

Research Article

First Taxonomic Records of Microalgae Inhabiting the Phytotelmata of *Billbergia pyramidalis* (Sims) Lindley

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ABSTRACT

Phytotelmata are miniature aquatic ecosystems that provide a unique environment conducive to the growth of rare and novel microalgal species. This taxonomic study represents the first taxonomic survey of microalgal species inhabiting the phytotelmata of *Billbergia pyramidalis* (Sims) Lindley. In total, 16 species were taxonomically described and reported for the first time in this unique aquatic habitat, marking new distributional records for the Philippines. The survey also identifies an additional ten species (*Phacus circulatus*, *Cocconeis placentula*, *Nitzschia fruticosa*, *Klebsormidium crenulatum*, *Closterium ehrenbergii*, *Desmococcus olivaceum*, *Tetrademus bernardii*, *Scenedesmus tibiscensis*, *Oscillatoria crassa*, and *Cyanothece aeruginosa*) as new records in the global registry of microalgae discovered in the phytotelmata of bromeliads. Furthermore, the study documents the presence of three rare microalgae—*Phacus circulatus* Pochmann, *Klebsormidium crenulatum* (Kützing) Lokhorst, and *Closterium ehrenbergii* Meneghini ex Ralfs—as taxonomically new records in the Philippines. This floristic survey enriches our understanding of algal diversity in phytotelmata of bromeliads and contributes valuable taxonomic and distributional data on microalgae associated with terrestrial plants in the Philippines.

Key words: Bromeliad, cyanobacteria, microalgae, microhabitat, Philippines

INTRODUCTION

Bromeliad tanks or phytotelmata are water bodies confined by terrestrial plants in structures such as modified leaves, trunk cavities, leaf axils, flowers, and tree holes (Paul *et al.*, 2025; Vecchi, 2025; Tamang *et al.*, 2024; Arguelles, 2021 a, b; Ramos & Moura, 2019; Wittman, 2000). These microhabitats provide ecological niches supporting communities of bacteria, fungi, insects, and microalgae. Recent studies suggest that microalgae interact within phytotelmata by contributing to nutrient cycles and supporting a diverse community of organisms. They produce oxygen through photosynthesis and release organic compounds that serve as food for bacteria, fungi, and insects. These interactions form a complex web of dependencies, enhancing the biodiversity and ecological stability of the microcosm. In addition, microalgae produce essential substances such as oxygen, nutrients, and polysaccharides, which benefit other organisms and the host bromeliad plant (Arguelles, 2025a, b; Paul *et al.*, 2025; Filho *et al.*, 2023; Brouard *et al.*, 2011).

Despite the potential of phytotelmata to support microalgal growth and proliferation, research on their taxonomy and diversity remains limited (Vecchi, 2025; Arguelles 2021a, b; Arguelles, 2020a; Poniewozik *et al.*, 2020; Ramos *et al.*, 2018). In Western countries, records of phytotelm microalgae from various bromeliad tanks and pitchers have

been documented in French Guiana, Brazil and Germany (Ramos & Moura, 2019; Gebühr *et al.*, 2006; Carrias *et al.*, 2004; Sophia *et al.*, 2004). In Asia, taxonomic studies of phytotelmata microalgae have been restricted to a few studies in Thailand and the Philippines (Arguelles, 2023; Arguelles, 2021a, b; Arguelles, 2020; Poniewozik *et al.*, 2020). These surveys documented 185 algal taxa across nine major taxonomic groups, with new records and rare species being identified in the process. Specifically, the Philippine taxonomic survey documented an additional 35 species as new entry records of phytotelm microalgae in the global registry list (Vecchi, 2025; Arguelles, 2023; Arguelles, 2021a, b; Arguelles, 2020). Moreover, 43 new taxa were identified as additional records of microalgae in aquatic microcosms in Asia. Notably, rare species such as *Lepocinclis marssonii*, *Phacus monilatus*, *Cosmarium impressulum*, *Monoraphidium lunare*, *Staurastrum avicula* var. *lunatum*, *Dictyochloropsis splendida*, *Cosmarium garrolense*, and *Crucigeniella crucifera* were newly recorded in the Philippines (Arguelles, 2023; Arguelles, 2021a, b; Arguelles, 2020).

Billbergia pyramidalis (Sims) Lindley is a perennial bromeliad that forms clumps of leaves, produces thick, red or pink brush-like flowers and can grow both terrestrially and epiphytically. Its green, strap-like, leathery leaves form jar-shaped rosettes that collect water, organic debris, and insects, providing extra nutrients in support of microorganisms such as

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microalgae. Such environment underscores the potential existence of diverse microalgal diversity within phytotelmata of this plant, revealing the potential existence of both endemic and rare strains that warrant further comprehensive floristic investigation (Paul *et al.*, 2025; Vecchi, 2025; Tamang *et al.*, 2024). Therefore, the objective of this study is to expand the current understanding of microalgal diversity in the phytotelmata of *B. pyramidalis* found in semi-natural environments found in the Philippines, specifically the gardens of florist wholesalers. By documenting and analyzing these communities, the study aims to provide valuable insights into the distribution and ecological roles of microalgae in these unique habitats, thereby contributing to the broader knowledge of microalgal biodiversity in phytotelmata.

MATERIALS AND METHODS

Collection of Sample from Aquatic Microcosms

The field data sampling and collection took place in randomly selected phytotelmata of *Billbergia pyramidalis* from two different florist wholesalers in Laguna, Philippines: Sardo's Garden in Calamba (14° 10' 35.76" N, 121° 11' 47.76" E); and Adela's Garden in Los Baños (14° 10' 34.14" N, 121° 14' 37.58" E) (Figure 1). From each site, 15 aquatic microcosm samples were gathered, totalling 30 samples across the two locations. Water samples were extracted using a sterile 50-mL syringe equipped with a sterile plastic hose. Each phytotelma was sampled three times to ensure a comprehensive collection of algal specimens (Arguelles, 2021a, b; Arguelles, 2020). The biological samples, ranging from 10 to 15 mL, were placed in sterile Tarson conical tubes, kept cool in a cooler, and promptly transported for detailed microscopic analysis in the laboratory. In the laboratory, aliquots from the collected water samples were used to prepare the specimens. Additionally, a 3-mL portion of each sample was preserved with 4% formaldehyde. These specimens were observed under a microscope (Olympus CX31) fitted with a digital camera (Infinity X) at 1000x magnification (Arguelles, 2023; Arguelles, 2020; Arguelles, 2021a, b). Whenever possible, microalgae were observed and identified in their living state. For diatom analysis, a portion of the preserved samples was chemically digested using the standard diatom cleaning protocol developed by Round *et al.* (1990).

Identification and Species Abundance

Microalgae were identified to the lowest practical taxonomic unit using all accessible taxonomic monographs, literature, and other sources (Whitton, 2002; Wehr & Sheath, 2003; Zafaralla, 1998; Prescott, 1962; Desikachary, 1959). The identification process considered various morphological features, including the color and characteristics of sheaths and cellular envelopes, the shape and size of vegetative cells, trichome characteristics, cellular filaments, the absence or presence of cellular constrictions and sheaths, and the number of cells in a coenobium (Arguelles, 2023). The specimens and prepared diatom slides, which serve as voucher specimens, are stored at PNCM, BIOTECH-UPLB, College, Laguna, Philippines. Taxonomic references used for classification and identification of all observed microalgal species are listed under the taxonomic description of each algal taxon. Additionally, the currently accepted taxon names based on the database AlgaeBase (Guiry & Guiry, 2024) are utilized in this study. The species abundance of each microalgal taxon was assessed based on the number of occurrences on each slide, following the five-degree scale established by Wołowski (1998):

- 4: The algal species formed a bloom on the water's surface of the prepared specimen, making it visible to the naked eye (in masses).
- 3: The algal species were present on every prepared slide and visible in every microscopic field (very frequent).
- 2: The algal species appeared on every slide, but not in every observable microscopic field (frequent).
- 1: The algal species were observed as up to 6 specimens on nearly every prepared slide (sparse).
- +: The algal species were seen as a single specimen on at least one prepared slide.

RESULTS AND DISCUSSION

A total of 16 species of microalgae were morphotaxonomically identified and described from the water samples collected in aquatic microcosms of *Billbergia pyramidalis* in the gardens of floral wholesalers in Laguna. Among these, four species each were classified under Bacillariophyceae, and three species under Chlorophyceae, two species each under Zygnematomyceae,

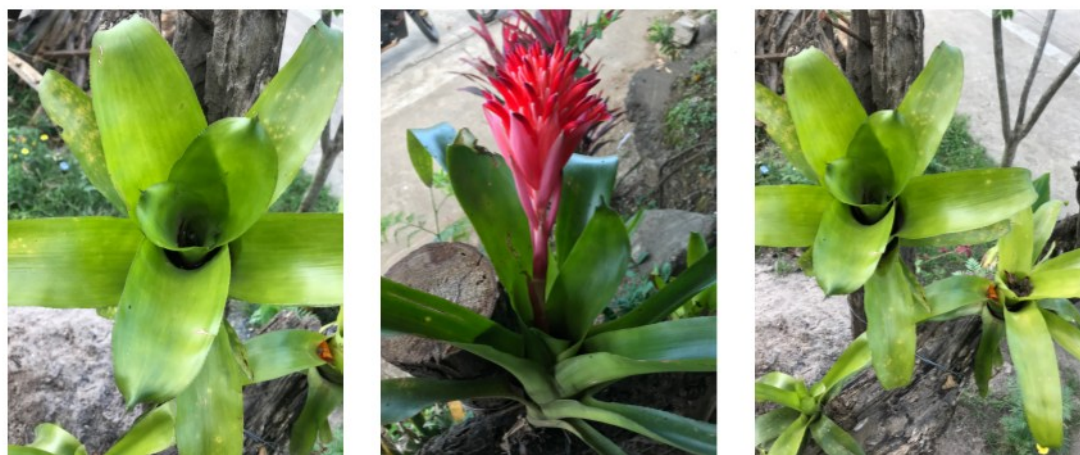


Figure 1. Phytotelmata of the ornamental bromeliad, *Billbergia pyramidalis* (Sims) Lindley from gardens of floral wholesalers in Laguna, Philippines.

Table 1. Occurrence of microalgae within phytotelmata of *B. pyramidalis* from two florists wholesalers in Laguna, Philippines.

Microalgae	Sardo's Garden (Calamba) Site 1		Adela's Garden (Los Baños) Site 2	
	February 12	July 4	February 12	July 4
<i>Phacus circulatus</i>	+	+	+	-
<i>Ceratium hirundinella</i>	+	+	+	1
<i>Cocconeis placentula</i>	1	1	1	2
<i>Nitzschia palea</i>	3	2	3	3
<i>Nitzschia fruticosa</i>	2	1	+	+
<i>Klebsormidium crenulatum</i>	4	1	1	+
<i>Closterium moniliferum</i>	+	+	-	-
<i>Closterium ehrenbergii</i>	+	+	+	+
<i>Desmococcus olivaceum</i>	-	-	+	+
<i>Tetradesmus bernardii</i>	+	+	1	2
<i>Scenedesmus quadricauda</i>	3	3	2	3
<i>Scenedesmus tibiscensis</i>	+	+	+	+
<i>Cyanothece aeruginosa</i>	1	2	+	+
<i>Oscillatoria crassa</i>	1	2	2	3
<i>Chlorella sp.</i>	2	3	3	3
<i>Cymbella sp.</i>	2	2	2	3

(-) – Absent; (+) — algal species were seen as a single specimen on at least one prepared slide; (1) — sparse; (2) — frequent; (3) — Very frequent; (4) – in masses.

*Sampling dates: 12 February, 2021 and 4 July, 2021

Trebouxiophyceae, and Cyanophyceae, and one species under Euglenophyceae, Dinophyceae, and Klebsormidiophyceae. This survey encompasses 13 orders, 13 families, 14 genera, and 16 species according to the current microalgal taxonomic classification system. This diversity highlights the range of microalgal taxa present in these aquatic microcosms.

Dichotomous Key

- 1. Cells with a defined nucleus and membrane-bound organelles 2
- 1. Cells lack a defined nucleus, with pigments scattered around the cell's periphery ... 12
- 2. Cells characterized with proteinaceous pellicle *Phacus circulatus*
- 2. Cells characterized without proteinaceous pellicle 3
- 3. Cells characterized with a red eyespot *Ceratium hirundinella*
- 3. Cells characterized without a red eyespot 4
- 4. Cells have cell walls made of silica 5
- 4. Cells have cell walls not made of silica 8
- 5. Cells are elongated, cymbelloid or linear -lanceolate 6
- 5. Cells are linear-elliptic and flat *Cocconeis placentula*

- 6. Valves are elongated and cymbelloid *Cymbella sp.*
- 6. Valves are elongated and linear -lanceolate 7
- 7. Valves are lanceolate in shape with broadly rounded rostrate apices ... *Nitzschia palea*
- 7. Valves are lanceolate and form rosette-like cluster (of cells) *Nitzschia fruticosa*
- 8. Filamentous and susceptible to fragmentation *Klebsormidium crenulatum*
- 8. Unicellular occurring as either solitary or in coenobium 9
- 9. Cells are lunate and solitary 10
- 9. Cells are coccoid and ellipsoidal and may occur as solitary or colonial 11
- 10. The chloroplast have axial rows of pyrenoids *Closterium moniliferum*
- 10. The chloroplast has longitudinal ridges and several scattered pyrenoids..... *Closterium ehrenbergii*
- 11. Cells are solitary and coccoid *Chlorella sp.*
- 11. Cells aggregate to form colonies or coenobium consisting of two or more cells .. 12
- 12. Cells form sarcinoid colonies consisting of coccoid cells ... *Desmococcus olivaceum*
- 12. Cells are fusiform or cylindrical and form colonies consisting of 2-8 cells 13

13. Cells are crescent-shaped
 *Tetradasmus bernardii*
 13. Compact elongated and cylindrical in shape
 14
14. Cells arranged linearly with terminal cells having
 spines... *Scenedesmus quadricauda*
 14. Cells arranged linearly with terminal cells without
 spine..... *Scenedesmus tibiscensis*
15. Cells may form solitary filaments or in groups of
 trichomes ... *Oscillatoria crassa*
 15. Unicellular, oval, cylindrical, or spherical in shape
 *Cyanothece aeruginosa*

Phylum: EUGLENOPHYTA**Class: Euglenophyceae****Order: Euglenida****Family: Phacaceae****Genus: Phacus Dujardin****1. Phacus circulator Pochmann****Fig. 2a**

Synonym: *Phacus platalea* Drezepolski,
Phacus orbicularis K.Hübner

The cell exhibits a flat, leaf-like morphology with a firm, longitudinally striped pellicle, maintaining a consistent body shape. It typically features small discoid chloroplasts, usually lacking pyrenoids. Cells are ovoid, approximately $52 \pm 3.6 \mu\text{m}$ long and $38 \pm 3.2 \mu\text{m}$ wide, with a broadly rounded posterior end and a short, $10 \mu\text{m}$ long tail-piece. The anterior end is slightly narrower and rounded, typically hosting 1 to 2 paramylon bodies.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

A new record for the Philippines

Reference: Kouassi *et al.*, 2013, Turkish Journal of Botany, 129p., Fig. 2g and 2h.

Phylum: CHAROPHYTA**Class: Zygnematophyceae****Order: Desmiales****Family: Closteriaceae****Genus: Closterium Corda ex Ralfs****1. Closterium moniliferum (Bory) Ehrenberg ex Ralfs****Fig. 2b**

Cells are unicellular and lunate in shape, featuring broad, rounded apices. Each cell is longer than it is wide, measuring between $214.0\text{--}227.0 \mu\text{m}$ long and $29.0\text{--}42.0 \mu\text{m}$ wide. The ventral side is curved or inflated. The chloroplast contains axial rows of pyrenoids and distinct terminal vacuoles with several granules.

Specimen: LUZON, Laguna, Calamba, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

References: Arguelles 2023, Philippine Journal of Science Pl. II, Fig. 8; Lippert 1967, Journal of Phycology, 183p., Fig. 1.

Class: Zygnematophyceae**Order: Desmiales****Family: Closteriaceae****Genus: Closterium Corda ex Ralfs****1. Closterium ehrenbergii Meneghini ex Ralfs****Fig. 2c**

Cells are sturdy and slightly curved, being 5 to 6 times longer than their width. They show a curvature of $130\text{--}140$ degrees. The ventral side is concave and inflated in the middle portion, while the dorsal side is convex. The cells gradually narrow to bluntly rounded ends. The cell wall is smooth and devoid of girdle bands. The chloroplast has 3 to 7 longitudinal ridges and numerous scattered pyrenoids. The cells range in length from $385.0\text{--}465.0 \mu\text{m}$ and have a width of $61\text{--}72 \mu\text{m}$.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

A new record for the Philippines.

Reference: Yasmin *et al.*, 2011, International Journal of Botany, 155p., Fig. 2h; Zongo *et al.*, 2011, Cryptogamie Algologie, 261p., Fig. 8.

Phylum: CHAROPHYTA**Class: Klebsormidiophyceae****Order: Klebsormidiales****Family: Klebsormidiaceae****Genus: Klebsormidium P.C. Silva, Mattox & W.H.****Blackwell****1. Klebsormidium crenulatum (Kützing)****Lokhorst****Fig. 2d**

Basionym: *Hormidium crenulatum* Kützing

The filaments are long, robust, and thick, measuring between 10.1 to $11.3 \mu\text{m}$ in width and 6.3 to $15.5 \mu\text{m}$ in length. They sometimes grow in rope-like aggregates. The cells within these filaments are cylindrical, becoming barrel-shaped and subquadrate as the filaments age. The cells are typically 0.5 to 1 (occasionally up to 1.5) times as long as they are wide. The cell wall is thin (young stage) but becomes corrugated and thick as the filaments mature. The chloroplast is girdle-shaped, nearly forming a ring, and occupies most of the inner cell surface. The margins (longitudinal) of the chloroplast are either smooth or slightly lobed. There is a large pyrenoid present, surrounded by multiple layers of starch grains.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

A new record for the Philippines

Reference: Mikhailyuk *et al.*, 2015, Journal of Phycology, 755p., Fig. 2k-n

Phylum: CHLOROPHYTA**Class: Chlorophyceae****Order: Sphaeropleales****Family: Scenedesmaceae****Genus: Tetradasmus G.M. Smith****1. Tetradasmus bernardii (G.M. Smith) M. J. Wynne****Fig. 2e**

Basionym: *Scenedesmus bernardii* G.M. Smith

Colonies consist of four cells, arranged in a distinct linear pattern. The outer cells are crescent-shaped, while the inner cells are fusiform with acute

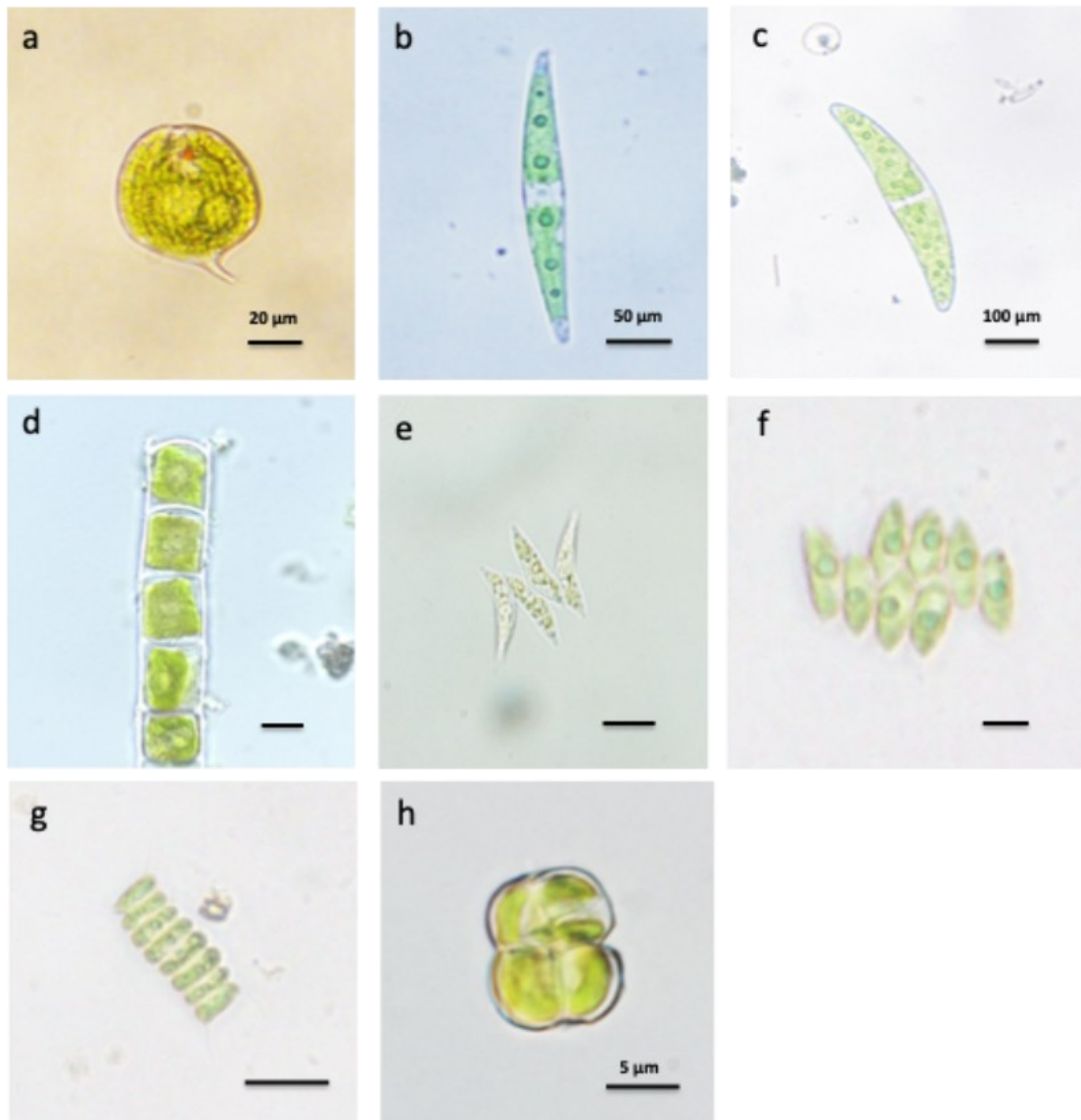


Figure 2. Photomicrographs of (a) *Phacus circulatus* Pochmann, (b) *Closterium moniliferum* (Bory) Ehrenberg ex Ralfs, (c) *Closterium ehrenbergii* Meneghini ex Ralfs, (d) *Klebsormidium crenulatum* (Kützing) Lokhorst, (e) *Tetradesmus bernardii* (G.M. Smith) M. J. Wynne, (f) *Scenedesmus tibiscensis* Uherkovich, (g) *Scenedesmus quadricauda* (Turpin) Brébisson, and (h) *Desmococcus olivaceus* (Persoon ex Archerson) J. R. Laundon. All

ends. The median portion of the outer cells is attached to the end portion of the inner cells, forming a cohesive structure. The inner cells are connected in the middle, creating a central axis within the colony. Notably, these cells lack spines, contributing to their smooth appearance. Each cell measures approximately 13.5-15.5 µm long and 2.8 – 4.2 µm wide.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

References: Aghashariatmadary *et al.*, 2017, Rostaniha, 173p., Fig. 2a; Desingurajan *et al.*, 2021, International Research Journal of Plant Science, 259p., Pl. 2., Fig. 18.

Class: Chlorophyceae
 Order: Sphaeropleales
 Family: Scenedesmaceae
Genus: *Scenedesmus* Meyen

1. *Scenedesmus tibiscensis* Uherkovich Fig. 2f

Cells are closely appressed, with adjacent cells often slightly overlapping. They are elongated, cylindrical to slightly fusiform, with rounded ends. Cell dimensions typically range from 11.5-19.7 µm long and 1.9-4.6 µm wide. The cell walls are smooth and lack spines or other surface ornamentations. Cell have one parietal chloroplast, which is usually plate-like and occupies a large portion of the cell's interior, and possess pyrenoids.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

References: Maraşlıoğlu *et al.*, 2022, Turkish Journal of Fisheries and Aquatic Sciences, 173p., Fig. 2a; Desingurajan *et al.*, 2021, International Research Journal of Plant Science, 259p., Fig. 22e.

Class: Chlorophyceae
 Order: Sphaeropleales
 Family: Scenedesmaceae
Genus: *Scenedesmus* Meyen

1. *Scenedesmus quadricauda* (Turpin) Brébisson**Fig. 2g**Basionym: *Achnanthes quadricauda* Turpin

Colonies are compact and composed of 4 to 8 cells aligned linearly in a single row. These cells are spherical to elliptical, measuring between 4.5 - 5.9 μm long and 2.8 - 4.2 μm wide. Each cell contains visible chloroplasts containing a pyrenoid. The cells are aligned (parallel) with the setae. Inner cells lack spines, whereas terminal cells have two visible spiny projections.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

References: Prescott, 1962, *Algae of the Western Great Lakes Area*, 280, pl. 64, fig. 2; Pantastico, 1977, *Taxonomy of the Freshwater Algae of Laguna de Bay and Vicinity*, 119, pl. IX, fig 8; Zafaralla, *Microalgae of Taal Lake*, 39, pl. 9g.j, 1988

Phylum: CHLOROPHYTA

Class: Trebouxiophyceae

Order: Prasiolales

Family: Prasiolaceae

Genus: *Desmococcus* F. Brand**1. *Desmococcus olivaceus* (Persoon ex Archerson) J. R. Laundon Fig. 2h**Basionym: *Lepraria olivacea* Persoon ex Archerson

Cells aggregate to form colonies consisting of 2 -4 cells (sarcinoid colonies). These colonies typically range in diameter from 4.0 to 8.5 μm . The individual cells within these colonies are coccoidal in shape (can be spherical or hemispherical), with a diameter of 2.0 to 3.9 μm . Cells have a parietal chloroplast positioned along the cell wall. The chloroplast typically have a single pyrenoid, though in some instances, this pyrenoid may not be distinguishable.

Specimen: LUZON, Laguna, Los Baños, E.DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

References: Arguelles, 2019a, *Journal of Microbiology, Biotechnology, and Food Sciences*, 5 p., Fig. 12; Rindi & Guiry, 2003, *Cryptogamie, Algologie*, 259p., Fig. 25.

Class: Trebouxiophyceae

Order: Chlorellales

Family: Chlorellaceae

Genus: *Chlorella* Beyerinck [Beijerinck]**1. *Chlorella* sp.****Fig. 3a**

Each cell is solitary and ranges from ellipsoidal to spherical in shape, with a diameter of 1.5 to 3.5 μm . Inside each cell, cup-shaped chloroplast is present that occupies a significant portion of the cell's interior. Cells produce autospores during reproduction and are released through the rupture of the parent cell wall.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

References: Arguelles 2025c, *Recoletos Multidisciplinary Research Journal*, 159p., Fig. 4B; Arguelles 2021b, *Tropical Natural History*, 176p., Fig. 5B; Arguelles 2019b, *Pertanika Journal of Tropical Agricultural Science*, 819p., Fig. 1a; Arguelles & Monsalud 2017, *Philippine Journal of Systematic Biology*, 31p., Pl. II Fig. 4; Prescott 1962, *Algae of the Western Great Lakes Area*, 237p., pl. 53, Fig. 13

Phylum: BACILLARIOPHYTA

Class: Bacillariophyceae

Order: Cymbellales

Family: Cymbellaceae

Genus: *Cymbella* C. Agardh**1. *Cymbella* sp.****Fig. 3b**

Valves are cymbelloid in shape, measuring between 5.9 to 7.9 μm wide and 22.5 to 35.9 μm long. The valve structure is characterized by a concave margin on the dorsal side, which curves inward, and a convex margin on the ventral portion, which curves outward. The valves have rounded ends, contributing to the overall smooth and streamlined appearance of the diatom.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

Reference: Kociolek & Spaulding 2003, *Eunotioid and Asymmetrical Naviculoid Diatoms*, In: *Freshwater Algae of North America: Ecology and Classification*, 655p., Figs. 2a-c.

Class: Bacillariophyceae

Order: Bacillariales

Family: Bacillariaceae

Genus: *Nitzschia* Hassall***Nitzschia palea* (Kützing) W. Smith****Fig. 3c**Basionym: *Synedra palea* Kützing

The valves are linear with capitated apices. The costae measure between 9.0 and 13.5 μm . The valve mantle is wider on the keel side and measures 25.5-33.7 μm in length and 2.9-6.1 μm in width. The fibulae, which include nodules, are discrete, with slightly visible striae.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

References: Arguelles 2025a, *Journal of Tropical Life Science*, 231p., Fig. 3.3; Arguelles 2021c, *Philippine Journal of Science*, 839p., Pl. II, Fig. 4; Arguelles & Monsalud 2021, *Journal of Microbiology, Biotechnology and Food Sciences*, 5p., Pl. I, Fig. 5.

Class: Bacillariophyceae

Order: Bacillariales

Family: Bacillariaceae

Genus: *Nitzschia* Hassall

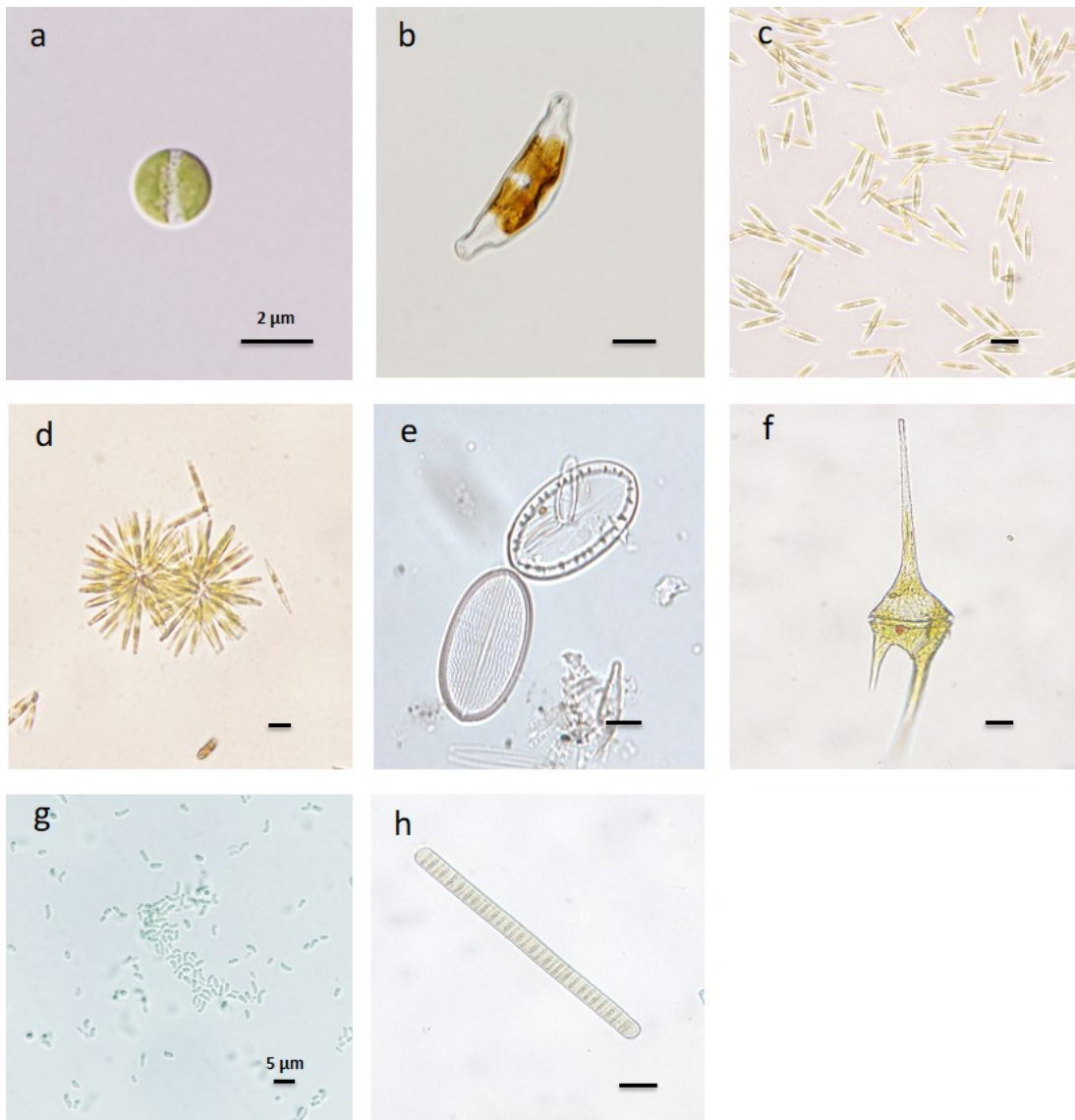


Figure 3. Photomicrographs of (a) *Chlorella* sp., (b) *Cymbella* sp., (c) *Nitzschia palea* (Kützing) W. Smith, (d) *Nitzschia fruticosa* Hustedt, (e) *Cocconeis placentula* Ehrenberg, (f) *Ceratium hirundinella* (O.F.Müller) Dujardin, (g) *Cyanothece aeruginosa* (Nägeli) Komárek, and (h) *Oscillatoria crassa* (C.B. Rao) Anagnostidis. All scale bars = 10 µm.

***Nitzschia fruticosa* Hustedt**

Fig. 3d

Cells are radially bundled with one end attached, forming loose rosette-like clusters, most commonly seven cells forming a single cluster. The valve surface is linear, and the edges are parallel to each other, and the distal end of the valve surface is short wedge-shaped or slightly cap-shaped with a rounded end. The valve length is 42-83 µm and the width is 2.0-2.5 µm.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

Reference: Faustino *et al.*, 2016, *Biota Neotropica*, 18p., Figs. 157-158.

Phylum: BACILLARIOPHYTA

Class: Bacillariophyceae

Order: Achnanthales

Family: Cocconeidaceae

Genus: ***Cocconeis* Ehrenberg**

1. *Cocconeis placentula* Ehrenberg

Fig. 2e

Frustules exhibit heterovalvar symmetry. Valves are elliptical to linear-elliptical, relatively flat, measuring between 11.0 - 61.0 µm long and 9.7 - 25.0 µm wide. The raphe valve displays a confined axial region and an oval or circular central area. The raphe itself is thread-like and straight. Striae are radiating from the center and are intersected by a clear ring (hyaline) near the valve edge. There are 16-24 areolae per 10 µm along each stria. The rapheless valve features a radiate striae and linear-lanceolate to linear axial area.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

Reference: Jahn *et al.*, 2009, *Fottea* 283p., Figs. 28-36.

Phylum: DINOFLAGELLATA

Class: Dinophyceae

Order: Gonyaulacales

Family: Ceratiaceae

Genus: ***Ceratium* F. Schrank**

Ceratium hirundinella* (O.F.Müller) Dujardin*Fig. 2f**

Basionym: *Bursaria hirundinella* O.F.Müller

Cells are golden brown, large, and typically exhibit a fusiform or spindle-like shape with long anterior horn and 3 or 2 pointed, extended horns. Each posterior horn is composed of 1 or 2 elongated thecal plates, while the anterior horn is formed by elongations of the four apical plates. The length of the cell, including the horns, ranges from 180 to 310 µm. Chloroplasts are numerous and small, disc-shaped, distributed throughout the cell.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen.

References: Varol, 2016, Turkish Journal of Botany, 116p., Fig. 4a-f; Dodge & Crawford, 1970, Journal of Phycology, 141p., Fig. 1.

Phylum: CYANOBACTERIA

Class Cyanophyceae

Order: Gomontiellales

Family: Cyanothecaceae

Genus: *Cyanothece* Komárek**1. *Cyanothece aeruginosa* (Nägeli) Komárek****Fig. 2g**

Basionym: *Synechococcus aeruginosus* Nägeli

Cells are unicellular, lack a sheath and are blue-green in color. They are spherical or oval-shaped. Cells measure between 4.0 and 8.0 µm long and 0.4 to 1.1 µm wide, occasionally forming groups without mucilage.

Specimen: LUZON, Laguna, Calamba and Los Baños, E. DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

Reference: Dvořák *et al.*, 2015, Biodiversity and Conservation, 741p., Fig. 1c.

Class Cyanophyceae

Order: Oscillatoriales

Family: Oscillatoriaceae

Genus: *Oscillatoria* Vaucher ex Gomont**1. *Oscillatoria crassa* (C.B. Rao)****Anagnostidis Fig. 3h**

Basionym: *Oscillatoria ornata* var. *crassa* C.B.

Rao

Trichomes are either solitary or found in clusters, slightly bent or straight ends, and cross-walls are constricted. They do not taper at the end poles and are 10.5-16.9 µm wide. The cells are brownish to bluish-green, usually 4-6 times wider than they are long, measuring 2.5-3.5 µm long. The apical end cells are flat-rounded. The apical cells of the trichomes are generally rounded or bluntly conical, not capitate (absence of calyptra); heterocytes and akinetes are not present.

Specimen: LUZON, Laguna, Calamba and Los Baños, E.DLR. Arguelles *s.n.* Photomicrograph prepared from the mounted specimen.

References: Kant, *et al.*, 2021, Plant Archives, 256p., Fig. 3M; Wui & Kim, 1987, The Korean Journal of Phycology, 198p., Fig. 5.

Phytotelmata are temporary and miniature aquatic ecosystems that provide a unique environment conducive to the growth of rare and novel microalgal species. However, only few studies were documented

in these habitats and, to date, no floristic survey of microalgal flora in phytotelmata of *Billbergia pyramidalis* found in the Philippines have been published (Paul *et al.*, 2025; Vecchi, 2025; Arguelles, 2023; Zafaralla 1998; Pantastico, 1977). This study documents the first taxonomic survey of microalgal species inhabiting the phytotelmata of *B. pyramidalis* found in gardens of florist wholesalers in the Philippines. Overall, 16 species were taxonomically described, including four species classified under Bacillariophyceae, three under Chlorophyceae, two species each under Zygnematophyceae, Trebouxiophyceae, and Cyanophyceae, and one species each under Euglenophyceae, Dinophyceae, and Klebsormidiophyceae. This survey encompasses 13 orders, 13 families, 14 genera, and 16 species according to the current microalgal taxonomic classification system. The documented microalgal taxa in this survey are reported for the first time in this unique aquatic habitat, marking new distributional records for the Philippines. Generally, a limited number of microalgal taxa were identified and documented at each sampling site, which may be attributed to the small habitat size. Based on the frequency of occurrence determined using the five-degree scale by Wołoski (1998), *Scenedesmus quadricauda*, *Chlorella* sp., and *Nitzschia palea* were the most frequently occurring algal groups in all collected samples (Table 1). These taxa are well-documented and widespread, commonly found in the phytotelmata of other bromeliads such as *Guzmania lingulata*, *Neoregelia carolinae*, *Neoregelia cruenta*, *Neoregelia compacta*, *Sarracenia purpurea*, *Collospermum hastatum*, *Freycinetia banksii*, and *Astelia solandri* (Paul *et al.*, 2025; Vecchi, 2025; Arguelles, 2025a, b, c; Tamang *et al.*, 2024; Arguelles, 2023; Arguelles, 2021a; Poniewozik *et al.*, 2020; Killick *et al.*, 2014; Gebühr *et al.*, 2006). This suggests that these microalgal groups may be considered original and consistent inhabitants of the phytotelmata of bromeliads, notable for their broad habitat tolerance. The survey also identifies an additional ten species (*Phacus circulatus*, *Cocconeis placentula*, *Nitzschia fruticosa*, *Klebsormidium crenulatum*, *Closterium ehrenbergii*, *Desmococcus olivaceus*, *Tetradesmus bernardii*, *Scenedesmus tibiscensis*, *Oscillatoria crassa*, and *Cyanothece aeruginosa*) as new records in the global registry of microalgae discovered in the phytotelmata of bromeliads (Ramos & Moura, 2019). Furthermore, the study documents the presence of three rare microalgae—*Phacus circulatus* Pochmann, *Klebsormidium crenulatum* (Kützing) Lokhorst, and *Closterium ehrenbergii* Meneghini ex Ralfs—as taxonomically new records in the Philippines.

The number of microalgal taxa identified and described in this survey is comparable to the previous taxonomic survey conducted by Van Oye (1923) on the phytotelmata of *Billbergia pallidiflora*, which also documented 16 microalgal taxa. In this study, only one genus, *Closterium*, was found to be common in both *Billbergia* species. Euglenoids were the dominant algal species in *B. pallidiflora*, whereas diatoms predominated in *B. pyramidalis* (this study). Of the microalgae identified in this study, only six species (*Ceratium hirundinella*, *Scenedesmus quadricauda*, *Closterium moniliferum*, *Nitzschia palea*, *Chlorella* sp., and *Cymbella* sp.) were previously observed in other studies (Ramos *et al.*, 2018; Arguelles 2021a, b; Arguelles 2020a; Ramos and Moura, 2019; Carrias *et al.*, 2004; Sophia *et al.*, 2004). Earlier research highlighted diatoms, green microalgae,

and cyanobacteria as the predominant classes of algae in phytotelmata, consistent with the findings of this study (Arguelles, 2023; Ramos & Moura, 2019; Gebühr *et al.*, 2006; Carrias *et al.*, 2004). Additionally, several microalgal species documented in the current survey were not reported in previous taxonomic surveys, underscoring the unique diversity of microalgal flora in the phytotelmata of bromeliads in the Philippines. The diversity and richness of microalgae in *B. pyramidalis* are likely linked to the morphology of bromeliad tank, which features extensively exposed pools of warm water. This structure is highly susceptible to microalgae introduced by living organisms like invertebrates and insects, as well as other factors such as air and rain (Arguelles, 2025a, b, c; Arguelles, 2021a; Poniewozik *et al.*, 2020). However, in semi-natural environments (such as gardens of florist wholesalers), these factors are considered less significant. It is probable that human activities, such as people visiting gardens and greenhouses, are the primary means of dispersing microalgae in these bromeliads. Several studies have shown that people unintentionally contribute to algal dispersal in these settings (Arguelles, 2021a; Arguelles, 2021a; Poniewozik *et al.*, 2020). These potential carriers can transport airborne cells and dormant spores on their clothing, which may be transferred to the phytotelmata of *B. pyramidalis* when they visit gardens and greenhouses (Paul *et al.*, 2025; Vecchi, 2025; Tamang *et al.*, 2024; Arguelles, 2021a; Poniewozik *et al.*, 2020).

CONCLUSION

Phytotelmata are aquatic ecosystems that supports the growth of rare and novel microalgal species. This taxonomic study represents the first taxonomic survey of microalgal species inhabiting the phytotelmata of *Billbergia pyramidalis* (Sims) Lindley. In total, 16 species were taxonomically described and reported for the first time in this unique aquatic habitat, marking new distributional records in the global registry of microalgae discovered in the phytotelmata of bromeliads. To date, there are limited microalgal floristic study on phytotelmata of bromeliads in the world. The algal records from this survey are thus a significant contribution to the growing body of knowledge on the diversity of microalgae in this unique habitat. It is crucial to highlight that our understanding of the diversity of microalgae in small aquatic ecosystems such as phytotelmata remains limited. Therefore, further taxonomic surveys and ecological studies are necessary and should be prioritized in future research. Additionally, it is recommended that microbial diversity analyses using next generation sequencing (such as metabarcoding and metagenomics) be conducted to better understand the ecological interactions and microbial succession within this unique habitat.

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