the colonies, varying from spherical (when loosely united) to subtriangular or subtrapeziform (when densely packed).

The specimens from the Marimbus Wetlands are in agreement with the descriptions, measurements, and illustrations presented by Komárek & Fott (1983) and Prescott (1951) for the United States, except in terms of the linear disposition of the cells in the colonies in lateral view.

In addition to the United States, *W. linearis* has been reported from Asia, Europe, and Oceania (Guiry & Guiry 2013). This represents the first report of this genus from the Neotropics.

Class: TREBOUXIOPHYCEAE
Order: CHLORELLALES
Family: CHLORELLACEAE


Fig. 3F

Colonies star-shaped, composed of 4 cells; cells elongated-cylindrical, poles truncated; a single chloroplast, parietal, with only one pyrenoid. Cells 33.5-35 μm long by 1.5-2.5 μm wide.


Habitat: plankton

According to Komárek & Fott (1983), *Actinastrum gracillimum* var. *elongatum* differs from the typical variety of that species only in terms of the longer lengths of its cells (30-37 μm).

The material collected in the Marimbus Wetlands coincides with the measurements, illustrations, and descriptions provided by Komárek & Fott (1983), except in terms of the cell width (4-5 μm) of the specimens reported from Germany.

This variety was represented by very few collected specimens, and each of the colonies was composed of four cells.


Fig. 3G
Colonies star-shaped, composed of 8 cells; cells elongated-cylindrical to lanceolate, poles tapering; a single chloroplast, parietal, pyrenoids not observed. Cells 18.5-25 μm long by 2.5-3.2 μm wide.


Habitat: periphyton

Morphologically, Actinastrum rhaphidioides is similar to individuals of Actinastrum gracillimum G.M.Sm., although the latter species differs by having cylindrical cells, with truncated poles, as well as proportionally larger cell dimensions.

The material examined from the Marimbus Wetlands coincided with the measurements, illustrations, and descriptions presented by Komárek & Fott (1983). According to those authors, Actinastrum rhaphidioides is generally found among the plankton populations of small lakes and swampy areas. It is encountered globally in both temperate and tropical regions.

Comparing the occurrence of these taxa between the two areas studied within the Marimbus Wetlands (Marimbus do Baiano and Marimbus do Remanso), we observed that six taxa (Monoraphidium fontinale, M. indicum, M. subclavatum, Coelastrum verrucosum, Enallax costatus and Westellopsis linearis) were common between the two areas. However, five taxa occurred exclusively in the Marimbus do Baiano area: M. obtusum, Raphidocelis danubiana, Quadrigula closterioides, Actinastrum gracillimum var. elongatum and A. rhaphidioides. None of the taxa occurred exclusively in the Marimbus do Remanso area.

Regarding habitats, most of taxa occurred within the periphytic community. Only one taxon occurred exclusively within the planktonic community (Actinastrum gracillimum var. elongatum). The main reason for the dominance of periphytic representatives is probably due to the extensive and diverse populations of aquatic macrophytes in the two study areas, especially Utricularia foliosa, Cabomba haynesii, Eichhornia azurea, Nymphaea ampla, and Salvinia auriculata, favoring the establishment and development of several organisms, mostly the periphyton.

Figure 3. A and B. Coelastrum verrucosum (Reinsch) Reinsch C. Enallax costatus (Schmidle) Pascher; D and E. Westellopsis linearis (G.M.Sm.) C.-C. Jao; E. Side-view detail; F. Actinastrum gracillimum var. elongatum (G.M.Sm.) Fott; G. A. rhaphidioides (Reinsch) Brunnth.
Bars = 10 μm.
All the 11 taxa identified in the Marimbus Wetlands represent new records for Brazil, expanding the geographic distribution of coccoid green algae to include the Caatinga Biome. This underscores the importance of taxonomic studies of algae in the biome, further studies being necessary in order to increase knowledge of the biodiversity of coccoid green algae in northeastern Brazil.

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