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TAXONOMY AND SPECIES COMPOSITION OF EPIPHYTIC ALGAE IN STA. CRUZ RIVER, LAGUNA (PHILIPPINES)

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ABSTRACT

Algal epiphytes attached on three dominant aquatic macrophytes (*Pistia striatotes*, *Eichhornia crassipes* and *Ipomoea aquatic*) were investigated as part of a preliminary study on the ecological assessment of Sta. Cruz River, which has been used primarily for agriculture and fishery. In total, 22 algal taxa were identified on the studied macrophytes: 8 Chlorophyta, 4 Cyanobacteria, 7 Bacillariophyta, and 3 Euglenophyta. The taxa in this paper represent 8 classes, 16 orders, 20 families, 22 genera and 22 species based on the latest algal taxonomical nomenclature. Among these taxa, the existence of a rare filamentous cyanobacteria, *Planktothrix compressa* (Utermöhl) Anagnostidis et Komárek is described for the first time in the Philippines. A species of diatom is also reported in this study for the first time based on recent algal taxonomic nomenclature and this is *Ulnaria ulna* (Nitzsch) Compère that is based on the former name of *Synedra ulna* (Nitzsch) Ehrenberg. These taxonomic records proved that aquatic macrophytes represents a unique habitat for novel and diverse types of algal flora, which demands further investigations in the country.

Keywords: Epiphytic algae, macrophytes, Philippines, river, taxonomy

INTRODUCTION

Macrophytes are aquatic and amphibious plants found in the littoral zones of running waters (eg. rivers, streams, and the like) and shallow lakes contributing largely to the autochthonous carbon pool and oxygen budget of the aquatic ecosystem (**Janauer & Dokulil, 2006**). These plants have a significant function in water biocenoses, hydrology and sediment dynamics, biochemical cycles, structuring and altering the physico-chemical features (of an aquatic ecosystem) by photosynthesis, mineralization, and decomposition (**Jeppesen *et al.*, 2002; Joniak *et al.*, 2007; Špoljar *et al.*, 2012**). Macrophytes have diverse species of microalgae attached to submerged plant parts which have been shown to be an important productive component of the aquatic ecosystem (**Sheldon & Boylen, 1975**). Algal epiphytes form a matrix system of microalgae and cyanobacteria attached to submerged aquatic macrophytes. These algae are regarded as primary species in different lotic water systems and are involved in maintaining ecological balance among the different groups of macrophytes and aquatic organisms (**Hassan, *et al.*, 2014; Fawzy, 2016**). It is widely recognized that these organisms supply food to invertebrates, fish, and in other aquatic fauna in the littoral zone and contributes an estimated of 0.2% to 41% of the total primary production in an aquatic ecosystem (**Laugaste & Ruemamen, 2005; Effiong & Inyang, 2015**). Several observational and experimental studies on ecological status of bodies of water showed an increase in the population and diversity of algal epiphytes in response to nutrient loading and pollution (**Gil *et al.*, 2006; Peterson *et al.*, 2007; Fawzy, 2016**). This led to the consideration of these organisms as excellent bioindicators of environmental and water quality alterations because of its sensitivity to external sources of pollution (**Lowe, 1996; Fawzy, 2016**). Species of algal epiphytes associated with organically polluted enriched waters include *Euglena*, *Phacus*, *Nitzschia*, *Chlorella*, *Scenedesmus*, *Chlamydomonas*, *Cladophora*, and *Closterium* (**Effiong & Inyang, 2015**).
The biological interconnection and relationship between algal epiphytes and host aquatic macrophyte in the aquatic environment are still limited and incompletely studied (**Wetzel, 1996**). Several reports suggested that biotic and abiotic factors such as physico-chemical characteristics of submerged parts (stem, leaves and roots) of macrophytes, availability of substrates, temperature, light intensity and grazing affects the diversity and prevalence of epiphytic algal community (**Gil *et al.*, 2006; Fawzy, 2016**). Aquatic macrophytes are sometimes detrimental for algal epiphytes since they are capable of monopolizing light and assimilate nutrients within the vertical expanse of the water column, inhibiting algal epiphytes as well as other submerged macrophytes from acquiring enough resources for growth and survival (**Schramm & Jirka, 1989**). Moreover, morphology of several macrophyte species, specifically the length of stem and leaves, may limit the growth and proliferation of algal epiphytes by releasing inhibitory substances (allelochemicals) (**Tunca *et al.*, 2014**). Thus, development of algal epiphyton community as well as its distribution and abundance depend largely on macrophyte host species. On the other hand, in situations where there is an evident increased in algal epiphyte population, it is observed that there is a reduction in the total macrophyte biomass density due to restriction in nutrient diffusion from the water to host plant (**Fawzy, 2016**). In the Philippines, taxonomic studies of algal epiphytes associated to different macrophytes were done only to those plant species inhabiting Laguna de Bay (**Rañola, *et al.*, 1990; Arguelles, 2019 a,b,c; Arguelles, 2020a**). To date, a total of 82 taxa of algal epiphytes associated with four dominant aquatic macrophytes (*Hydrilla verticilata*, *Nymphaea pubescens*, *Eichhornia crassipes* and *Ipomoea aquatic*) found in Laguna de Bay were documented in in the Philippines. These taxonomic surveys reported the occurrence of five rare microalgae – namely, *Cryptoglena skujae* Marin and Melkonian, *Pseudanabaena minima* (G.S. An) Anagnostidis, *Synechococcus nidulans* (Pringsheim) Komárek, *Chroococcus schizodermaticus* West and *Franceia amphitricha* (Lagerheim) Hegewald – for the first time in the Philippines. Also, some of the microalgal genera documented in these taxonomic studies (eg. *Cryptoglena*, *Tetradesmus*, *Nitzschia*, *Euglena*, *Chroococcus*, *Oscillatoria*, *Phacus* and *Chlorella*) are usually associated with organically polluted enriched waters (**Arguelles, 2019 a,b,c; Arguelles, 2020a**). These algal epiphytes are regarded as good indicators of environmental changes and water quality due to their sensitivity to external sources of fertilization which can be use in the assessment of ecological status of Laguna de Bay (**Arguelles, 2020a**). The taxonomic records reported in these studies provided baseline information regarding distribution and diversity of Philippine epiphytic algae from aquatic macrophytes found in local freshwater habitat.
Diversity and ecological studies of epiphytic microalgae of different aquatic macrophytes found in running waters (such as rivers and streams) in the Philippines remain poorly understood. To date, no documented taxonomic survey was conducted on these group of microalgae. Thus, additional taxonomic survey of algal epiphytes of different aquatic macrophytes found in these aquatic ecosystems are needed to deepen our understanding of the diversity and

ecological roles of these microorganisms. The goal of this investigation is to account the species diversity of algal epiphytes associated to different aquatic macrophytes observed in Sta. Cruz River, one of the 21 major tributary rivers of Laguna de Bay. Also, morphotaxonomic description of each algal taxa were documented together with a brief description of the sampling sites and natural environment of its existence.

MATERIAL AND METHODS

Study Site

Sta. Cruz River is considered as one of the main branch rivers of Laguna de Bay. It lies at 14.3001 ºN and 121.4068 ºE, specifically within the municipalities of Liliw, Magdalena, Nagcarlan, Pagsanjan, Pila, and Sta. Cruz (Figure 1). The river is measured to be approximately 14.48 km in length, flowing towards Laguna de Bay. Currently, the principal use of this river is for fishery and agriculture (with coconut and rice production, livestock, poultry, and piggery raising as main activities). This body of water is known to be a receptacle for floodwaters coming from its small tributary rivers such as Maimpis river, Liliw river, San Diego river, Tipacan river, and Talahebeng river (**Madamba *et al.*, 1992**).

Sampling and Specimen Preparation of Epiphytic Algae

A single preliminary collection of algal epiphytes from submerged aquatic macrophytes was done from the littoral zone of Sta. Cruz River. The plant parts were put into sterile autoclavable plastics filled with water for laboratory examination. A total of 20 aquatic macrophyte samples (each for *Pistia striatotes*, *Eichhornia crassipes* and *Ipomoea aquatica*) were collected and analyzed throughout the study period. Immediately after collection, these samples were washed several times with sterile distilled water. The algal epiphytes from submerged leaves, stems and roots on the collected aquatic macrophytes were set apart from the plant by gently scraping the attached algae on the plant material (**Zimba & Hopson, 1997; Arguelles, 2021a,b,c**). The collected scraped algal epiphyte was carefully mixed, and a portion of 50 mL was kept for taxonomic enumeration. The mixed algal epiphyte sample was transferred into a sterile beaker and left overnight to allow settling of the scraped algal samples. An aliquot of 45 mL of the liquid specimen was removed in the beaker after the settling period. The residual 5 mL of the collected scraped material was transferred into a sterile drum vial for taxonomic enumeration of algal epiphytes and were preserved using 2-3 drops of Lugol's iodine from the prepared specimens (**Utermöhl, 1958; Arguelles *et al.*, 2014; Tunca *et al.*, 2014; Arguelles, 2019a,b,c; Arguelles, 2020b; Arguelles, 2021a,b,c**). A small portion (5 mL) of the concentrated scraped epiphytic algal samples was used for the analysis of diatom flora. The scraped samples were chemically digested following the standard procedure for diatom cleaning and slide preparation of **Round *et al.*, (1990)**. Mixture of cleaned diatoms were dried onto glass coverslips and mounted. Three slides were prepared for each aquatic macrophytes sample for microscopic observation and enumeration of diatoms. The preserved algal specimens and diatom slides were kept as voucher specimens at the Philippine National Collection of Microorganisms, National Institute of Molecular Biology and Biotechnology (BIOTECH), University of the Philippines Los Baños (UPLB), College, Laguna, Philippines.

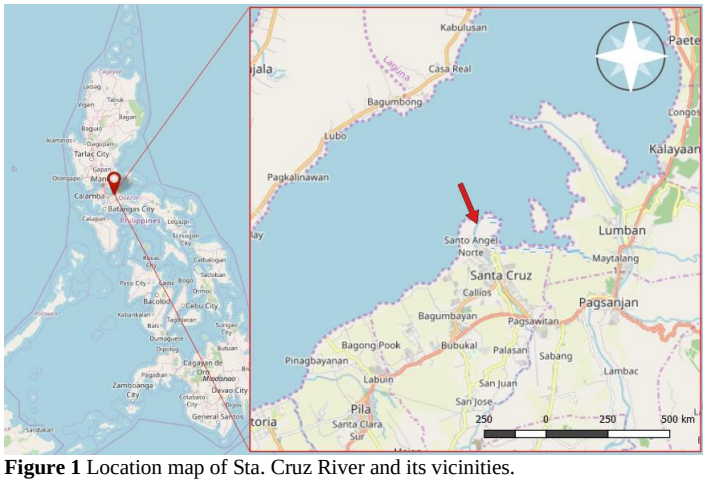

Figure 1 Location map of Sta. Cruz River and its vicinities.

RESULTS AND DISCUSSION

Epiphytic algal flora of three dominant aquatic macrophyte (*P. stratiotes*, *E. crassipes* and *I. aquatica*) observed in Sta. Cruz River consisted of 22 taxa. Of these, 8 belong to the Chlorophyta, 4 to the Cyanobacteria, 7 to the Bacillariophyta, and 3 to the Euglenophyta divisions. Chlorophyta was dominant and comprised 36.36% of all recorded taxa. Bacillariophyta, Cyanobacteria and Euglenophyta represented 31.81%, 18.18% and 13.63% of all recorded taxa, respectively. The taxonomic list of the algal epiphytes determined in Sta. Cruz River is given in Table 1. All the taxa are systematically enumerated with morphotaxonomic descriptions along with a simple habitat information where the alga was observed. Illustrative photomicrographs of some of the algal species are given in Plates I-IV. Currently accepted algal taxonomic names were used based on the recent nomenclatural indices for algae of the International Association of Plant Taxonomy (IAPT) and **Round *et al.* (1990).**

Dichotomous Key

1. Cells without membrane-bound organelles ……..……..……..…….. 2
1. Cells with membrane-bound organelles.……..……..……..…. 5

2. Unicellular and spherical occurring as singly or in clusters of 2 to 4 cells ... *Chroococcus minutus*
2. Filamentous occurring as single or in groups of trichomes ……3

3. Filamentous cyanobacteria exhibiting true branching *Hapalosiphon welwitschii*
3. Filamentous cyanobacteria not exhibiting true branching ……..… 4

4.Trichomes are straight and 5.0–7.0 µm wide ……..*Oscillatoria tenuis*
4.Trichomes are straight, cylindrical and 6.0-8.5 µm wide *Planktothrix compressa*

5. Cells with siliceous cell wall…….……..…… 6
5. Cells without siliceous cell wall……. 12

6. Cells radial in nature ……..…… 7
6. Cells bilateral in nature.……..……..... 8

7. Cells grow in linear colonies joined by linking spines... *Aulacoseira granulata*
7. Cells are not capable of forming linear colonies and without linking spines ……. *Cyclotella meneghiniana*

8. Cells with sigmoid shape in appearance ...……..…… *Gyrosigma acuminatum*
8. Cells not sigmoid shape in appearance.……..……..…… 9

9. Cells without raphe system (araphid) ……..... *Ulnaria ulna*
9. Cells with raphe system ……..……..... 10

10. Valves linear not inflated in the median part ……..... *Nitzschia palea*
10. Valves linear-elliptical and inflated in median part ……..…… 11

11. Valves with linear-arched central area ..……..…*Cymbella affinis*
11. Valves are linear-elliptical and inflated in median part ….. *Rhopalodia gibba*

12. Cells with red eyespot and proteinacious pellicle ……..……..…….. 13
12. Cells without red eyespot and proteinacious pellicle ..……..……..... 15

13. Protoplast without a rigid lorica ……..……..……..... 14
13. Protoplast with a rigid lorica …..……..… *Trachelomonas armata*

14. Cells flattened ……..……..……..……..…....*Phacus longicauda*
14. Cells broadly ellipsoid ……..……..……..….. *Leponcinclis acus*

15. Cells with stellate chloroplasts ……..... *Staurastrum gracile*
15. Cells without stellate chloroplasts ……..... 16

16. Unicellular, solitary or in clump.……..... 19
16. Colonial with several cells attached……..……..……..…….... 17

17. Cells are crescent shaped ……..……..……..... 18
17. Cells not crescent shaped.……..…… 20

18. Crescent-shaped cells and needle-like in appearance *Ankistrodesmus falcatus*
18. Crescent-shaped cells and lunate in appearance ……. *Kirchneriella lunaris*

19. Cells spherical (10-13 µm in diameter) ..…..... *Chlorococcum infusionum*
19. Cells spherical or ellipsoidal (2-5 µm in diameter)……. *Chlorella vulgaris*

20. Coenobia with spiny projections (terminal cells) …*Scenedesmus quadricauda*
20. Coenobia without spiny projections (terminal cells) ……. 21

21. Coenobia is composed of 16 cells (100–110 µm in diameter) *Lacunastrum gracillimum*
21. Coenobia is composed of 4-6 cells (10.0-15.0 µm in diameter) *Westella botryoides*

Table 1 Distribution of epiphytic algae on dominant aquatic macrophytes from Sta. Cruz River (Laguna, Philippines).

Algal Species	Dominant Aquatic Macrophytes		
	Water Lettuce (*Pistia stratiotes*)	**Water Hyacinth (*Eichhornia crassipes*)**	**Water Spinach (*Ipomoea aquatica*)**
Cyanobacteria			
Class Cyanophyceae			
Order: Chroococcales			
Family: Chroococcaceae			
***Chroococcus minutus* (Kützing) Nägeli**	+	+	
Order: Oscillatoriales			
Family: Oscillatoriaceae			
***Oscillatoria tenuis* C. Agardh *ex* Gomont**	+	+	
Family: Microcoleaceae			
***Planktothrix compressa* (Utermöhl) Anagnostidis *et* Komárek**	+		
Order: Nostocales			
Family: Hapalosiphonaceae			
***Hapalosiphon welwitschii* West & G.S.West**			+
Chlorophyta			
Class: Trebouxiophyceae			
Order: Chlorellales			
Family: Chlorellaceae			
***Chlorella vulgaris* Beyerinck [Beijerinck]**			+
Family: Chlorococcaceae			
***Chlorococcum infusionum* (Schrank) Meneghini**		+	+
Family: Hydrodictyaceae			
***Lacunastrum gracillimum* (West & G.S. West) H. McManus**		+	
Class: Chlorophyceae			
Order: Sphaeropleales			
Family: Scenedesmaceae			
***Scenedesmus quadricauda* (Turpin) Brébisson**	+		+
***Westella botryoides* (West) De Wildeman**		+	
Order: Sphaeropleales			
Family: Selenastraceae			
***Kirchneriella lunaris* (Kirchner) Möbius**	+	+	
***Ankistrodesmus falcatus* Corda (Ralfs)**	+	+	
Class: Conjugatophyceae (Zygnematophyceae)			
Order: Desmidiales			
Family: Desmidiaceae			
***Staurastrum gracile* Ralfs ex Ralfs**		+	
Bacillariophyta			
Class: Bacillariophyceae			
Order: Bacillariales			
Family: Bacillariaceae			
***Nitzschia palea* (Kützing) W. Smith**		+	+
Order: Naviculales			
Family: Naviculaceae			
***Gyrosigma acuminatum* (Kützing) Rabenhorst**		+	+
Order: Cymbellales			
Family:Cymbellaceae			
***Cymbella affinis* Kützing**			+
Order: Rhopalodiales			
Family: Rhophalodiaceae			
***Rhopalodia gibba* (Ehrenberg) O. Müller**		+	
Order: Licmophorales			
Family: Ulnariaceae			
***Ulnaria ulna* (Nitzsch) Compère**	+		
Class: Mediophyceae			
Order: Stephanodiscales			
Family: Stephanodiscaceae			
***Cyclotella meneghiniana* Kützing**	+		+
Class: Coscinodiscophyceae			
Order: Aulacoseirales			
Family: Aulacoseiraceae			
***Aulacoseira granulata* (Ehrenberg) Simonsen**			+
Euglenophyta			
Class: Euglenophyceaea			
Order: Euglenales			
Family: Phacaceae			
***Phacus longicauda* (Ehrenberg) Dujardin**			+
***Lepocinclis acus* (O.F. Müller) B. Marin and Melkonian**		+	+
Family: Euglenaceae			
Genus: *Trachelomonas* Ehrenberg			
***Trachelomonas armata* (Ehrenberg) F. Stein**	+		

+ = Present

Taxonomic Enumeration of Algal Epiphytes

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

1. *Chroococcus minutus* (Kützing) Nägeli **Pl. I, Fig. 1**
BASIONYM: *Protococcus minutus* Kützing

Cells spherical or irregularly spherical usually occurring as single or in cluster of 2-4 cells, bluish green to light green in color; colonies enclosed in an amorphous, colorless, homogenous mucilage diffluent at the margin; 5.0-7.0 µm in diameter with sheath and 3.0-5.0 µm in diameter without sheath; protoplast is smooth or slightly granulated.

Found existing as a bluish green or light green layer associated on stems and roots of water lettuce and water hyacinth together with other green microalgae and filamentous cyanobacteria.

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

1. *Oscillatoria tenuis* C. Agardh *ex* Gomont **Pl. I, Fig. 2**

Trichomes usually are scattered and straight (5.0–7.0 µm broad); crosswalls are constricted; terminal cells not attenuated (usually rounded) and lacks calyptra; specialized cells (eg. akinetes and heterocytes) are not present; cells are bluish green in color, 1.0–3.0 µm long and 4.0–5.0 µm wide, granulated protoplasm; terminal cell hemispherical to rounded.

Found existing as greenish to bluish-green layer on leaves and stem of water lettuce and water hyacinth submerged slightly in water together with several filamentous cyanobacteria.

Class: Cyanophyceae
Order: Oscillatoriales
Family: Microcoleaceae
Genus: *Planktothrix* K. Anagnostidis & J. Komárek

1. *Planktothrix compressa* (Utermöhl) Anagnostidis *et* Komárek **Pl. I, Fig. 3**
BASIONYM: *Lyngbya compressa* Utermöhl 1925
SYNONYM: *Oscillatoria compressa* (Utermöhl) Geitler 1925

Filaments occurring as planktonic, solitary and without mucilaginous sheaths; trichomes are cylindrical (6.0-7.5 µm wide), dark blue green to brownish in color, cross-walls are slightly constricted and attenuated towards the ends without false branching. Cells are shorter than wide and with few aerotopes. Apical cells widely rounded and not capitated. Specialized cell such as heterocytes and akinetes are absent.

A new record for the Philippines.

Found existing as a bluish-green layer on leaves of water lettuce submerged in water together with several filamentous green algae and cyanobacteria.

Class: Cyanophyceae
Order: Nostocales
Family: Hapalosiphonaceae
Genus: *Hapalosiphon* Nägeli ex É. Bornet & C. Flahault

1. *Hapalosiphon welwitschii* West & G.S. West **Pl. I, Fig. 4**

Cells are elongate and sub-spherical; dark green to bluish green in color, 1.0-2.0 µm in length and 2.0-3.0 µm in width, characterized with protoplasm that are smooth, septa of each cell is granulated, terminal end cells usually rounded; trichomes are arranged in one series exhibiting true branches along the filament, anterior end cell is not capitated and attenuated; gelatinous sheaths are colorless and thin; and lateral branches are usually shorter than the main filament.

Found existing as a greenish to blue green layer on stem and leaves of water spinach submerged in water together with other green algae and cyanobacteria.

Bacillariophyta
Class: Bacillariophyceae
Order: Bacillariales
Family: Bacillariaceae
Genus: *Nitzschia* Hassall

1. *Nitzschia palea* (Kützing) W. Smith **Pl. I, Fig. 5**
BASIONYM: *Synedra palea* Kützing

Valves are linear lanceolate tapering rapidly at the terminal poles with protracted round to capitate apices. Fibulae with central nodule are discrete and with striae that are slightly visible (18.0–24.0 striae in 10.0 µm). Valve mantle wider on keel side; 25.0–45.0 µm (length) and 4.0–8.0 µm (width), costae is 9.0-15.0 µm.

Found existing as a brownish layer on submerged roots and leaves of water hyacinth and water spinach together with other filamentous fungi and diatoms.

Class: Bacillariophyceae
Order: Naviculales
Family: Pleurosigmatacea
Genus: *Gyrosigma* Hassall

1. *Gyrosigma acuminatum* (Kützing) Rabenhorst **Pl. I, Fig. 6**
BASIONYM: *Frustulia acuminata* Kützing

Valves are slender and sigmoid in shape with terminal ends that are rounded. The raphe is central and follows an S-shaped appearance. Cells are large 65.0-147.0 µm in length and 11.0-20.0 µm in width. Middle area of the cell is oval, not rotated. The cells have two chloroplasts plate-like in appearance. Striae on the valve surface are both parallel and transverse to the raphe.

Found existing as a brownish layer on leaves and stem of water hyacinth and water spinach submerged in water together with cyanobacteria and green algae.

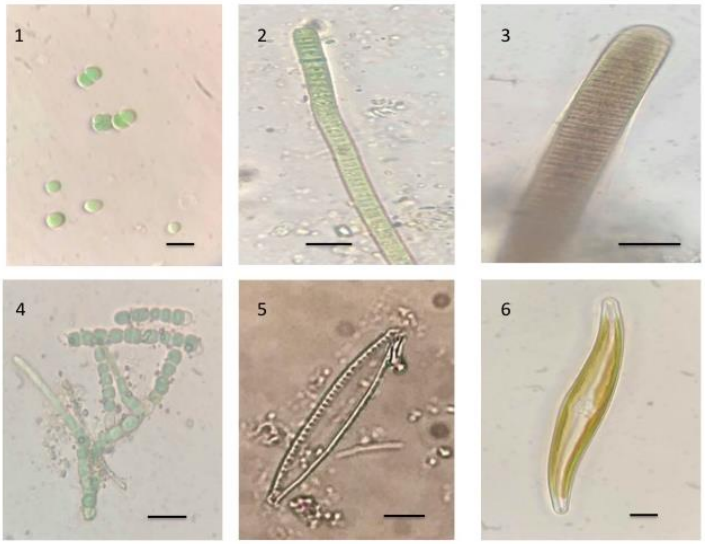

Plate I. Photomicrographs of (1) *Chroococcus minutus* (Kützing) Nägeli, (2) *Oscillatoria tenuis* C. Agardh *ex* Gomont, (3) *Planktothrix compressa* (Utermöhl) Anagnostidis *et* Komárek, (4) *Hapalosiphon welwitschii* West & G.S.West, (5) *Nitzschia palea* (Kützing) W. Smith, (6) *Gyrosigma acuminatum* (Kützing) Rabenhorst. All scale bars = 10 µm.

Class: Bacillariophyceae
Order: Cymbellales
Family: Cymbellaceae
Genus: *Cymbella* C. Agardh

1. *Cymbella affinis* Kützing **Pl. II, Fig. 1**

Cells are solitary and naviculoid; cell length is 21.5–28.0 µm and breadth of 6.0–8.0 µm. Valves are lanceolate with protracted to slightly subrostrate or subcapitate terminal ends. Cells have narrow axial area and central area that is linear-arched, and indistinct; striae are 8–11 for every 10 µm.

Found existing as a brownish layer on leaves and stem of water spinach submerged in water together with filamentous fungi and cyanobacteria.

Class: Bacillariophyceae
Order: Rhopalodiales
Family: Rhopalodiaceae
Genus: *Rhopalodia* O. Müller

1. *Rhopalodia gibba* (Ehrenberg) O. Müller **Pl. II, Fig. 2**
BASIONYM: *Navicula gibba* Ehrenberg

Frustules with swollen middle and are bracket in shape (valve view), apices are sharply bent with convex margin; in girdle view, valves linear-elliptical, inflated in median part with rounded poles; valves 45.5–53.5 µm long and 11.5–15.0 µm broad; ventral margin are usually straight and curve at the ends while the dorsal margin is convex; striae slightly radiate to parallel; striae 14-16 in 10 µm.

Found existing as a brownish layer on stem and leaves of water hyacinth submerged in water together with several filamentous cyanobacteria and green microalgae.

Class: Bacillariophyceae
Order: Licmophorales

Family: Ulnariaceae
Genus: *Ulnaria* (Kutzing) Compère

1. *Ulnaria ulna* (Nitzsch) Compère Pl. II, Fig. 3
BASIONYM: *Bacillaria ulna* Nitzsch

Valves are linear-lanceolate to linear with blunt rostrate to sub-rostrate terminal ends. Cell length is usually 91.0-192.0 µm and width of 4.5-8.5 µm. Central area is characterized by having roughly square outline (sometimes circular or elliptical outline) extending to the margin of the valves. Ghost striae are noticeable within the central area of the cell. Striae are parallel and usually 7-9 for every 10 µm.

Found existing as a brownish layer on stems and leaves of water lettuce submerged in water together with other unicellular and filamentous fungi as well as cyanobacteria.

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

1. *Aulacoseira granulata* (Ehrenberg) Simonsen Pl. II, Fig. 4
BASIONYM: *Gaillonella granulata* Ehrenberg

Frustules are cylindrical, joined together forming filamentous type of colonies. Valves are 5.0-17.0 µm in diameter, with height of the mantle of 4.0-21.0 µm. The ratio of the height of the mantle to diameter of the valve is greater than 0.9 and lower than 5. The mantle is characterized by having sides that are straight and valve face that is flat. Linking spines are triangular and short and located at the end of each pervalvar costa.

Found existing as a brownish layer on leaves of water spinach submerged in water together with other green microalgae and filamentous cyanobacteria.

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

1. *Cyclotella meneghiniana* Kützing Pl. II, Fig. 5

Cells rounded with central and marginal areas. Valves are small and disc-shaped with a narrow mantle; cells 8.0-19.0 µm in diameter characterized by having marginal chambered striae with flat and smooth central area covering 1/3 of the valve surface.

Found existing as a brownish layer on stem and leaves of water lettuce and water spinach slightly submerged in water together with diatoms, green microalgae, and filamentous cyanobacteria.

Chlorophyta
Class: Chlorophyceae
Order: Sphaeropleales
Family: Selenastraceae
Genus: *Kirchneriella* Schmidle

1. *Kirchneriella lunaris* (Kirchner) Möbius Pl. II, Fig. 6
BASIONYM: *Rhapidium convolatum* var. *lunare* Kirchner
***Kirchneriella lunata* Schmidle**

Thallus is microscopic and colonial (cells are seldom solitary); clusters of 2-4-8 up to 64 crescent-shaped cells within a mucilaginous sheath. Cells are lunate, cylindrical, or sickle-shaped, 3.0-4.0 x 2.0-8.0 µm (length x width). Cells with single parietal chloroplast adjacent at the margin of the cell with 1-4 pyrenoids per cell.

Found existing as a light greenish layer on stem and leaves of water hyacinth and water lettuce submerged in water together with other filamentous cyanobacteria.

Class: Chlorophyceae
Order: Sphaeropleales
Family: Selenastraceae
Genus: *Ankistrodesmus* Corda

1. *Ankistrodesmus falcatus* Corda (Ralfs) Pl. III, Fig. 1
BASIONYM: *Micrasterias falcatus* Corda

Cells are solitary or sometimes in clustered bundles or in tufts or mixed with other microscopic algae, lacking a mucilage envelope, cells are crescent-shaped and needle-like in appearance; 21.0-33.0 µm in length and 2.0-4.0 µm in width; narrowly tapering toward the anterior and posterior end, sometimes straight but majority of the times occurring as curved rods; parietal chloroplast with pyrenoid.

Found existing as a dark greenish layer on stem and leaves of water lettuce and water hyacinth submerged in water together with filamentous fungi and cyanobacteria.

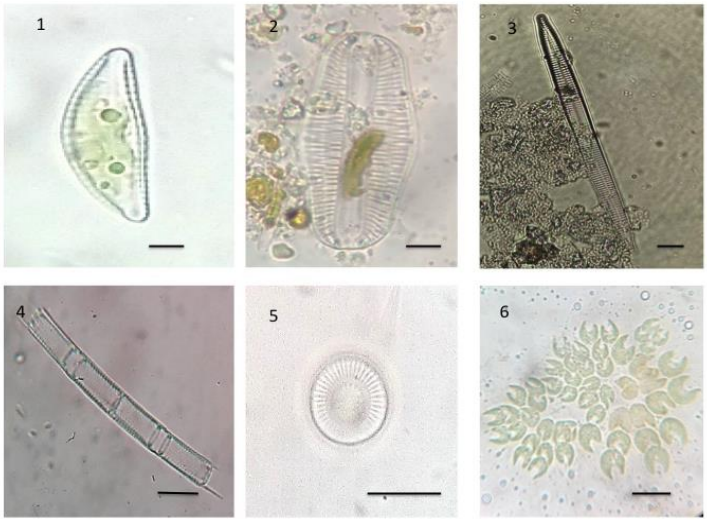

Plate II. Photomicrographs of (1) *Cymbella affinis* Kützing, (2) *Rhopalodia gibba* (Ehrenberg) O. Müller, (3) *Ulnaria ulna* (Nitzsch) Compère, (4) *Aulacoseira granulata* (Ehrenberg) Simonsen, (5) *Cyclotella meneghiniana* Kützing, (6) *Kirchneriella lunaris* (Kirchner) Möbius. All scale bars = 10 µm.

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

1. *Scenedesmus quadricauda* Chodat Pl. III, Fig. 2
BASIONYM: *Achnanthes quadricauda* Turpin

Cells oblong to spherical in shape (5.0-6.0 µm in length and 1.0-3.0 µm in width); parietal chloroplasts are present with a solitary pyrenoid; cells usually occur in parallel attached adjacent to each other (organized linearly in groups); inner cells of the coenobium are usually without spines while the terminal cells with two spiny projections.

Found existing as a light greenish layer on stems of water spinach and water lettuce submerged in water together with other filamentous cyanobacteria.

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

1. *Westella botryoides* (West) De Wildeman Pl. III, Fig. 3
BASIONYM: *Tetracoccus botryoides* West

Colonies occurring usually in 4-6 celled coenobia (10.0-15.0 µm in diameter). Cells spherical but are flat and are in contact with other cells in the colony, 3.0-8.0.0 µm in diameter, with smooth cell walls. Cells are uninucleated with single parietal chloroplast and a pyrenoid. Usually assemble to form irregular colonies (compound colonies to over 100 cells with 90.0-110.0 µm in diameter)

Found existing as a brownish to greenish layer on leaves of water hyacinth submerged slightly in water together with several cyanobacteria.

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

1. *Chlorella vulgaris* Beyerinck [Beijerinck] Pl. III, Fig. 4
BASIONYM: *Chlorella pyrenoidosa* var. *duplex* (Kützing)

Cells are 2.0-5.0 µm in diameter, symmetrical; chloroplast band-shaped or lobed; pyrenoid is solitary associated with starch grains; cell reproduction is by formation of autospores released by rupture from the mother cell wall.

Found existing as a brownish to greenish layer on stem and leaves of water spinach submerged slightly in water together with other filamentous fungi and cyanobacteria.

Class: Trebouxiophyceae
Order: Chlorellales
Family: Chlorococcaceae
Genus: *Chlorococcum* Meneghini

1. *Chlorococcum infusionum* (Schrank) Meneghini Pl. III, Fig. 5
SYNONYM: *Chlorococcum humicola* (Nägeli) Rabenhorst 1868
BASIONYM: *Cystococcus humicola* Nägeli

Spherical cells with a diameter of 10.0–13.0 µm, solitary but sometimes several cells form a cluster of greenish cells, parietal chloroplasts with a single pyrenoid covering the cells.

Found existing as a light greenish layer on stem and leaves of water hyacinth and water spinach submerged in water together with several filamentous blue green algae.

Class: Trebouxiophyceae
Order: Chlorellales
Family: Hydrodictyaceae
Genus: *Lacunastrum* H. McManus

1. *Lacunastrum gracillimum* (West & G.S. West) H. McManus Pl. III, Fig. 6

BASIONYM: *Pediastrum duplex* var. *gracillimum* (Kützing)

Coenobia is composed of 8.0-16.0 cells (100.0–110.0 µm in diameter); marginal cells are morphologically similar or with two processes that are horn-like in appearance. Cell walls are characterized as smooth. Marginal cells of the coenobium are 16.0– 21.0 µm long, 14.0–18.0 µm in diameter; inner cells 13.0–19.0 µm long, 16.0–22.0 µm in diameter.

Found existing as a greenish layer on stem and leaves of water hyacinth submerged in water together with other filamentous green algae and cyanobacteria.

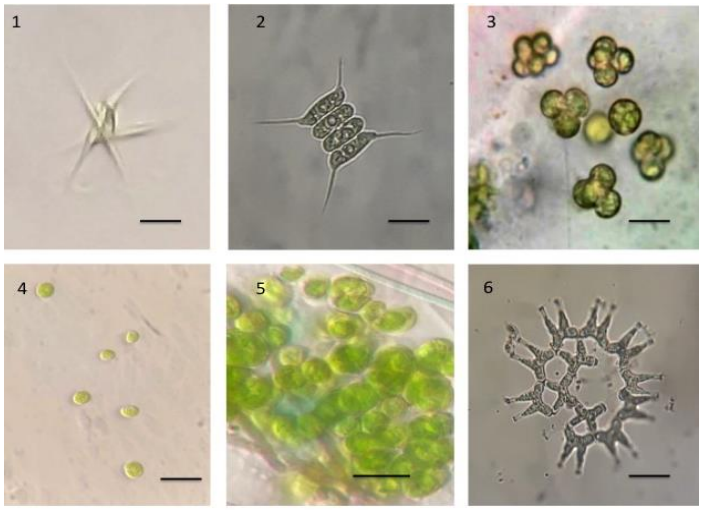

Plate III. Photomicrographs of (1) *Ankistrodesmus falcatus* Corda (Ralfs), (2) *Scenedesmus quadricauda* Chodat, (3) *Westella botryoides* (West) De Wildeman, (4) *Chlorella vulgaris* Beyerinck [Beijerinck], (5) *Chlorococcum infusionum* (Schrank) Meneghini, (6) *Lacunastrum gracillimum* (West & G.S. West) H. McManus. All scale bars = 10 µm.

Class: Conjugatophyceae (Zygnematophyceae)
Order: Desmidiales
Family: Desmidiaceae
Genus: *Staurastrum* Meyen ex Ralfs

1. *Staurastrum gracile* Ralfs ex Ralfs Pl. IV, Fig. 1

Cells are small to large with 13.0-54.0 µm in length and 21.0-107.0 µm in width; shallow median constriction (isthmus) is present where semicell walls overlap, usually occurring in two intergrading cell morphologies. Single stellate (lobed) chloroplasts (end view), with one or several pyrenoid. Reproduction is by cell division and formation of semicell typical of desmids.

Found existing as a light greenish layer on leaves and stem of water hyacinth submerged slightly in water together with other diatoms, green algae, and filamentous cyanobacteria.

Euglenophyta
Class: Euglenophyceaea
Order: Euglenales
Family: Phacaceae
Genus: *Phacus* Dujardin

1. *Phacus longicauda* (Ehrenberg) Dujardin Pl. IV, Fig. 2

BASIONYM: *Euglena longicauda* Ehrenberg

Cells are solitary, elliptic and broadly flattened (71.5 µm × 43.5 µm); anterior end is broadly rounded while the terminal end are tapering into a long cauda (nearly straight or slightly curved usually 20.0 - 25.0 µm long); numerous small discoid chloroplasts; single paramylon grain lies at the center; spirally striated pellicle; eyespot is present.

Found existing as a light greenish layer on stems and leaves of water spinach submerged slightly in water together with other cyanobacteria.

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

1. *Lepocinclis acus* (O.F. Müller) B. Marin and Melkonian Pl. IV, Fig. 3

BASIONYM: *Vibrio acus* O.F. Müller

Cells are elongated and spindle-shaped characterized by having a pointed anterior and posterior end; 59.3 µm × 16.5 µm; posterior end about 11.0 µm long; two big and elongated rod-shaped paramylon bodies and numerous disc-shaped chloroplasts are distributed within the cell.

Found existing as a light greenish layer on leaves and stems of water spinach and water hyacinth submerged slightly in water together with other filamentous green algae and cyanobacteria.

Class: Euglenophyceaea
Order: Euglenales
Family: Euglenaceae
Genus: *Trachelomonas* Ehrenberg

1. *Trachelomonas armata* (Ehrenberg) F. Stein Pl. IV, Fig. 4

BASIONYM: *Pantotrichum armatum* Ehrenberg

Cells are always solitary, and protoplasts are highly metabolic and are loosely enclosed in a firm gelatinous shell (lorica). Lorica broadly ovoid, (27.4 µm × 23.0 µm); presence of (4-6) spines at the posterior end of the cell; apical pore of the cell encircled with low collar; parietal chloroplasts which may or may not have pyrenoids; single emergent flagellum can be observed in an aperture.

Found existing as a brownish to greenish layer on stem and leaves of water lettuce submerged slightly in water together with other filamentous fungi and cyanobacteria.

Plate IV. Photomicrographs of (1) *Staurastrum gracile* Ralfs ex Ralfs, (2) *Phacus longicauda* (Ehrenberg) Dujardin, (3) *Lepocinclis acus* (O.F. Müller) B. Marin and Melkonian, (4) *Trachelomonas armata* (Ehrenberg) F. Stein. All scale bars = 10 µm.

In the Philippines, little is known on the distribution, taxonomy and diversity of cyanobacteria and microalgae associated with aquatic macrophytes found in marine and freshwater ecosystems. A total of 22 epiphytic algal taxa from three dominant aquatic macrophyte (*Pistia stratiotes*, *Eichhornia crassipes* and *Ipomoea aquatica*) found in Sta. Cruz River were observed in the study. The taxonomic list present 8 taxa belonging to the Chlorophyta, 4 to the Cyanobacteria, 7 to the Bacillariophyta, and 3 taxa to the division Euglenophyta. This study reported and described for the first time in the Philippines the existence of *Planktothrix compressa* (Utermöhl) Anagnostidis et Komárek, a rare cyanobacteria first reported in submerged roots of *Pistia stratiotes* found in Sta. Cruz River. One species is also reported here for the first time in the Philippines based on recent algal taxonomic nomenclature and this is *Ulnaria ulna* (Nitzsch) Compère that is based on the former name of *Synedra ulna* (Nitzsch) Ehrenberg. In general, it was observed that the consortium of algal mats in submerged stem, leaves and roots of the dominant macrophytes are composed mainly of unicellular and filamentous type of the eukaryotic algae and cyanobacteria as well as other filamentous fungi. The algal groups observed on the macrophytes have been recorded to be similar in other taxonomic studies done for macrophytes in aquatic ecosystems found in the Philippines and other countries (**Rañola *et al.*, 1990; Sultana *et al.*, 2004; Arguelles, 2019 a, b**). Algal epiphytes associated with a macrophyte, *Vallisneria americana* in St. John Rivers in Florida (USA) documented a total of 122 taxa of algal epiphytes wherein thirteen genera (*Cyclotella*, *Nitzschia*, *Synedra* (*Ulnaria*), *Rhopalodia*, *Ankistrodemus*, *Lacunastrum* (*Pediastrum*), *Chroococcus*, *Oscillatoria*, *Chlorococcum*, *Scenedesmus*, *Chlorella*, *Euglena* and *Trachelomonas*) were observed to be similar to the taxa reported on the current investigation (**Dunn *et***

***al.*, 2008**). Also, taxonomic survey on the composition of algal epiphytes from three aquatic macrophytes (*Typha latifolia*, *Nymphaea alba*, and *Ceratophyllum demersum*,) at Acarlal floodplain forest in Northern Turkey reported the occurrence of similar algal taxa such as *Phacus longicauda*, *Trachelomonas armata*, *Cyclotella meneghiniana*, *Nitzschia palea*, *Rhopalodia gibba*, and *Chroococcus minutus* (**Tunca *et al.*, 2014**). In running water environment, submerged aquatic macrophytes contribute to oxygen pool and are considered important habitats for several aquatic organisms (microbes as well small invertebrates and vertebrates). Macrophytes are abundant in the littoral zones of rivers worldwide, frequently considered as dominant species in the periphyton communities and sometimes associated in producing nuisance growths under eutrophic conditions. The environmental persistence of these organisms in an aquatic environment promotes the occurrence of high taxonomic diversity of cyanobacterial and microalgal epiphytes that can be use as good ecological indicators to determine the quality of water in a river system. In this study, several algal taxa were identified which can be use as biological indicator for aquatic ecosystem health assessment of Sta. Cruz River. Some of the algal taxa identified such as *Aulacoseira granulata*, *Cyclotella meneghiniana*, *Nitzschia palea*, *Phacus longicauda*, *Lepocinclis acus*, *Trachelomonas armata*, *Oscillatoria tenuis*, *Planktothrix compressa*, *Chroococcus minutus*, *Scenedesmus quadricauda*, and *Chlorella vulgaris* are indicative of nutrient pollution in a eutrophic system (**Dunn *et al.*, 2008; Effiong & Inyang, 2015; Arguelles, 2020a**). The taxonomic data obtained on this survey will serve as baseline data in the evaluation of the current ecological status of Sta. Cruz River. Also, evaluation of the interaction of other environmental parameters (such as dissolved oxygen, pH, light intensity, and temperature) in relation to the spatial-temporal distribution of algal epiphytes in Sta. Cruz River is important to further understand the ecological state of the river.

CONCLUSION

The taxonomic survey done in this study shows diverse collection of microalgae and cyanobacteria associated with aquatic macrophytes found in Philippine freshwater ecosystem. Among these taxa, the existence of a rare filamentous cyanobacteria, *Planktothrix compressa* (Utermöhl) Anagnostidis et Komárek is described for the first time in the Philippines. The result of this survey suggests that further study on the diversity and ecological interactions of algal epiphytes in relation to other aquatic macrophytes found in both marine and freshwater habitat is needed since only few studies were reported in the Philippines. Also, the use of combined morphological and molecular techniques for future taxonomic studies of epiphytic algae in the Philippines is recommended. The current survey provided a quick assessment of some of the dominant algal epiphytes in a river ecosystem and provides basal information for further molecular studies.

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