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Morphotaxonomic Study of Algal Epiphytes from *Ipomoea aquatica* Forssk. (Convolvulaceae) found in Laguna de Bay (Philippines)

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ABSTRACT

Epiphytic algae existing on submerged leaves, stems and roots of *Ipomoea aquatica* Forssk. (Convolvulaceae) found in Laguna de Bay was studied. Examination of the prepared specimen showed a total of 15 infrageneric taxa belonging to 10 orders, 13 families, 15 genera and 15 species were identified during the study period. Of these taxa, the occurrence of a rare photosynthetic euglenoid, *Cryptoglena skujae* Marin and Melkonian is reported as new record for the Philippines. Two species are also presented here based on current accepted taxonomic names and these are *Limnococcus limneticus* (Lemmermann) Komárková, Jezberová, O.Komárek & Zapomelová, and *Anabaenopsis circularis* (G. S. West) Woloszynska & V. Miller in V. Miller. The algal taxonomic records reported in this survey expand the knowledge regarding diversity and distribution of epiphytic algae from aquatic macrophytes found in Philippine freshwater environment.

Keywords: Epiphytic algae, Laguna de bay, macrophyte, morphotaxonomy, water spinach

INTRODUCTION

Ipomoea aquatica Forsk. (water spinach) is an edible aquatic macrophyte characterized by having a long, hollow stem (allowing a large number of air passages) with rooting at the nodes growing floating or prostrate in surface water or marshy ground (Baysa et al., 2006; Nagendra et al., 2008). This aquatic macrophyte is capable of forming tightly-packed masses of entangled vegetation, consequently forming thick layer above the water surface causing restriction in light distribution into the body of water. It is widely distributed geographically in tropical countries and is being planted and raised

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abundantly in Myanmar, Philippines, India, China, Bangladesh, Thailand, Indonesia and Vietnam, (Mandal et al., 2008; Naskar, 1990). Macrophytes (such as *Ipomoea aquatica*) play a crucial role in preserving and enhancing the water quality of a lake. These aquatic plants have a huge capability of assimilating nutrients and other harmful substances from a water system and thus lowering the content of pollutants (Dhote, 2007). Effective withdrawal of nitrogen, carbon, biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, organic, phosphorus, heavy metals and the like from lake water were observed from aquatic macrophytes showing its potential for restoration and bioremediation of a polluted aquatic ecosystem (Dhote, 2007; Gupta, 1980).

Algal epiphytes are microalgae and cyanobacteria attached directly on aquatic macrophytes by means of secretion of jelly-like substances colonizing the leaf, roots and stem surfaces of the macrophyte and sediment surfaces (Adam et al., 2017). In addition, these microorganisms can colonize the aquatic plant and are responsible in the accumulation of large amounts of carbonate on submerged stem, leaves and roots of the macrophyte (Adam et al., 2017; Gaiser et al., 2011). Epiphytic algae play a crucial role as primary producers in lake and shallow freshwater ecosystems by acting as natural food to many grazers, zooplankton, and fish. Colonizing epiphytic microalgae and cyanobacteria are beneficial to macrophytes by reducing water movement in the aquatic ecosystem and by provision of alternative source of organic nutrients important for growth and proliferation of the aquatic plant (Adam et al., 2017). The diversity and density of algal epiphytes are influenced by several ecological factors such as water level, water temperature, location, light, seasonal change and morphology of macrophyte host as well as abundance and growth phases of host plant (Adam et al., 2017; Hassan et al., 2007).

In the Philippines, limited information is available on the distribution and diversity of epiphytic algae in submerged aquatic macrophytes (Rañola et al., 1990). Therefore, this study was conducted to do a preliminary survey and taxonomic account of some noteworthy epiphytic algae attached to submerged parts *Ipomoea aquatica* found abundantly in Laguna de Bay.

MATERIALS AND METHODS

Epiphytic Algae Sampling from Water Spinach

Samples of water spinach (*Ipomoea aquatica* Forsk.) where evident growth of epiphytic algae were observed were collected from the littoral to sublittoral zone of Laguna de Bay (14^{o} 10'- 14^{o} 35' N, 121^{o}-121^{o}30' E). Thereafter, the samples were placed in polyethylene plastic bags filled with lake water for laboratory analysis and examination. Twelve *Ipomoea aquatica* samples were analyzed during the conduct of the study. The epiphytic algae attached on the water spinach were separated following the procedure done by Zimba and Hopson (1997). Epiphytic algae observed in submerged stem, leaves and roots of water

spinach were separated by manual scraping and shaking for 30 minutes. The shaking procedure was repeated several times to make sure that the bulk of the attached organisms were separated. The samples were then filtered using 100 µm mesh sieves to separate the host aquatic plant and other large particles (Arguelles, 2019). The concentrated microalgae were then preserved using 4% neutralized formalin. The collected scraped epiphyte samples were thoroughly mixed and a 50 mL portion was kept for analysis and identification of diatoms. Scraped samples for analysis of diatom flora were digested following the protocol of Tunca et al. (2014) and Utermöhl (1958). An aliquot of treated diatom was air dried and mounted onto coverslips. The remaining water sample was transferred into a sterile graduated cylinder and allowed to settle for 24 hours. Thereafter, 45 mL of water was removed and the remaining 5 mL of water was placed into a sterile drum vial for microscopic observation (Tunca et al., 2014; Utermöhl, 1958).

Micrometry, Photomicrography and Identification

Morphotaxonomic description and identification of the epiphytic algae were done using an Olympus CX31 binocular research microscope with a built in Infinity X digital camera. The identification of microalgal species documented in this study was identified and described using the monographs and standard works of Desikachary (1959), John and Tsarenko (2011), McGregor et al. (2007), Presscott (1962), Velasquez (1962), Whitton (2011) and Wolowski (2011). Identification of the recovered epiphytic algae was done up to the species level using each of the available information. Current accepted taxonomic names of each of the alga are presented in the paper which was based on Guiry and Guiry (2018).

RESULTS AND DISCUSSION

Morphotaxonomic notes and illustrations of the algal taxa observed and identified in the samples collected in March, 2018 are presented below. A total of 15 microalgal and cyanobacterial species were identified from the studied water macrophyte, of which five species belong to Cyanophyceae, four species to Euglenophyceae, three species for Bacillariophyceae, two species for Trebouxiophyceae and one species for Chlorophyceae. References used in the identification of the various algal taxa are listed directly below the name of the relevant taxon. Also, short description of the habitat where the algae were collected is presented in the paper.

Morphotaxonomic Description of the Isolates

Chlorophyta
Class: Trebouxiophyceae
Order: Chlorellales
Family: Chlorellaceae
Genus: *Chlorella* Beyerinck [Beijerinck]

***Chlorella vulgaris* Beyerinck [Beijerinck] (Figure 1a)**

BASIONYM: *Chlorella pyrenoidosa var. duplex* (Kützing)

REFERENCES: Arguelles and Monsalud (2017); John and Tsarenko (2011); Ortega-Calvo et al. (1993); Zafaralla (1998).

DESCRIPTION: Cells are greenish, spherical and solitary with smooth and delicate cell wall; single parietal chloroplast that is cup-shaped with a single pyrenoid; diameter of the vegetative cell is 2.5 - 3.5 µm; cell proliferation through production of autospores (2 or 4) released from the mother cell.

SPECIMEN: LUZON, Laguna, Los Baños (Tadlak), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a greenish covering on leaves and stems of water spinach mixed with other planktonic algae and aquatic molds.

Class: Chlorophyceae
Order: Chlamydomonadales
Family: Chlorococcaceae
Genus: *Chlorococcum* Meneghini

***Chlorococcum infusionum* (Schrank) Meneghini (Figure 1b)**

SYNONYM: *Chlorococcum humicola* (Nägeli) Rabenhorst 1868
BASIONYM: *Lepra infusionum* Schrank

REFERENCES: Arguelles and Monsalud (2017); Kumar et al. (2012); Vijayan and Ray (2015).

DESCRIPTION: Cells are greenish in color, spherical, solitary or sometimes in groups of several cells crowded together forming a stratum; occurring either as uni- or multinucleate; chloroplast is parietal with one or more pyrenoids; cells 8.0-15.0 µm in diameter.

SPECIMEN: LUZON, Laguna, Victoria (San Benito), E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen. Observed existing as a brownish to greenish crust on stem and leaves of water spinach mixed with other diatoms and cyanobacteria.

Class: Chlorophyceae
Order: Sphaeropleales
Family: Scenedesmaceae
Genus: *Tetradesmus* G.M. Smith

***Tetradesmus obliquus* (Turpin) M. J. Wynne (Figure 1c)**

SYNONYM: *Scenedesmus obliquus* Turpin (Kützing)

BASIONYM: *Achnanthes obliqua* Turpin

REFERENCES: Bose et al., (2016); Kim (2015); Hegewald and Silva (1988).

DESCRIPTION: Colony comprised 2-4 celled, linearly arranged or in alternating cells in 1 or 2 rows, rarely to be observed in solitary cells, joined side by side with almost three-quarters of the algal cell length. Cells are usually fusiform in shape with pointed end (12.0-28.5 µm long and 6.0-9.0 µm

wide). The marginal cells are shaped like a bow (arcuate) while the inner cells are straight. Cell walls are smooth and without teeth or spines. Cells have a parietal chloroplast with a single pyrenoid.

SPECIMEN: LUZON, Laguna, Calamba (Pansol), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a brownish to greenish crust on submerged stem and leaves of water spinach mixed with other filamentous cyanobacteria.

Bacillariophyta
Class: Bacillariophyceae
Order: Cymbellales
Family: Gomphonemataceae
Genus: *Gomphonema* Ehrenberg

***Gomphonema gracile* Ehrenberg (Figure 1d)**

REFERENCES: Bartozek et al. (2013); de Souza Santos et al. (2012).

DESCRIPTION: Valves are lanceolate in shape gradually attenuating at the end portion with round apices; valves are longer than wide, length 36.9-79.5 µm, width 7.5-12.5 µm; central area is characterized by having a shortened median stria; a stigma is located at the central nodule at the end of the central stria; striae uniseriate, parallel to slightly radiate towards the ends; striae density 10.0-12.0 in 10.0 µm.

SPECIMEN: LUZON, Laguna, Bay (Sto. Domingo), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a brownish crust on submerged stem and leaves of water spinach mixed with other microalgae and cyanobacteria.

Class: Coscinodiscophyceae
Order: Aulacoseirales
Family: Aulacoseiraceae
Genus: *Aulacoseira* Thwaites

***Aulacoseira granulata* var. *angustissima* (Otto Müller) Simonsen (Figure 1e)**

BASIONYM: *Melosira granulata* var. *angustissima* Otto Müller

REFERENCES: Cavalcante et al. (2013); Joh (2017).

DESCRIPTION: Frustules are linear, cylindrical forming colonies. Valves are longer than wide, 3.5–4.5 µm in diameter with a mantle height of 7.0-18.0 µm. The mantle height to valve diameter ratio is more than 3 (high mantle). The areolae are characterized to be square to round, but frequently elongate. Spines are situated at the end of each pervalvar mantle costa.

SPECIMEN: LUZON, Laguna, Los Baños (Tadlak), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a brownish crust on stem and leaves of water spinach mixed with other filamentous cyanobacteria.

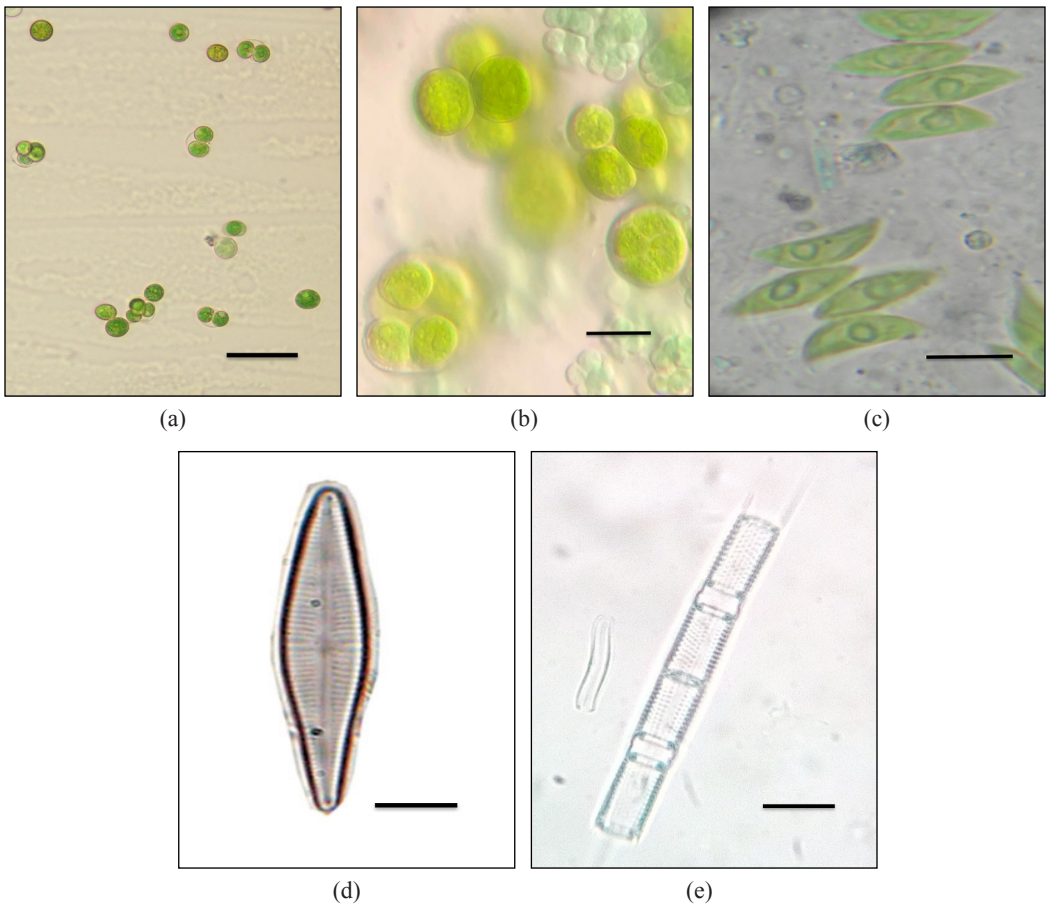


Figure 1. Photomicrographs of (a) *Chlorella vulgaris* Beyerinck [Beijerinck], (b) *Chlorococcum infusionum* (Schrank) Meneghini, (c) *Tetradesmus obliquus* (Turpin) M. J. Wynne, (d) *Gomphonema gracile* Ehrenberg, (e) *Aulacoseira granulata* var. *angustissima* (Otto Müller) Simonsen. All scale bars = 10 µm

Class: Mediophyceae
Order: Stephanodiscales
Family: Stephanodiscaceae
Genus: *Cyclotella* (Kützing) Brébisson

***Cyclotella meneghiniana* Kützing (Figure 2a)**

REFERENCES: Akbulut (2003); Costa et al. (2017); Leira et al. (2017); Marra et al. (2016).

DESCRIPTION: Cells rounded with central and marginal areas. Valves are small and disc-shaped with a narrow mantle; cells 7.0-15.0 µm in diameter and are characterized by having marginal chambered striae with flat and smooth central area covering 1/3 of the valve surface.

SPECIMEN: LUZON, Laguna, LUZON, Laguna, Victoria (San Benito), E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen. Observed existing as a brownish crust

on submerged roots of water spinach mixed with other filamentous fungi and green microalgae.

Euglenophyta
Class: Euglenophyceae
Order: Euglenales
Family: Euglenaceae
Genus: *Trachelomonas* Ehrenberg

***Trachelomonas volvocina* (Ehrenberg) Ehrenberg (Figure 2b)**

BASIONYM: *Microglena volvocina* Ehrenberg

REFERENCES: Kouassi et al. (2013); Wolowski et al. (2017).

DESCRIPTION: Lorica are globular (13.5–21.0 µm in diameter) with smooth wall; reddish- brown in color; flagellum at the anterior part of the cell without a collar and is three times longer than lorica; presence of two lateral chloroplasts with double sheathed pyrenoids.

SPECIMEN: LUZON, Laguna, Los Baños (Mayondon) E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a greenish film on submerged leaves of water spinach mixed with other green microalgae.

Class: Euglenophyceae
Order: Euglenales
Family: Phacaceae
Genus: *Lepocinclis* Perty

***Lepocinclis steinii* Lemmerman (Figure 2c)**

REFERENCES: Arguelles et al. (2014); Wolowski (2011); Wolowski et al. (2013).

DESCRIPTION: Cells are fusiform to elliptical (30.5–31.0 µm in length and 9.50– 11.0 µm in diameter) with short, pointed cauda at the posterior end with visible paramylon bodies occurring as large rings; numerous disc-shaped chloroplasts are present and pellicle is longitudinally striated.

SPECIMEN: LUZON, Laguna, Los Baños (Mayondon) E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a greenish film on submerged leaves and stems of water spinach mixed with other filamentous cyanobacteria with other planktonic algae.

Class: Euglenophyceae
Order: Euglenales
Family: Euglenaceae
Genus: *Cryptoglena* Ehrenberg

***Cryptoglena skujae* Marin & Melkonian (Figure 2d)**

SYNONYM: *Phacus agilis* Skuja

REFERENCES: Alves-Da Silva and Bicudo (2009); Araujo et al. (2012); Roy and Pal (2016); Wolowski (2011).

DESCRIPTION: Cells are small and elliptical, 13.5-21.0 µm in length, 9.0-13.0 µm in width; anterior end slightly indented in the central portion; posterior pole rounded and without caudal process; exhibit longitudinal furrow extending along the length of

the ventral surface of the cell; a single red eyespot (stigma) is observed near the anterior end of the cell; pellicle is smooth and rigid (no metaboly); presence of two chloroplasts that are lateral discs in shape; presence of two large lobed structures (paramylon bodies) are present.

A New Record for the Philippines. SPECIMEN: LUZON, Laguna, Bay (Sto. Domingo), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a greenish film on submerged leaves of water spinach mixed with other filamentous algae.

Class: Euglenophyceae
Order: Euglenales
Family: Euglenaceae
Genus: *Monomorphina* Mereschkowsky

***Monomorphina pyrum* (Ehrenberg) Mereschkowsky (Figure 2e)**

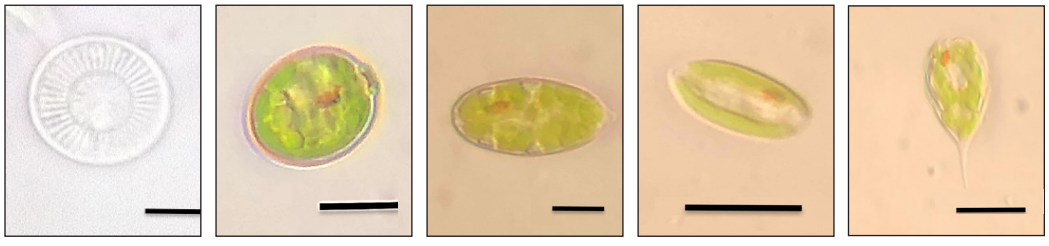
BASIONYM: *Euglena pyrum* Ehrenberg

REFERENCES: Alves-Da Silva and Bicudo (2009); Arguelles et al. (2014); Boonmee et al. (2011); Satpati and Pal (2017); Wolowski et al. (2013).

DESCRIPTION: Cells are oval-shaped (24.0–26.0 µm long and 10.5–12.0 µm wide); cells are gradually tapered at the posterior end forming a short, pointed caudus; anterior end cell is broadly rounded; pellicle is spirally striated (arranged in an S-shaped pattern) overlaying the entire cell; chloroplasts are small and numerous with two lateral paramylon bodies.

SPECIMEN: LUZON, Laguna, Bay (Sto. Domingo), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a greenish film on submerged leaves of water spinach mixed with other filamentous algae.

Cyanobacteria
Class Cyanophyceae
Order: Synechococcales
Family: Merismopediaceae



(a) (b) (c) (d) (e)

Figure 2. Photomicrographs of (a) *Cyclotella meneghiniana* Kützing, (b) *Trachelomonas volvocina* (Ehrenberg) Ehrenberg, (c) *Lepocinclis steinii* Lemmerman, (d) *Cryptoglena skujae* Marin & Melkonian, (e) *Monomorphina pyrum* (Ehrenberg) Mereschkowsky. All scale bars = 10 µm

Genus: *Limnococcus* (Komárek & Anagnostidis) Komárková, Jezberová, O. Komárek & Zapomelová

***Limnococcus limneticus* (Lemmermann) Komárková, Jezberová, O.Komárek & Zapomelová (Figure 3a)**

BASIONYM: *Chroococcus limneticus* Lemmermann

REFERENCES: Desikachary (1959); Komárková et al. (2010); Martinez (1984); McGregor (2013); McGregor et al. (2007); Prescott (1962); Whitton (2011); Zafaralla (1998).

DESCRIPTION: Colonies microscopic, free-floating, with mucilaginous slime, composed of sphaerical, subsphaerical to hemisphaerical cells. Cells are irregularly arranged, bright blue-green or sometimes appearing as greyish blue-green, with protoplast that is finely granulated, without aerotopes, 7.0-11.5 (-21.0) μm in diameter. Cell division is by three perpendicular planes in successive generations. Colonial mucilage is colorless, delicate, homogeneous, clearly delimited or diffluent at the margin, outer margin of colony usually distinct, sometimes scarcely visible, not lamellate, distant from the cells.

SPECIMEN: LUZON, Laguna, Calamba (Pansol), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen**.** Observed existing as a bluish-green layer attached on leaves and stems of water spinach mixed with other filamentous cyanobacteria and plaktonic green algae.

Class Cyanophyceae
Order: Chroococcales
Family: Chroococcaceae
Genus: *Chroococcus* Nägeli

***Chroococcus major* Komarék & Komákova-Legnerová (Figure 3b)**

REFERENCES: Comas-Gonzales et al. (2017); Komárek and Komákova-Legnerová (2007); McGregor (2013).

DESCRIPTION: Colonies are small, solitary, spherical or sometimes ellipsoidal, usually occurring with 2-4 cells characterized by having a well-defined colorless, homogeneous or sometimes slightly lamellated colonial envelopes. Cells blue-green in color, spherical to hemispherical in shape, 15.0-21.5 μm in diameter. Cell reproduction is by binary fission in 2-3 planes that are perpendicular to one another and is propagated by release of cells and/or group of cells.

SPECIMEN: LUZON, Laguna, Bay (Sto. Domingo), E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen**.** Observed existing as a slimy, bluish-green covering on submerged leaves and stems of water spinach mixed with other filamentous cyanobacteria, diatom and green microalgae.

Class Cyanophyceae
Order: Oscillatoriales
Family: Oscillatoriaceae
Genus: *Oscillatoria* Vaucher ex Gomont

***Oscillatoria limosa* C. Agardh *ex* Gomont (Figure 3c)**

REFERENCES: Desikachary (1959); Martinez (1984); Pantastico (1977); Prescott (1962); Velasquez (1962).

DESCRIPTION: Trichomes blue green in color, filamentous, straight and slightly constricted to crosswalls showing typical oscillatory movement; anterior end cells are rounded or flattened, not attenuated and without calyptra; specialized cells (heterocytes and akinetes) are absent; cells 9.0-11.0 µm long and 2.5-4.5 µm wide, protoplasm is slightly granulated; crosswalls often granulated.

SPECIMEN: LUZON, Laguna, Calamba (Pansol), E.DLR. Arguelles *s.n*. Photograph prepared from the mounted specimen. Observed existing as a bluish-green layer on submerged leaves roots and stems of water spinach mixed with other filamentous fungi and diatoms.

Class Cyanophyceae
Order: Oscillatoriales
Family: Microcoleaceae
Genus: *Arthrospira* Sitzenberger ex Gomont

***Arthrospira platensis* Gomont (Figure 3d)**

REFERENCES: Barman et al. (2015); Desikachary (1959).

DESCRIPTION: Trichomes, solitary, blue green, 5.0-8.0 µm wide, trichome ends not attenuated, regularly spirally (screw-like) coiled. Spirals 25.0-36.0 µm broad, distance between the spirals 42.0-54.0 µm; cells nearly as long as broad, or shorter than broad; cells nearly as long as broad, or shorter than broad, 2.0-6.0 µ long, cross walls granulated; end cells rounded.

SPECIMEN: LUZON, Laguna, Los Baños (Tadlak), E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen. Observed existing as a bluish-green crust on submerged roots and stems of water spinach mixed with other green microalgae and cyanobacteria.

Class Cyanophyceae
Order: Nostocales
Family: Aphanizomenonaceae
Genus: *Anabaenopsis* (V.V. Miller)

***Anabaenopsis circularis* (G.S. West) Woloszynska & V. Miller (Figure 3e)**

BASIONYM: *Anabaena flosaquae* var. *circularis* (G.S. West)

REFERENCES: Aguilera et al. (2016); Komárek (2005); Martinez (1984).

DESCRIPTION: Trichomes free floating, are circular and spirally-coiled (1-3 coils), contricted at crosswalls without mucilaginous envelopes. Cells cylindrical to barrel-shaped, slightly curved, 6.0–12.0 µm long and 2.5–5.5

μm wide, with aerotopes. Heterocytes are spherical or ovoid, 2.5–4.5 μm in diameter. Akinetes are elliptical to oval and solitary, 8.8–14.5 × 4.5–6.5 μm.

SPECIMEN: LUZON, Laguna, Victoria (San Benito), E.DLR. Arguelles *s.n.* Photograph prepared from the mounted specimen. Observed existing as a bluish-green film on submerged roots and stems of water spinach mixed with other filamentous cyanobacteria, molds and diatoms.

Epiphytic microalgae and cyanobacteria from aquatic macrophytes are ubiquitous in freshwater bodies but have not been investigated properly. In this survey, a preliminary enumeration of algal epiphytes associated with water spinach (collected from selected sites in the vicinity of Laguna de Bay) was taxonomically studied. A total of 15 infrageneric taxa belonging to 10 orders, 13 families, 15 genera and 15 species were identified over the study period. Of these taxa, the occurrence of a rare photosynthetic euglenoid, *Cryptoglena skujae* Marin & Melkonian represents a new record for the Philippines. Dominant algal epiphytes such as diatoms, cyanobacteria, and photosynthetic euglenophytes were observed in the sampling sites. A number

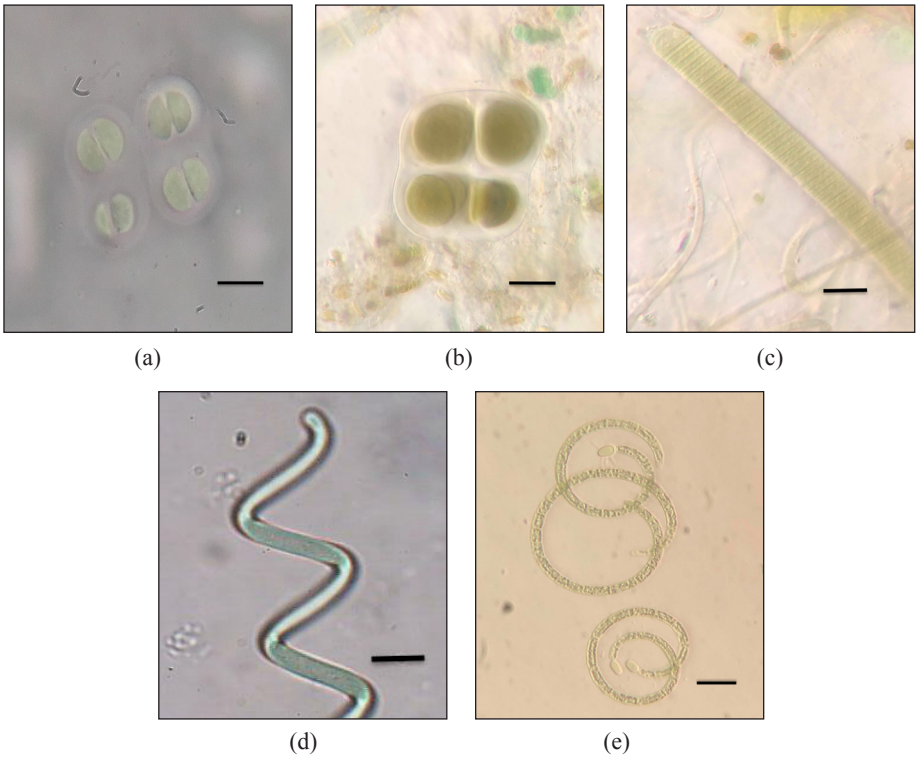


Figure 3. Photomicrographs of (a) *Limnococcus limneticus* (Lemmermann) Komárková, Jezberová, O.Komárek & Zapomelová, (b) *Chroococcus major* Komarék & Komákova-Legnerová, (c) *Oscillatoria limosa* C. Agardh ex Gomont, (d) *Arthrospira platensis* Gomont, (e) *Anabaenopsis circularis* (G.S.West) Woloszynska & V. Miller. All scale bars = 10 μm

of filamentous forms of cyanobacteria composed of the genera *Arthrospira, Oscillatoria,* and *Anabaenopsis,* together with unicellular forms such as *Chroococcus* and *Limnococcus* were observed from submerged stem, leaves and roots of the macrophyte. On the other hand, certain species of diatoms and green microalga that are considered ubiquitous and cosmopolitan genera such as *Gomphonema, Cyclotella, Chlorella* and *Tetradesmus* were present in all of the sampling sites. Strains of photosysnthetic euglenoids were represented by four taxa but their distribution was limited in two sampling sites only. The study shows that there is a variance observed in the distribution of the reported algal epiphyte species in the host macrophyte. The number and distribution of algal epiphytes on the host plant is dependant on several factors such as grazing pressure (fish and macro and micro-invertebrate grazing), changes in light intensity, growth form of macrophyte, texture of the plant parts, leaf arrangement and surface area of the host plant **(**Albay & Aykulu, 2002; Dunn et al., 2008; Salman et al., 2014). These factors can change the number of species, biomass and distribution of algal epiphytes on aquatic macrophytes. On the other hand, the growth and proliferation of aquatic macrophytes in bodies of water are also affected by epiphytic algae under elevated levels of nutrients in the water body. An increase in the level of water nutrients such as phosphorus and nitrogen promotes the growth and proliferation of both submerged aquatic macrophytes and the attached epiphytic algae, however, the proliferation of epiphytic algae interfere aquatic plants' growth by lowering the chlorophyll content and stimulating peroxidation of lipids in cell membrane of plants (Song et al., 2017).

CONCLUSION

From this preliminary survey it appears that the diversity of algal epiphytes are much more than it is expected. The algal taxonomic records reported in this survey expand the knowledge regarding diversity and geographic distribution of algal epiphytes in the Philippines. This highlights the significance of taxonomic studies of epiphytic algae in other aquatic macrophytes found in freshwater environments in the country. Further studies are necessary in order to increase knowledge of the taxonomy, distribution and ecology of these alga in plants and seaweeds found in the marine environment.

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REFERENCES

Adam, M. S., Hifney, A. F., Fawzy, M. A., & Al-Badaani, A. A. (2017). Seasonal biodiversity and ecological studies on the epiphytic microalgae communities in polluted and unpolluted aquatic ecosystem at Assiut, Egypt. *European Journal of Ecology*, *3*(2), 92-106. doi: 10.1515/eje-2017-0017

Aguilera, A., Komárek, J., & Echenique, R. O. (2016). *Anabaenopsis* morphospecies (Cyanobacteria, Nostocales) from Los Patos shallow lake (Province of Buenos Aires, Argentina). *Phytotaxa*, *272*(3), 173–183. doi: 10.11646/phytotaxa.272.3.1

Akbulut, A. (2003). Planktonic diatom (Bacillariophyceae) flora of Sultan Sazlığı marshes (Kayseri). *Turkish Journal Botany*, *27*(4), 285-301.

Albay, M., & Aykulu, G. (2002). Invertebrate Grazer – Epiphytic algae interactions on submerged macrophytes in a mesotrophic Turkish lake. *Ege Journal of Fisheries and Aquatic Sciences*, *19*(1), 247-258.

Alves-Da Silva, S. M., & Bicudo, C. E. (2009). *Cryptoglena*, *Monomorphina* and *Phacus* (Euglenophyceae) of a reservoir in the State of Rio Grande do Sul, southern Brazil. *Brazilian Journal of Botany*, *32*(2), 253-270. doi: 10.1590/S0100-84042009000200006

Araujo, G. J. M., Barbosa, J. E. D. L., & Barbosa, L.G. (2012). Pigmented Euglenophytes in a natural and shallow lake in the semiarid region of Paraíba State Brazil. *Brazilian Journal of Botany*, *35*(1), 17-30. doi: 10.1590/S0100-84042012000100004

Arguelles, E. D. L. R. (2019). Systematic study of some epiphytic algae (non-diatoms) on the submerged parts of water hyacinth [*Eichhornia crassipes* (Mart.) Solms-Loubach] found in Laguna de Bay, Philippines. *Tropical Life Sciences Research*, *30*(1), 1–20. doi: 10.21315/tlsr2019.30.1.1

Arguelles, E. D. L. R., & Monsalud, R. G. (2017). Morphotaxonomy and diversity of terrestrial microalgae and cyanobacteria in biological crusts of soil from paddy fields of Los Baños, Laguna (Philippines). *Philippine Journal of Systematic Biology*, *11*(2), 25-36.

Arguelles, E. D. L. R., Martinez-Goss, M. R., & Shin, W. (2014). Some noteworthy photosynthetic Euglenophytes from Laguna and vicinities. *Philippine Scientist*, *51*, 1-36.

Barman, N., Satpati, G. G., & Pal, R. A. (2015). Morphotaxonomic account of cyanobacterial diversity of Indian Sundarbans. *Journal of Algal Biomass Utilization*, *6*(3), 39-46.

Bartozek, E. C. R., Bueno, N. C., Ludwig, T. A. V., Tremarin, P. I., Nardelli, M. S., & da Rocha, A. C. R. (2013). Diatoms (Bacillariophyceae) of Iguaçu National Park, Foz do Iguaçu, Brazil. *Acta Botanica Brasilica*, *27*(1), 108-123. doi: 10.1590/S0102-33062013000100012

Baysa, M. C., Anuncio, R. R. S., Chiombon, M. L. G., Dela Cruz, J. P. R., & Ramelb, J. R. O. (2006). Lead and cadmium contents in *Ipomoea aquatica* Forsk. grown in Laguna de Bay. *Philippine Journal of Science*, *135*(2), 139-143.

Boonmee, S., Martinez-Goss, M. R., & Shin, W. (2011). Taxonomy of flagellated algae in brackish and freshwater fishponds in Central, Luzon, Philippines. *Asia Life Science*s, *20*(1), 99–141.

Bose, R., Nandi, C., Roy, A. S., Gorain, P. C., & Pal, R. (2016). Floristic survey of microplanktonic cyanobacteria and chlorophyta from different ecological niches of west Bengal, India. *Phytomorphology*, *66*(3&4), 77-93.

Cavalcante, K. P., Tremarin, P. I., & Ludwig, T. A. V. (2013). Taxonomic studies of centric diatoms (Diatomeae): Unusual nanoplanktonic forms

and new records for Brazil. *Acta Botanica Brasilica*, *27*(2), 237-251. doi: 10.1590/S0102-33062013000200001

Comas-González, A. A., Valle-Pombrol, A., & Moreira-González, A. R. (2017). Tropical chroococcalean morphospecies (Cyanobacteria) in Cuban waters. *Pan-American Journal of Aquatic Sciences*, *12*(1), 14-20.

Costa, L. F., Wengrat, S., & Bicudo, D. C. (2017). Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil. *Hoehnea*, *44*(4), 559-579. doi: 10.1590/2236-8906-12/2017

de Souza Santos, K. R., da Rocha, A. C. R., & Sant' Anna, C. L. (2012). Diatoms from shallow lakes in the Pantanal of Nhecolândia, Brazilian wetland. *Oecologia Australis*, *16*(4), 756-769. doi: 10.4257/oeco.2012.1604.03

Desikachary, T. V. (1959). *Cyanophyta*. New Delhi, India: Indian Council of Agricultural Research.

Dhote, S. (2007). Role of macrophytes in improving water quality of an aquatic eco-system. *Journal of Applied Science and Environmental Management*, *11*(4), 133-135.

Dunn, A. E., Dobberfuhl, D. R., & Casamatta, D. A. (2008). A survey of algal epiphytes from *Vallisneria americana* Michx. (Hydrocharitaceae) in the lower St. Johns River, Florida. *Southeastern Naturalist*, *7*(2), 229–244.

Gaiser, E. E., McCormick, P. V., Hagerthey, S. E., & Gottlieb, A. D. (2011). Landscape patterns of periphyton in the Florida Everglades. *Critical Reviews in Environmental Science and Technology*, *41*(S1), 92-120. doi: 10.1080/10643389.2010.531192

Guiry, M. D., & Guiry, G. M. (2018*). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway*. Retrieved August 03, 2018, from the AlgaeBase website: http://www.algaebase.org

Gupta, G. C. (1980). Use of water hyacinth in wastewater treatment (a brief literature review). *Journal of Environmental Health*, *43*(2), 80-82.

Hassan, F. M., Salah, M. M., & Salman, J. M. (2007). Quantitative and qualitative variability of epiphytic algae on three aquatic plants in Euphrates River, Iraq. *Iraqi Journal of Aquaculture*, *1*, 1-16.

Hegewald, E., & Silva, P. C. (1988). Annotated catalogue of *Scenedesmus* and nomenclaturally related genera, including original description and figures. *Bibliotheca Phycologica*, *80*, 1-587.

Joh, G. (2017). Diatom species of genera *Navicula* and *Craticula* collected from three Korean islands in the Yellow Sea. *Korean Journal Environmental Biology*, *35*(3), 240-250.

John, D. M., & Tsarenko, P. M. (2011). Order Chlorococcales. In D. M. John, B. A. Whitton, & A. J. Brook (Eds.), *The freshwater algal flora of the British Isles: An identification guide to freshwater and terrestrial algae* (pp. 327-409). New York, NY: Cambridge University Press.

Kim, Y. J. (2015). Algal flora of Korea: Chlorophyta: Chlorophyceae: Chlorococcales III: Scenedesmaceae. *NIBR Ministry of Environment, Incheon*, *6*(8), 1-134.

Komárek, J. (2005). Phenotype diversity of the heterocystous cyanoprokaryotic genus *Anabaenopsis*. *Fottea*, *5*(1), 1-35.

Komárek, J., & Komárkova-Legnerová, J. (2007). Taxonomic evaluation of the cyanobacterial microflora from alkaline marshes of northern Belize. 1. Phenotypic diversity of coccoid morphotypes. *Nova Hedwigia*, *84*(1–2), 65–111. doi: 10.1127/0029-5035/2007/0084-0065

Komárková, J., Jezberová, J., Komárek, O., & Zapomělová, E. (2010). Variability of *Chroococcus* (Cyanobacteria) morphospecies with regard to phylogenetic relationships. *Hydrobiologia*, *639*(1), 69–83. doi: 10.1007/s10750-009-0015-3

Kouassi, B. A. T., Ouattara, A., & Da, K. P. (2013). Euglenozoa occurring in Adzopé reservoir, Côte D'Ivoire [Euglenozoa occurring in Adzope reservoir, Ivory Coast]. *Turkish Journal of Botany*, *37*, 1176-1187.

Kumar, R., Seth, M. K., & Suseela, M. R. (2012). Chlorophyceae of district Kangra of Himachal Pradesh. *Phycological Society of India*, *42*(2), 35-38.

Leira, M., López-Rodríguez, M. C., & Carballeira, R. (2017). Epilithic diatoms (Bacillariophyceae) from running waters in NW Iberian Peninsula (Galicia, Spain). *Anales del Jardín Botánico de Madrid*, *74*(2), e062. doi: 10.3989/ajbm.2421

Mandal, R. N., Saha, G. S., Kalita, P., Mukhopadhyay, P. K. (2008, April 20). *Ipomoea aquatica* – An aquaculture friendly macrophyte. Sustainable aquaculture. *Aquaculture Asia Magazine*, 12-13.

Marra, R. C., Tremarin, P. I., Algarte, V. M., & Ludwig, T. V. (2016). Epiphytic diatoms (Diatomeae) from Piraquara II urban reservoir, Paraná state. *Biota Neotropica*, *16*(4), e20160200. doi: 10.1590/1676-0611-BN-2016-0200

Martinez, M. R. (1984). *A checklist of blue-green algae of the Philippines*. Los Baños, Philippines: University of the Philippines Los Baños Press.

McGregor, G., Fabbro, L. D., & Lobegeiger, J. S. (2007). Freshwater planktic Chroococcales (Cyanoprokaryota) from North-Eastern Australia: A morphological evaluation. *Nova Hedwigia*, *84*(3/4), 299-331. doi: 10.1127/0029-5035/2007/0084-0299

McGregor, G. B. (2013). Freshwater cyanobacteria from north-eastern Australia: 2. Chroococcales. *Phytotaxa*, *133*(1), 1-130. doi: 10.11646/phytotaxa.133.1.1

Nagendra, P. K., Shivamurthy, G. R., & Aradhya, S. M. (2008). *Ipomoea aquatica*, an underutilized green leafy vegetable: A review. *International Journal of Botany*, *4*(1), 123-129.

Naskar, K. R. (1990). *Aquatic and semi-aquatic plants of lower Ganga delta*. New Delhi, India: Daya Publishing House.

Ortega-Calvo, J. J., Sánchez-Castillo, P. M., Hernández-Mariné, M., & Sáiz-Jiménez, C. (1993). Isolation and characterization of epilithic chlorophyta and cyanobacteria from two Spanish cathedrals (Salamanca and Toledo). *Nova Hedwigia*, *57*(1-2), 239–253.

Pantastico, J. B. (1977). *Taxonomy of the fresh-water algae of Laguna de Bay and vicinity.* Metro Manila, Philippines: National Research Council of the Philippines.

Prescott, G. W. (1962). *Algae of the western great lakes area*. Dubuque, USA: Wm. C. Brown Company.

Rañola, M. C. G., Zafaralla, M. T., & Valmonte, R. A. D. (1990). A preliminary investigation on the epiphyton of *Eichhornia crassipes* (Mart.) Solm. roots in Laguna de Bay. *UP Los Baños Journal*, *1*(1), 53-67.

Roy, A. S., & Pal, R. (2016). Fresh water euglenophytes from East Kolkata wetlands - A Ramsar site. *Phytomorphology*, *66*(3&4), 113-121.

Salman, J. M., Hassan, F. M., Hadi, S. J., & Motar, A. A. (2014). An ecological study of epiphytic algae on two aquatic macrophytes in lotic ecosystem. *Asian Journal of Natural and Applied Sciences*, *3*(3), 37-52.

Satpati, G. G., & Pal, R. (2017). Taxonomic diversity and SEM study of euglenoids from brackish water ecosystems of Indian Sundarbans Biosphere Reserve. *Phykos*, *47*(1), 105-122.

Song, Y. Z., Wang, J. Q., & Gao, Y. X. (2017). Effects of epiphytic algae on biomass and physiology of *Myriophyllum spicatum* L. with the increase of nitrogen and phosphorus availability in the water body. *Environmental Science Pollution Research*, *24*(10), 9548–9555. doi: 10.1007/s11356-017-8604-6

Tunca, H., Ongun-Sevindik, T., Bal, D. N., & Arabaci, S. (2014). Community structure of epiphytic algae on three different macrophytes at Acarlar floodplain forest (northern Turkey). *Chinese Journal of Oceanology and Limnology*, *32*(4), 847-857. doi: 10.1007/s00343-014-3205-4

Utermöhl, H. (1958). Zur vervollkommnung der quantitativen phytoplankton-methodik: Mit 1 tabelle und 15 abbildungen im text und auf 1 tafel [To complete the quantitative phytoplankton methodology: With 1 table and 15 pictures in the text and on 1 board]. *Internationale Vereinigung für theoretische und angewandte Limnologie: Mitteilungen*, *9*(1), 1-38. doi: 10.1080/05384680.1958.11904091

Velasquez, G. T. (1962). The blue green-algae of the Philippines. *Philippine Journal Science*, *91*(3), 267-380.

Vijayan, D., & Ray, J. G. (2015). Green algae of a unique tropical wetland, *Kuttanadu*, Kerala, India, in relation to soil regions, seasons, and paddy growth stages. *International Journal of Science, Environment and Technology*, *4*(3), 770-803.

Whitton, B. A. (2011). Phylum cyanobacteria (Cyanophyta). In D. M. John, B. A. Whitton, & A. J. Brook (Eds.), *The freshwater algal flora of the British Isles: An identification guide to freshwater and terrestrial algae* (pp. 31-158). New York, NY: Cambridge University Press.

Wolowski, K. (2011). Phylum Euglenophyta. In D. M. John, B. A. Whitton, & A. J. Brook (Eds.), *The freshwater algal flora of the British Isles. An identification guide to freshwater and terrestrial algae* (pp. 181-239). New York, NY: Cambridge University Press.

Wolowski, K., Poniewozik, M., & Walne, P. L. (2013). Pigmented euglenophytes of the genera *Euglena*, *Euglenaria*, *Lepocinclis*, *Phacus* and *Monomorphina* from southeastern United States. *Polish Botanical Journal*, *58*(2), 659–685. doi: 10.2478/pbj-2013-0071

Wolowski, K., Saber, A. A., & Cantonati, M. (2017). Euglenoids from the El Farafra Oasis (Western Desert, Egypt). *Polish Botanical Journal*, *62*(2), 241–251. doi: 10.1515/pbj-2017-0017

Zafaralla, M. T. (1998). *Microalgae of Taal lake*. Taguig, Philippines: National Academy of Science and Technology.

Zimba, P. V., & Hopson, M. S. (1997). Quantification of epiphyte removal efficiency from submersed aquatic plants. *Aquatic Botany*, *58*(2), 173-179. doi: 10.1016/S0304-3770(97)00002-8