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Diversity of green algae (Chlorophyta) from bromeliad phytotelmata in areas of rocky outcrops and "restinga", Bahia state, Brazil

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Abstract

A floristic survey for green algae (Chlorophyta) from bromeliad phytotelmata of areas of rocky outcrop (Serra da Jibóia) and "restinga" (Parque das Dunas), Bahia state, Brazil is presented here. A total of twenty-three taxa were identified, including three species (*Asterococcus superbus*, *Gongrosira papuasica* and *Lagerhemia chodatti*) that are newly reported for Brazil and two *Oedogonium* species (*Oedogonium pulchrum* and *O. areschougii*) that were recollected in Brazilian territory after 115 years.
Key words: Bromeliaceae, microcosm, morphology, phytotelm, taxonomy.

Resumo

O presente estudo refere-se ao levantamento das espécies de algas verdes (Chlorophyta) ocorrentes em ambientes fitotelmatas bromelícolas de áreas de afloramentos rochosos (Serra da Jibóia) e restinga (Parque das Dunas), Bahia, Brasil. Foram identificados 23 táxons incluindo três espécies (*Asterococcus superbus*, *Gongrosira papuasica* e *Lagerhemia chodatti*) que estão sendo registradas pela primeira vez para o Brasil e duas espécies de *Oedogonium* (*Oedogonium pulchrum* and *O. areschougii*) que foram novamente coletadas para o Brasil após 115 anos.
Palavras-chave: Bromeliaceae, microcosmo, morfologia, fitotelmo, taxonomia.

Introduction

Bromeliaceae Family is one of the main components of the Neotropical flora, and their leaves disposition forming small reservoirs allow accumulation of rain water favoring development of a microcosm known as phytotelmata, composed of several associated organisms (Picado 1913; Varga 1928). Due to their water retention capacity and the complex and diverse architecture of their leaves, bromeliad tanks are well-known biodiversity magnifiers (Rocha *et al*. 1997). Besides the number of leaves, the main elements of the plant architecture such as diameter, height and volume directly affect the richness and abundance of organisms associated to it (Lawton 1983; Oliveira & Rocha 1997). Thus, the greater the complexity of the leaves' architecture of a bromeliad, the higher will be the interaction between these organisms.

Taxonomic and ecological studies of algae from such environments are scarce, so that reports of the occurrence of green algae in bromeliad tanks are rather rare (Hernández-Rodríguez *et al*. 2014) and the identification of these algae is usually restricted to the genus level (Laessle 1961; Brouard *et al*. 2011; Killick *et al*. 2014). One of the few reports on the importance of this group in the phytotelmata community is that of Carrias *et al.* (2014) conducted in French Guiana, in which Chlorophyta contributed with 90% to total algal biomass in *Aechmea aquilega* (Salisbury) Grisebach tanks.

Floristic studies aiming at the chlorophytes in bromeliad phytotelmata are inexistent. The few records of the occurrence of green algae in this type of environment in Brazil were reported by Lyra (1976), who cited some chlorophytes in bromeliad from Pernambuco state; Nogueira (1991) that reported the first occurrence of *Scotiellopsis terrestris* (Reisigl) Puncochárová & Kalina [= *Coelastrella terrestris* (Reisigl) Hegewald & N.Hanagata] for phytotelmata environment in tropical region; and Sophia (1999) that conducted a taxonomic survey of the desmids and some other algal groups, including eight chlorophytes.

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To improve understanding of the algal flora of phytotelmata environments in Brazil, present study aimed at carrying a floristic survey of the green algae (Chlorophyta) occurring in bromeliad tanks from two areas of Bahia State, highlighting their morphological characteristics and environmental conditions.

Material and Methods

Study was carried out in two areas of Bahia state, northeast Brazil: Serra da Jibóia (Santa Teresinha) and Parque das Dunas (Salvador) (Fig. 1). Serra da Jibóia (39º28'W, 12º51'S) is located in the eastern part of the Bahia state, made up

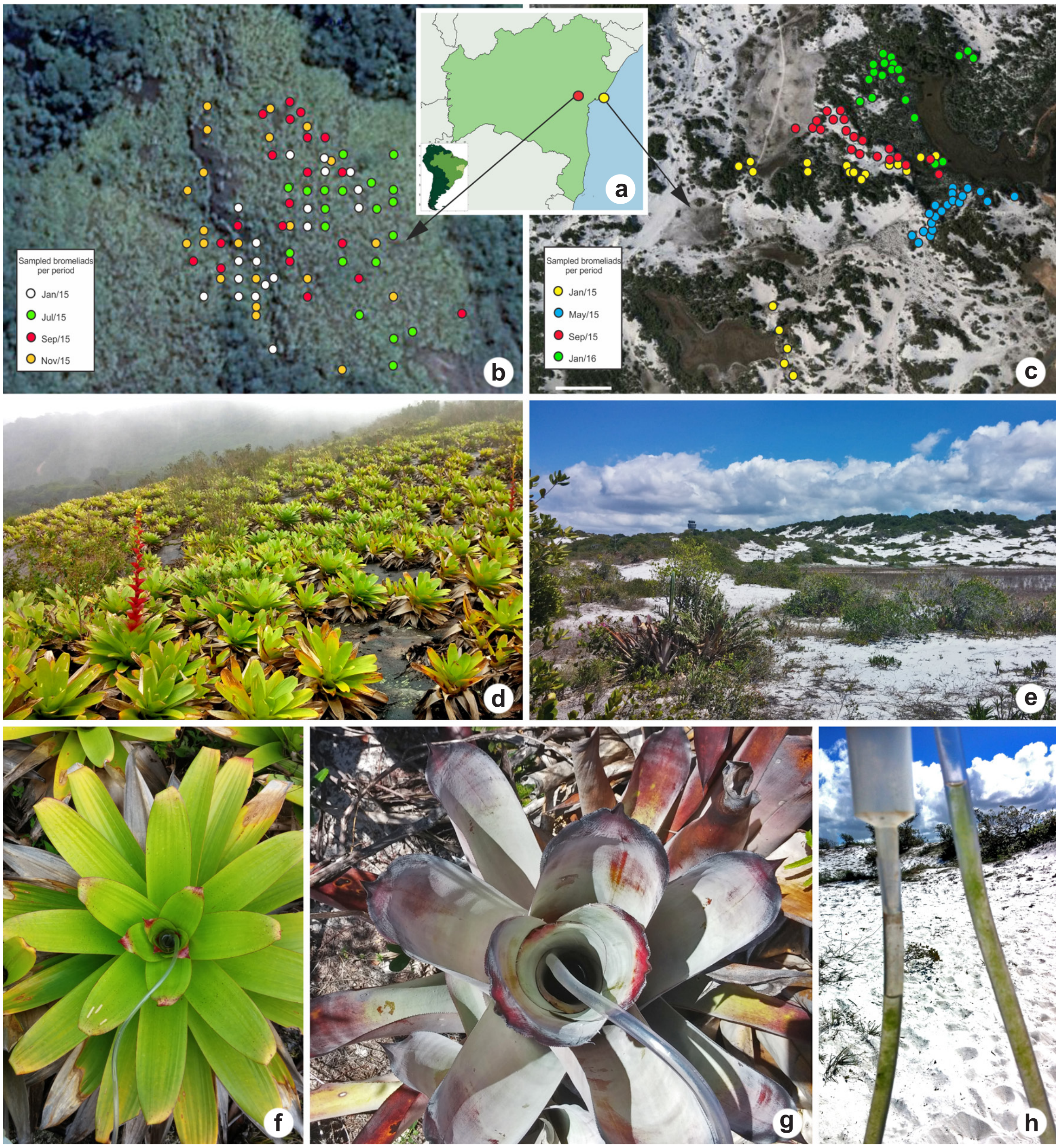

Figure 1 – a. Location of Serra da Jibóia (red dot) and Parque das Dunas (yellow dot) in the Bahia state, Brazil; b. Satellite image with distribution of sampled bromeliads in Serra da Jibóia; c. Satellite image with distribution of the sampled bromeliads in Parque das Dunas, Salvador; d. Overview of bromeliads on rocky outcrops of Serra da Jibóia; e. Overview of bromeliads in the Parque das Dunas; f. Sampling in the central tank of *Alcantarea nahoumii*; g. Sampling in the central tank of *Hohenbergia littoralis*; h. Hose detail with algae collected from the bromeliad tanks.

by a complex of small hills (Pioneira, Oiti, Monte Cruzeiro, Água Branca, etc.) and covers the area of approximately 22,500 km^2. This area is located in the outskirts of the Atlantic Forest and the Semi-Arid Domains. Local vegetation includes rocky fields at the rocky outcrops of the top, tropical rain forest on the east slope, and "Caatinga" on the west and north (Juncá & Borges 2002).

Parque das Dunas (38°19'W, 12°55'S) is inserted in the lakes and dunes Environmental Protection Area of Abaeté, which comprises an area of about 6 million square meters enclaved in the city of Salvador, Bahia state, Brazil. The locality has great environmental importance since it represents one of the last urban remnants of dunes, lakes and "restinga" ecosystem of Brazil. Parque das Dunas vegetation is represented by the "restinga" ecosystem and the plant communities are mainly formed by herbaceous and shrub halophytes, but also by some arboreal representatives (UNIDUNAS 2015).

Material examined was collected from phytotelmata of the bromeliads *Alcantarea nahoumii* (Leme) J.R.Grant (Serra da Jibóia) and *Hohenbergia littoralis* L.B.Smith (Parque das Dunas) randomly selected in January, May, July, September, November 2015 and January 2016. The liquid material from the bromeliad tanks was collected with the aid of a 50-ml syringe coupled to a polyethylene hose. During collection of water, the abiotic features such as temperature, pH, electric conductivity (EC) and total dissolved solids (TDS) were measured using a multiparameter probe Hanna HI98130 equipment; and dissolved oxygen (DO) measurements were performed with a portable digital equipment Instrutherm (MO-910). For each species, values minimum, maximum and mean of the water abiotic features were provided. Only the new records for Bahia and Brazil were described. Taxonomic identification of algal material was based on the specialized literature such as Komárek & Fott (1983), Hindák (1984), Mrozinska-Webb (1985), Comas (1996), Tsarenko & John (2011) and Pentecost (2011).

All material was analyzed using an Olympus BX43 optical microscope, and photographed with a MicroPublisher camera QImaging MP5.0-RTV-CLR-10-C. After analyses, samples were preserved in Transeau solution (Bicudo & Menezes 2006) and deposited at the Herbarium collection of the Universidade Estadual de Feira de Santana (HUEFS).

Frequency of occurrence of algae was calculated in each locality according to Matteucci & Colma (1982): > 70% - very frequent; ≤ 70% and > 40% - frequent; ≤ 40% and > 10% - uncommon; ≤ 10% - rare.

To observe the cell wall ornamentation of *Enallax costatus* (Schmidle) Pascher, specimens were adhered to a glass coverslip with poly-L-lysine (Sigma, 1:10 in distilled water) to guarantee better adhesion. Cover slips with *E. costatus* attached were dehydrated in acetone series (30, 50, 70, 85, 95 and 100%, 100% 10 min each). In addition, the material was dried to critical-point in a Leica EM CPD030 apparatus; the stubs were mounted and coated with a gold layer and examined using a JEOL 6390 LV SEM.

Results & Discussion

During the taxonomic survey of the green algae from Serra da Jibóia (rocky outcrops) and Parque das Dunas (restinga) 23 taxa were identified including three species that are mentioned for the first time for Brazil. The species already known for Bahia and their cell dimensions, figures, previous records and respective vouchers are listed in the Table 1 (Figs. 2-4).

It is important to note that all species in the present study, except for *Monoraphidium contortum* (Thuret) Komárková-Legnerová (Sophia 1999), are being mentioned for the first time for bromeliad phytotelmata.

Asterococcus superbus (Cienkowski) Scherffel - Ber. Deutsch. Bot. Ges. 26A: 762. 1909.

Fig. 2d,e

Cells solitary or in groups of 2, 4 or 8 surrounded by a stratified mucilaginous envelope, chloroplast star-shaped, one pyrenoid. Cells 11.2–17.8 μm diam.

Material examined: Santa Teresinha, Serra da Jibóia, 14.I.2015, *G.J.P. Ramos et al.* (HUEFS 155295); 18.VII.2015, *G.J.P. Ramos et al.* (HUEFS 224675).

Despite of the cell diameter be smaller than reported by Pentecost (2011: 30–43 μm) we decided to identify present specimens as *Asterococcus superbus* because of the presence of a stratified mucilaginous envelope, which is absent in *Asterococcus limneticus* G.M.Smith. According to Bicudo & Menezes (2006), *Asterococcus* includes two species that are usually very seldom collected because they live in the littoral zone of stagnant water systems, and always associated with other algae and plants. In Brazil, the presence of only one *Asterococcus* species, *A. limneticus*, was recorded for Ribeirão Preto (Silva 1999) and Goiânia (Nogueira 1999). Thus, *A. superbus* is presently registered for the first time for Brazil.

Table 1 – Chlorophyta species known for Bahia, their cell dimensions, figures, previous records in Bahia and herbarium vouchers (HUEFS).

Species	Cell dimensions	Fig.	Previous records in Bahia	HUEFS
Ankistrodesmus falcatus (Corda) Ralfs	37.5–45 µm × 1.5–2 µm	2a	Ramos *et al.* (2012)	224658
Ankistrodesmus fusiformis Corda *ex* Koršikov	22.5–27.5 µm × 1.5–2.5 µm	2b,c	Fuentes *et al.* (2010); Mendes *et al.* (2012); Ramos *et al.* (2012)	224653, 224675, 224698, 224715
Coelastrum indicum W.B.Turner	8.8–13.8 µm	2f,g	Mendes *et al.* (2012); Ramos *et al.* (2015a)	224656, 224676, 224696, 224721
Crucigenia quadrata Morren	4–6.5 µm × 2.5–3.5 µm	2h	Martins *et al.* (1991); Fuentes *et al.* (2010)	224662
Enallax costatus (Schmidle) Pascher	12–18 µm × 8–10 µm	2j-l	Ramos *et al.* (2014)	224655, 224677, 224694, 224717
Monoraphidium caribeum Hindák	12.5–18.7 µm × 1.5–2.5 µm	3f	Ramos *et al.* (2012)	224659, 224716
Monoraphidium contortum (Thuret) Komárková-Legnerová	10–22 µm × 1.5–2.5 µm	3g	Ramos *et al.* (2012)	224658
Monoraphidium griffithii (Berkeley) Komárková-Legnerová	40–58 µm × 2.5–3 µm	3h	Ramos *et al.* (2012)	224654, 224675, 224698, 224715
Monoraphidium komarkovae Nygaard	61–68.8 µm × 1.5–2.1 µm	3i	Fuentes *et al.* (2010); Ramos *et al.* (2012)	224656, 224721
Monoraphidium subclavatum Nygaard	25–31 µm × 5–6 µm	3j	Ramos *et al.* (2014)	224662
Oocystis borgei J.W.Snow	12.5–17.5 µm × 10–13.5 µm	4h	Martins *et al.* (1991); Ramos *et al.* (2015b)	155295, 224680, 224698, 224714
Oocystis lacustris Chodat	10–17.5 µm × µm 7–8.5	4i	Martins *et al.* (1991); Ramos *et al.* (2015b)	224676, 224699
Scenedesmus ecornis (Ehrenberg) Chodat	8.7–11.5 µm × 2.5–5 µm	4j	Fuentes *et al.* (2010); Ramos *et al.* (2015a)	224655, 224673, 224694, 224715
Scenedesmus obtusus Meyen	8.5–18 µm × 5–8.5 µm	4k,l	Ramos *et al.* (2015a)	224668, 224676, 224700, 224717
Sorastrum americanum (Bohlin) Schmidle	10–11.5 µm × 5–7.5 µm	4m	Ramos *et al.* (2016)	224656, 224721
Sorastrum spinulosum Nägeli	18.7–22 µm × 6.5–12.5 µm	4n	Ramos *et al.* (2016)	224662, 224721

Dispora speciosa Koršikov - Protococcinae: 334. 1953. Fig. 2i

Colonies rectangular, 4, 8 or 16 groups of tetrahedral cells arranged in parallel rows; cells subglobose, asymmetric, chloroplast parietal, without pyrenoid. Cells 7.4–8.1 µm length, 5.5–7.1 µm width.

Material examined: Santa Teresinha, Serra da Jibóia, 14.I.2015, *G.J.P. Ramos et al.* (HUEFS 224659); 18.VII.2015, *G.J.P. Ramos et al.* (HUEFS 224675); 11.IX.2015, *G.J.P. Ramos et al.* (HUEFS 224704); 20.XI.2015, *G.J.P. Ramos et al.* (HUEFS 224715).

According to Koršikov (1953), *Dispora speciosa* is characterized by having cells without pyrenoid arranged in rectangular colonies. The only work containing taxonomic information on *Dispora speciosa* in Brazil is that by Nogueira & Oliveira (2009) based on material from Goiás state. However, after comparing the species description with the illustration in that paper (Nogueira &

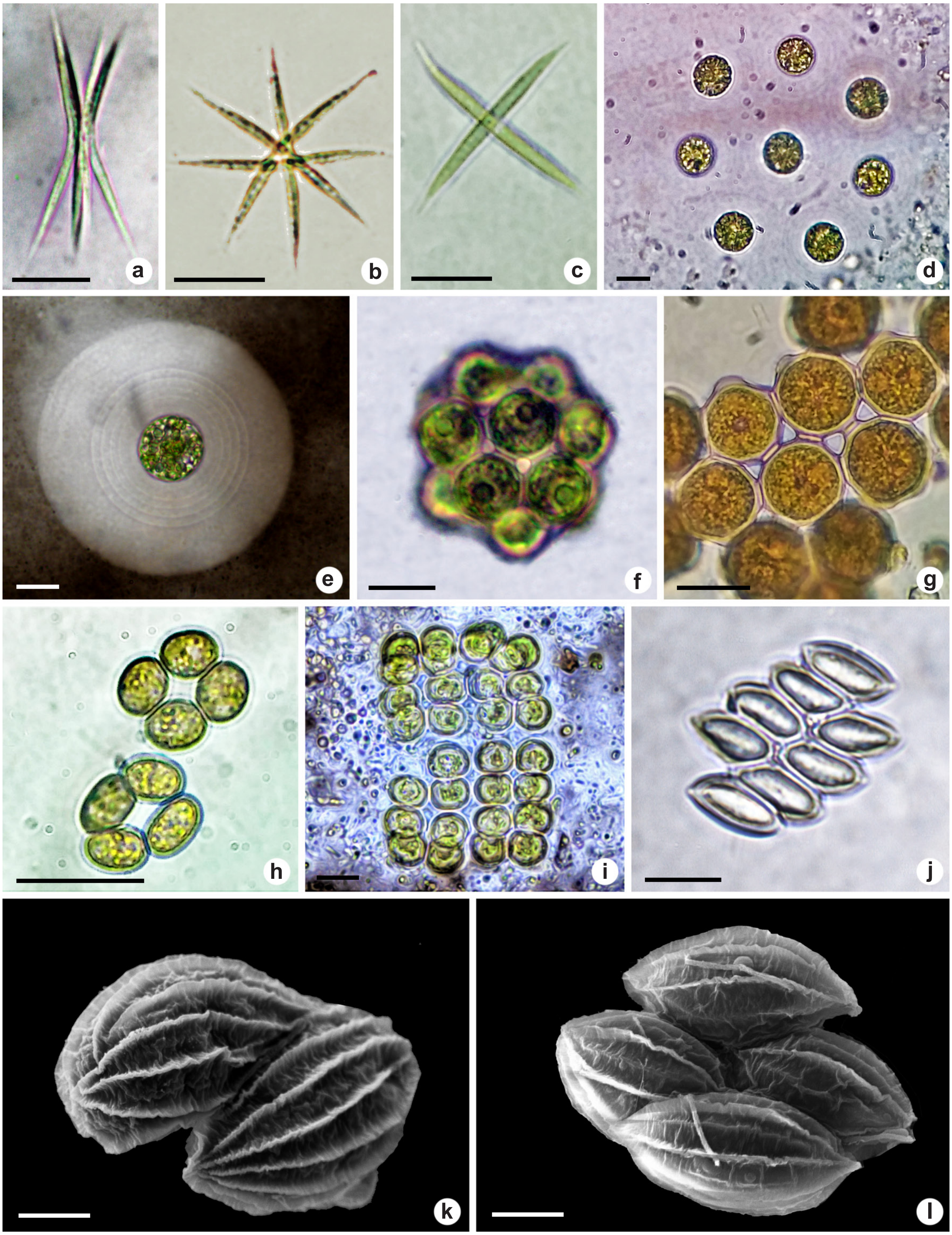

Figure 2 – a. *Ankistrodesmus falcatus*; b,c. *A. fusiformis*; d,e. *Asterococcus superbus*; f,g. *Coelastrum indicum*; h. *Crucigenia quadrata*; i. *Dispora speciosa*; j-l. *Enallax costatus*. (a-h. Bars = 10 µm; k,l. Bars = 5 µm).

Oliveira 2009: 138, Fig. 12) it became clear that most possibly occurred a misidentification, because the illustration refers to *Dispora cuneiformis* (Schimdle) Printz (see Komárek & Fott 1983: 425, pl. 129, Fig. 4). Moreover, the latter authors mentioned that *D. speciosa* has pyrenoid and spherical colonies, features observed in the present material identified as *D. speciosa*. Thus, we consider the present the first confirmed record of *D. speciosa* for Brazil.

Eremosphaera viridis De Bary - Untersuch. Conjugaten. 56. 1858. Fig. 3a-c

Cells usually solitary, spherical, sometimes colonial, in clusters of 2 or 4; cell wall smooth, thick; chloroplast parietal, several pyrenoids. Cells 23.0–32.0 µm diam.

Material examined: Santa Teresinha, Serra da Jibóia, 14.I.2015, *G.J.P. Ramos et al.* (HUEFS 224657); 18.VII.2015, *G.J.P. Ramos et al.* (HUEFS 224679); 11.IX.2015, *G.J.P. Ramos et al.* (HUEFS 224693); 20.XI.2015, *G.J.P. Ramos et al.* (HUEFS 224719).

Presence of representatives of *Eremosphaera* was mentioned only once for Bahia state by Fuentes *et al*. (2010) in a checklist prepared for Rio de Contas. However, authors gave no details such as description, cell dimensions or illustration of *Eremosphaera eremosphaeria* R.L.Smith & Bold to taxonomic comparison. Thus, this is the first confirmed record of the genus for Bahia and, consequently, of *E. viridis* for the state.

Gongrosira papuasica (Borzì) Tupa - Beih. Nova Hedwigia 46: 37. 1974. Fig. 3d

Talli formed by uniseriate filaments, with a prostrate pseudoparenchymatous system and some irregular, sparingly divided erect branches; cells cylindrical, sometimes inflated; chloroplast parietal, with one pyrenoid. Cells 7.1–14.4 µm length, 3.1–4.5 µm width.

Material examined: Salvador, Parque das Dunas, 27.I.2016, *G.J.P. Ramos et al.* (HUEFS 224787, HUEFS 224791, HUEFS 224794).

Gongrosira papuasica was registered only from Parque das Dunas bromeliads during the summer, after a period of some heavy rains in Salvador. The species is morphologically close to *Gongrosira pseudoprostata* L.R.Johnson, that is different by usually not having the erect filaments system and, when it does, they are underdeveloped (Johnson & John 1992; John 2011).

The species is probably cosmopolitan (John 2011) occurring in England, Papua New Guinea, and Iraq. Additionally, the species was reported for North America where it was found living on the surface of vascular aquatic plants. This is the first time *G. papuasica* is recorded for Brazil.

Lagerheimia chodatii C.Bernard - Protococcacées *et* Desmidiées. 170. 1908. Fig. 3e

Cells solitary, spherical, 4 polar spines cruciate arranged, slight arcuate; chloroplast parietal, with one pyrenoid. Cells 8.6–10.1 µm diam, spines 7.7–9.9 µm length.

Material examined: Salvador, Parque das Dunas, 27.I.2016, *G.J.P. Ramos et al.* (HUEFS 224795).

According Hindák (1984), *Lagerheimia chodatii* is the only species in the genus that has spherical cells, different from all other species that have them ellipsoid, morphologically close to those of *Oocystis* Nägeli *ex* A.Braun. Description of the present material is in accordance with those in Tsarenko & John (2011) and Hindák (1984), although the cells identified by the latter author are slightly smaller (7 µm diam.).

This species occurred in just one bromeliad from Parque das Dunas. According to Tsarenko & John (2011), *L. chodatii* is probably cosmopolitan and widely distributed in small water bodies, what may explain its occurrence in phytotelmata. This is the first time the species is recorded for Brazil.

Oedogonium areschougii Wittrock *ex* K.E.Hirn - Acta Soc. Sci. Fenn. 27: 270. 1900. Fig. 4a-c

Plant dioecious, nannandrous, gynandrosporic (?); vegetative cells cylindrical-capitellate, 54–68 µm long, 12–15.5 µm broad, apical cell with obtuse apex; oogonia solitary or in pairs, usually subglobose, opening by a median operculum, 32–40 µm diam.; oospore depressed-globose, 27–31.5 µm diam.; androsporangia not observed, dwarf males attached to oogonia, 11.4–12.5 µm long, 8–8.5 µm broad, suffultory cells identical to vegetative cells.

Material examined: Santa Teresinha, Serra da Jibóia, 14.I.2015, *G.J.P. Ramos et al.* (HUEFS 224654); 18.VII.2015, *G.J.P. Ramos et al.* (HUEFS 224676); 11.IX.2015, *G.J.P. Ramos et al.* (HUEFS 224692); 20.XI.2015, *G.J.P. Ramos et al.* (HUEFS 224716).

Specimens presently identified as *Oedogonium areschougii* agree with both description and illustration provided by Hirn (1900), when the species proposed by Wittrock (1870) was validated. In Brazil, the first record of *O. areschougii* is in Hirn (1900) collected from Porto Alegre, Rio Grande do Sul state, the record later on referred in the checklist of algae of that state (Torgan *et al.* 2001). Present species was collected 115 years after Hirn (1900), and now its geographic distribution was expanded to the Northeast region of Brazil.

It was observed that in some of the samples *O. areschougii* was predominant, forming large masses composed of numerous filaments, and that the other green algae diversity was low. In these samples, it was common to find a large number of desmids associated to *O. areschougii*.

Oedogonium pulchrum Nordstedt & K.E.Hirn - Acta Soc. Sci. Fenn. 27: 312. 1900. Fig. 4d-g

Plant dioecious (?), macandrous; vegetative cells cylindrical-capitellate, 20–47.2 µm long, 5.7–9.5 µm broad; oogonia 20–27 µm diam., depressed-globose, with 7–10 radial shallow, rounded projections in apical view, operculate, division inframedian, oospore globose-subglobose, 13–14 µm diam., suffultory cell often shorter than vegetative cells; androsporangia not observed.

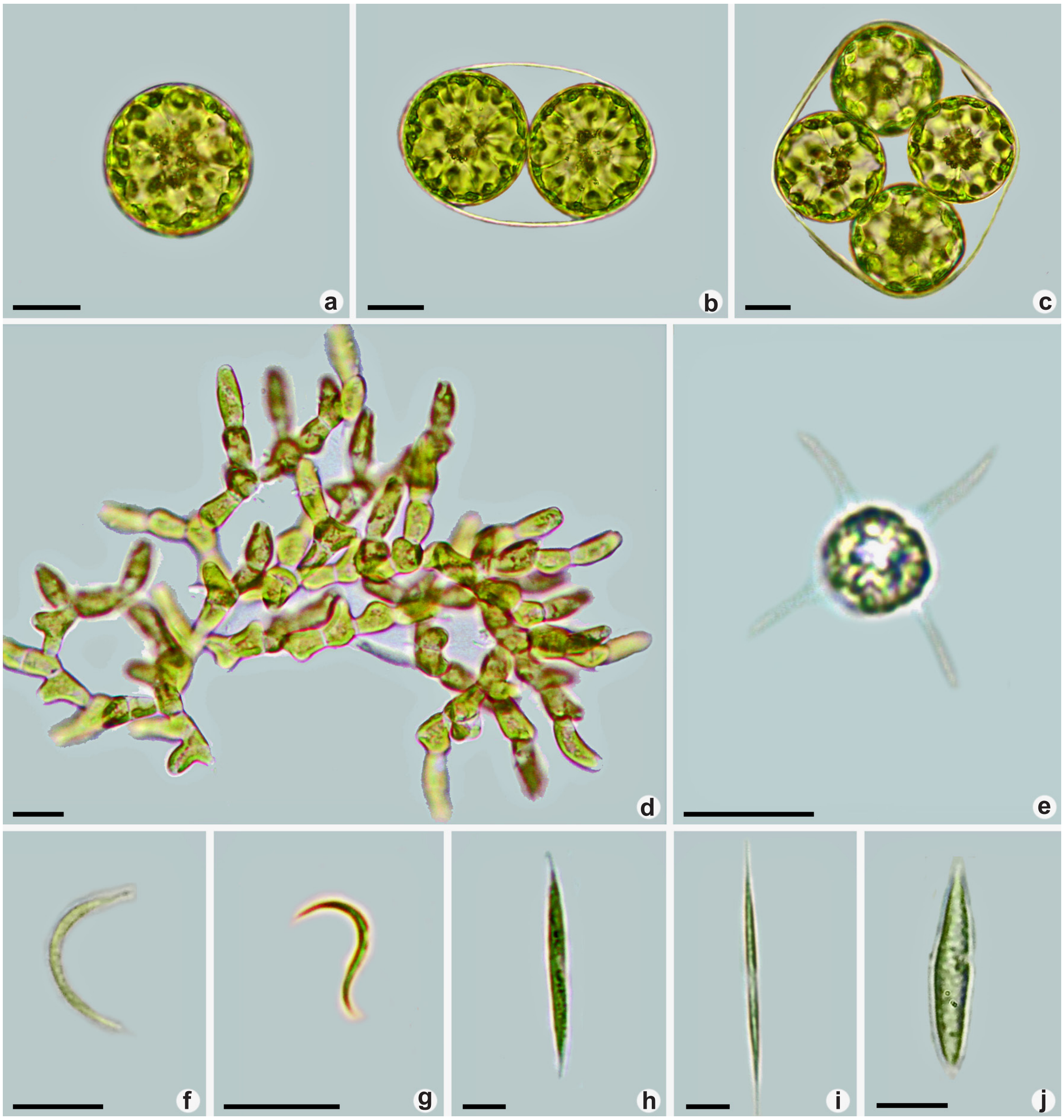

Figure 3 – a-c. *Eremosphaera viridis*; d. *Gongrosira papuasica*; e. *Lagerheimia chodatii*; f. *Monoraphidium caribeum*; g. *M. contortum*; h. *M. griffithii*; i. *M. komarkovae*; j. *M. subclavatum*; k. (Bars = 10 µm).

Material examined: Salvador, Parque das Dunas, 29.I.2015, *G.J.P. Ramos & M.A. Santos* (HUEFS 224739); 26.V.2015, *G.J.P. Ramos et al.* (HUEFS 224749); 4.IX.2015, *G.J.P. Ramos et al.* (HUEFS 224768); 27.I.2016, *G.J.P. Ramos et al.* (HUEFS 224786).

Oedogonium pulchrum was described by Nordstedt & K.E.Hirn from material collected at Pirassununga, São Paulo state (Hirn 1900). The species is being recorded again in Brazil 117 years after its proposition. Morphologically, *O. pulchrum* resembles *O. itzigsohnii*, however, the latter species differs by having projections (usually conical) more elongated round the oogonia (Mrozinska-Webb 1985).

Despite of being little reported in the literature, *O. pulchrum* was very common in this study and restricted to Parque das Dunas, occurring in most of *Hohenbergia littoralis* plants forming large green masses in the central rosette as well as on the side leaves. Presence of numerous oospores is most probably related to some survival strategy due the low rainfall precipitation during certain periods of the year.

Figure 4 – a-c. *Oedogonium areschougii*; d-g. *O. pulchrum*; h. *Oocystis borgei*; i. *O. lacustris*; j. *Scenedesmus ecornis*; k,l. *S. obtusus*; m. *Sorastrum americanum*; n. *S. spinulosum.* (Bars = 10 µm).

In addition, *O. pulchrum* was a well-adapted species to large variation of dissolved oxygen, but under low DO concentration (< 4 mg L^{-1}) it was more common to find oospores than in the more oxygenated tanks (DO < 7 mg L^{-1}), where it was more frequent to find sterile filaments.

Several factors may affect the spatial distribution pattern of bromeliads, among which are the reproductive mechanism adopted by the plant (Crawley & May 1987), substrate type (Fischer 1994), as well as light, temperature and humidity. The bromeliads of the two areas studied live in different conditions, *i.e. Hohenbergia littoralis* inhabits an area of sandbank dunes ("restinga" area) near the sea level, whereas *Alcantarea nahoumii* occupies an area of rocky outcrops, stony substrate, at an altitude of 850 m. Despite of these differences of environmental conditions, both bromeliads accumulate sufficient amount of water, leading to the development of algae, including chlorophytes.

Freshwater chlorophytes may be represented by unicellular to filamentous forms. In the present study, there was a prevalence of coenobial/colonial (10 species), followed by coccoid (8), filamentous (2) and pseudoparenchymatous thalli (*Gongrosira papuasica*). The most representative genus in number of species during this study was *Monoraphidium* with five. Apart from *Oedogonium*, the other chlorophytes had their occurrence restricted to one of the two areas studied.

Comparison of the green algae diversity of both areas allowed observing that the bromeliads from Serra da Jibóia showed a greater taxonomic richness (20 taxa) in relation to that of Parque das Dunas (3 taxa). However, all taxa recorded for the last area were considered rare (*Oedogonium pulchrum*, recollected in Brazil after 115 years of its original description) and new occurrences for Brazil (*Gongrosira papuasica* and *Lagerhemia chodatti*). At Serra da Jibóia, *Oedogonium areschougii* (recorded 116 years after its first report of occurrence in the country) and *Dispora speciosa* (first confirmed record for Brazil) were highlighted. *Eremosphaera viridis* is presently reported for the first time for Bahia state.

Analysis of the taxa studied distribution according to their frequency of occurrence showed the prevalence of rare taxa (12) followed by the uncommon (7) and the frequent taxa (3) (Tab. 2). Among all species identified, the most common found in bromeliads from Serra da Jibóia was *Enallax costatus*, which was considered a frequent taxon (F = 65%), whereas at Parque das Dunas the leading species was *Oedogonium pulchrum* with a frequency of occurrence over 80%.

Regarding the abiotic features measured in the bromeliad tanks, water pH was dominantly acidic in both studied areas (Serra da Jibóia 5.9 ± 0.6; Parque das Dunas 4.3 ± 0.6), as typical this kind of environment (Laessle 1961; Kitching 2000; Guimarães-Souza *et al*. 2006), although some species recorded for Serra da Jibóia as *Eremosphaera viridis*, *Monoraphidium griffithii*, *Scenedesmus ecornis*, *S. obtusus* and *Coelastrum indicum* also occurred in tanks with slightly alkaline condition (pH 7.6) (Tab. 3). Coccoid green algae prevailed in alkaline and neutral waters; however, they can also grow in acidic waters (Philipose 1967; Comas 1996).

Overall, conductivity in the bromeliad tanks was considered higher (0.22 ± 0.16 mS cm^{-1}) in the Serra da Jibóia bromeliads compared to those of Parque das Dunas (0.07 ± 0.09 mS cm^{-1}), despite the fact of the latter area be located closer to the sea. These values are near those reported by Sophia *et al*. (2004) and Guimarães-Souza *et al*. (2006) for bromeliad tanks exposed to the sun located in the "restinga" of the Jurubatiba National Park, Macaé, Rio de Janeiro state. Acidification produced by the bromeliads, besides the low conductivity could be relevant factors acting on the selection of the community colonization (Lopez *et al*. 2009), and most probably contributed for the development of green algae in the tanks.

High temperature is another favorable condition for development of green algae in general, mainly of coccoid species (Philipose 1967; Sant'Anna & Martins 1982; Comas 1996). The water temperature in the bromeliad tanks was mostly considered high reaching 34.9 ºC (Serra da Jibóia 27 ± 2.9 ºC, Parque das Dunas 30.3 ± 2.1 ºC). *Gongrosira papuasica*, *Lagerheimia chodatii* and *Oedogonium pulchrum* were recorded present in bromeliads from Parque das Dunas growing at an average temperature > 30 ºC, while *Monoraphidium contortum* was the only species of the Serra da Jibóia found growing under these conditions.

Dissolved Oxygen (DO) is also an important factor for the phytotelmata community dynamics, and their regimens are influenced by the presence or absence of algae which, in turn reflects the position of the plant with respect to sun or shade (Laessle 1961; Kitching 2000). As the bromeliads of two areas were exposed to the sun, DO concentration

Table 2 – Distribution, frequency (F) and classification (C) of Chlorophyta species in two areas of the Bahia state. VF = very frequent; F = frequent; U = uncommon; R = rare.

Species	Serra da Jibóia				Parque das Dunas				F (%)	C
	2015				2015			2016		
	jan	jul	sep	nov	jan	may	sep	jan		
Oedogonium pulchrum					x	x	x	x	85	VF
Enallax costatus	x	x	x	x					65	F
Eremosphaera viridis	x	x	x	x					48.75	F
Coelastrum indicum	x	x	x	x					42.5	F
Monoraphidium griffithii	x	x	x	x					30	U
Oedogonium areschougii	x	x	x	x					26.25	U
Ankistrodesmus fusiformis	x	x	x	x					20	U
Scenedesmus obtusus	x	x	x	x					18.75	U
Oocystis borgei	x	x	x	x					15	U
Oocystis lacustris		x	x						12.5	U
Scenedesmus ecornis	x	x	x	x					11.25	U
Dispora speciosa	x	x	x	x					6.25	R
Monoraphidium caribeum	x			x					5	R
Asterococcus superbus	x	x							3.75	R
Gongrosira papuasica								x	3.75	R
Monoraphidium komarkovae	x			x					3.75	R
Sorastrum americanum	x			x					3.75	R
Monoraphidium subclavatum	x								2.5	R
Sorastrum spinulosum	x			x					2.5	R
Monoraphidium contortum	x								2.5	R
Ankistrodesmus falcatus	x								1.25	R
Crucigenia quadrata	x								1.25	R
Lagerheimia chodatii								x	1.25	R

was primarily high (Serra da Jibóia 7.8 ± 3.7 mg L^{-1}, Parque das Dunas 6.8 ± 3.9 mg L^{-1}). The main species often found in conditions of high dissolved oxygen concentration (DO mean values > 8 mg L^{-1}) were *Coelastrum indicum*, *Oocystis borgei*, *O. lacustris* and *Oedogonium areschougii*.

Rainfall precipitation influenced water accumulation in the bromeliad tanks in both areas of present study, so that the lack of rain between October and December 2015 at Parque das Dunas (a less rainy area in the Salvador region) did not allow formation of an algal community. During the same period at Serra da Jibóia it was observed a water volume significant decline; however, completely dry bromeliads in the area were seldom found. This was possibly due to the local environmental conditions (high altitude and high humidity brought through the woods surrounding the Serra da Jibóia) that tends to maintain some humidity regularity for the phytotelmata community to establish.

The bromeliads leaf morphology and architecture may also be considered relevant features for the establishment of phytotelmata communities (Laessle 1961; Kitching 2000; Marino *et al*. 2011), provided that different bromeliad species can shape their algal community diversity

Table 3 – Amplitude of environmental variables in which each species of Chlorophyta occurred in the bromeliad tanks from two areas of Bahia state. T = Water temperature; C = Conductivity; TDS = Total Dissolved Solids; DO = Dissolved Oxygen.

Species	T (°C)	pH	C (mS.cm^{-1})	TDS (ppt)	DO (mg.L^{-1})
Ankistrodesmus falcatus	29.8	5.7	0.4	0.15	4.1
Ankistrodesmus fusiformis	21.8–32.3 (28.7)*	5.1–6.7 (5.9)*	0.03–0.55 (0.2)*	0.01–0.6 (0.14)*	2.9–13.1 (5.9)*
Asterococcus superbus	21.6–30.2 (27)	5.5–5.7 (5.6)	0.07–0.39 (0.27)	0.04–0.2 (0.14)	3.5–6.6 (5.4)
Coelastrum indicum	22.2–32.9 (27.4)	4.8–7.6 (6)	0.04–0.68 (0.14)	0.04–0.2 (0.14)	3.4–23.5 (8.3)
Crucigenia quadrata	27.5	6.2	0.33	0.11	4.6
Dispora speciosa	21.6–30.7 (27.9)	5.3–6.6 (6)	0.07–0.68 (0.3)	0.04–0.6 (0.2)	3.4–23.5 (7.1)
Enallax costatus	21.8–32.9 (27.6)	4.3–6.9 (5.9)	0.04–0.68 (0.25)	0.02–0.6 (0.13)	2.9–18.9 (7.3)
Eremosphaera viridis	21.7–32.3 (26.9)	3.5–7.6 (5.8)	0.03–0.65 (0.23)	0.01–0.6 (0.12)	3.4–13.9 (7.5)
Gongrosira papuasica	29.6–31.8 (30.6)	3.9–4 (4)	0.04–0.12 (0.07)	0.02–0.6 (0.4)	3.8–11.0 (7.9)
Lagerheimia chodatii	31.4	4.1	0.03	0.02	1.3
Monoraphidium caribeum	27.2–30.7 (29.1)	5.5–6.2 (5.9)	0.09–0.37 (0.23)	0.05–0.6 (0.2)	3.4–11.4 (5.9)
Monoraphidium contortum	29.8–30.7 (30.2)	5.6–6.0 (5.8)	0.13–0.39 (0.26)	0.15–0.60 (0.37)	3.5–4.1 (3.8)
Monoraphidium griffithii	21.7–32.3 (26.9)	3.5–7.6 (5.8)	0.03–0.65 (0.23)	0.01–0.6 (0.12)	3.4–13.9 (7.5)
Monoraphidium komarkovae	27.4–31 (29.8)	5.8–6.3 (6)	0.1–0.55 (0.3)	0.12–0.6 (0.26)	3.5–5.9 (4.8)
Monoraphidium subclavatum	27.5–30.7 (29.1)	6.0–6.2 (6.1)	0.13–0.33 (0.23)	0.11-0.6 (0.35)	3.5–4.6 (4)
Oedogonium areschougii	22–31 (26.8)	4.6–6.6 (5.7)	0.04–0.68 (0.2)	0.02–0.34 (0.09)	3.5–23.5 (8.1)
Oedogonium pulchrum	26.2–34.9 (30.4)	3.2–6.3 (4.3)	0.0–0.48 (0.07)	0.0–0.24 (0.03)	1.7–23.6 (7.3)
Oocystis borgei	21.7–30.2 (26)	3.5–6.7 (5.8)	0.08–0.65 (0.25)	0.04–0.33 (0.12)	2.9–23.5 (9.3)
Oocystis lacustris	22.0–29.7 (25)	3.8–5.5 (4.7)	0.01-0.23 (0.08)	0.0-0.11 (0.11)	5.6–13.2 (9)
Scenedesmus ecornis	21.7–32 (26.9)	3.5–7.6 (5.9)	0.09–0.68 (0.36)	0.18–0.34 (0.18)	2.9–13.2 (7.1)
S. obtusus	21.8–32.9 (25.7)	3.5–7.6 (6)	0.04–0.68 (0.29)	0.02–0.34 (0.14)	2.9–13.6 (7.7)
Sorastrum americanum	27.4–30.3 (29.1)	5.8–6.3 (6)	0.1–0.43 (0.27)	0.12–0.21 (0.2)	4.5–5.9 (5.2)
S. spinulosum	27.4–29.9 (28.4)	5.8–6.3 (6.1)	0.22–0.43 (0.32)	0.11–0.21 (0.15)	4.3–5.9 (5)

*Mean values are shown in parentheses.

(Carrias *et al*. 2014). In the present study, it was observed that the algal community species richness was greater in *Alcantarea nahoumii* (bromeliad from Serra da Jibóia), probably also due to an increased water retention promoted by the great number of leaves (up to 56) that contributed to the formation of more tanks. On the other hand, the leaf architecture of *Hohenbergia littoralis* (bromeliad from Parque das Dunas) probably influenced the low richness of taxa, since the plant has fewer leaves (up to 24), usually more grouped, providing a large accumulation of water in the central tank and much less in the side leaves.

Thus, a combined analysis of abiotic variables of water, bromeliad's position (shade or sun) and plant architecture is essential to understand the patterns of algal community in phytotelmata environments. Finally, more floristic studies of the algae living in phytotelmata (bromeliads and/ or another plants) are needed not only to expand the knowledge of the green algae, but also of other groups, because it is probably that other rare species will occur in these microcosms.

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