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Revised and an updated checklist of cyanobacteria in mangrove environments: Chroococcales, Chroococcidiopsidales, Gloeobacterales and Synechococcales

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ABSTRACT

Based on the literature about cyanobacteria from the mangrove environments of representing the orders, Chroococcales, Chroococcidiopsidales, Gloeobacterales and Synechococcales, we consulted 42 publications (national and international journals and books published from 1980 to 2020). A total of 141 species were referred, in which 72 taxa of Chroococcales, 66 taxa of Synechococcales, 2 taxa of Chroococcidiopsidales and 1 taxon of Gloeobacterales respectively. The dominant family was Chroococcaceae with 46 species, followed by Merismopediaceae and Oculatellaceae with 23 species each, Microcystaceae with 11 species, Aphanothecaceae with 8 species, Heteroleibleiniaceae with 6 species, Shizotrichaceae and Synechococcaceae with 3 species, Entophysalidaceae, Gomphosphaeriaceae, Stichosiphonaceae, Chroococcidiopsidaceae, Chamaesiphonaceae, Coleofasciculaceae, Oculatellaceae and Trichocoleusaceae with 2 species each, Cyanothrichaceae and Gloeobacteraceae with one species each. Cyanobacterial diversity is underestimated in mangrove ecosystems when compared to the number of recognised species.

Keywords: Cyanobacteria, Taxonomy, Mangrove environment, Biodiversity, Distribution

1. INTRODUCTION

Cyanobacteria are a vast and diverse category of prokaryotes with significant biological relevance. They range from unicellular to colonial filamentous and are important components of photosynthetic assemblages in planktic, benthic, epiphytic and edaphic habitats of the mangrove ecosystem (Rajaneesh et al.,



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2020). Nowadays, knowledge on the diversity and distribution of cyanobacteria in mangrove environments is very inconsistent. The order Chroococcales embraces all the unicellular or colonial cyanobacteria which do not form true filaments. The families of Chroococcales are classified based on the type of cell division, the polarity of cells and colonies, the form and structure of a colony, formation of various types of mucilaginous strands, layers and the position of cells in a colony (Komarek and Anagnostidis, 1998). According to this work, the cyanobacteria group contains four orders such as Chroococcales, Chroococciopsidales, Gloeobacterales and Synechococcales. The taxonomy and classification of Synechococcales and Synechococcus-like cyanobacteria has been extensively studied by Mai et al., 2018 and Komarek et al., 2020. The members of the order Synechococcales are still problematic since it contains coccoid, bacilloid unicellular and colonial genera to simple filamentous forms. This work aims to create a real list of recent cyanobacterial taxa inhabiting the mangrove environment based on modern taxonomic revisions and update nomenclature to reflect current taxonomic understanding for previously described taxa.

2. MATERIAL AND METHODS

The data of coccoid and non-heterocytous members of the order Synechococcales of cyanobacteria in mangrove habitats has been compiled solely from published works of literature from 1980-2020. We used 42 research papers and books published nationally and internationally to create a catalogue of cyanobacterial species and the articles in which they are cited. In mangrove ecosystems, cyanobacteria can be found in a variety of habitats, including epipsammic/edaphic, epizoic, epiphytic, planktic, benthic, and epilithic forms. Some publications may not explicitly mention the occurrence of cyanobacterial species, such species are included under the category 'mangrove environment'. Different techniques for collecting cyanobacteria were described in the original literature mentioned in this study.

The list of cyanobacterial species is based on the published works of literature. We considered only the published works that mentioned cyanobacteria at the species level. Names of taxa are given with proper author citation. Species are classified according to respective family. The species are classified based on the current classification system proposed by Komarek et al., 2014 and Hauer and Komarek, 2021 and the entity of the taxonomically accepted species are verified by Guiry and Guiry, 2021. When a specific or infraspecific taxon is recorded under a synonym if cited, it is represented under the currently accepted names and marked with an equal symbol (=). Newly discovered species are marked with an asterisk (*).

3. RESULT AND DISCUSSION

The total list of cyanobacteria in mangrove environments comprises 141 species that occupy a variety of habitats, including epipsammic/edaphic, epizoic, epiphytic, planktic, benthic, and epilithic forms. From 42 research articles, books and theses published nationally and internationally from 1980 to 2020, we considered cyanobacteria having species-level identification (Table 1). The result showed that 141 cyanobacterial species belong to the orders, Chroococcales (72 taxa), Chroococciopsidales (2 taxa), Gloeobacterales (1 taxon) and Synechococcales (66 taxa). From this documentation analysis, the dominant family was Chroococcaceae with 46 species, followed by Merismopediaceae and Oculatellaceae with 23 species in each, Microcystaceae with 11 species, Aphanothecaceae with 8 species, Heteroleibleiniaceae with 6 species, Shizotrichaceae and Synechococcaceae with 3 species, Entophysalidaceae, Gomphosphaeriaceae, Stichosiphonaceae, Chroococciopsidaceae, Chamaesiphonaceae, Coleofasciculaceae, Oculatellaceae and Trichocoleusaceae with 2 species in each, Cyanotrachaceae and Gloeobacteraceae with one species in each (Table 2; Figure 1).

Table 1. Studies used in the compilation of the taxa occurring from the mangrove environments from 1980 to 2020.

No.	Reference	Country / Province
1.	Potts, 1980	Sinai estuary
2.	Potts and Whitton, 1980	Aldabra Islands
3.	Lambert et al., 1989	Africa
4.	Coppejans and Gallin, 1989	Kenya
5.	Rodriguez and Stoner, 1990	Puerto Rico
6.	Silva, 1991	Africa
7.	Hussain and Khoja, 1993	Saudi Arabia
8.	Branco et al., 1994	Africa

9.	Dhargalkar, 1994	India
10.	Phillips et al., 1994	Africa
11.	Branco et al., 1996	Brazil
12.	Phillips et al., 1996	Africa
13.	Branco et al., 1997	Brazil
14.	Saifullah et al., 1997	Pakistan
15.	Zaib-Un-Nisa et al., 2000	Pakistan
16.	Nogueira and Ferrieira-Correia, 2001	Brazil
17.	Selvakumar and Sundararaman, 2001	India
18.	Sen and Naskar, 2003	India
19.	Branco et al., 2003	Brazil
20.	Steinke et al., 2003	Africa
21.	Sudha, 2005	India
22.	Sudha et al., 2007	India
23.	Bano and Siddiqui, 2007	Pakistan
24.	Nedumaran et al., 2008	India
25.	Boopathi, 2011	India
26.	Leon-Tejera et al., 2011	Mexico
27.	Perez-Estrada et al., 2012	Mexico
28.	Silambarasan et al., 2012	India
29.	Sakthivel and Kathiresan, 2013	India
30.	Shamina et al., 2014	India
31.	Barman et al., 2015	India
32.	Ram and Shamina, 2015	India
33.	Mohammed and Al-Shehri, 2015	Saudi Arabia
34.	Ahmed et al., 2016	Pakistan
35.	Bhuvaneshwari and Muruganandam, 2016	India
36.	Joseph and Saramma, 2016	India
37.	Ramamurthy and Abhinand, 2016	India
38.	Kumar et al., 2017	India
39.	Ram and Shamina, 2017	India
40.	Chakraborty et al., 2019	India
41.	Priya et al., 2019	India
42.	Singh and Bhadury, 2019	India

Table 2. Occurrence of cyanobacteria from mangrove environments, habitat and respective citations are given below. (=) symbol represents the synonyms cited in the consulted work, (*) symbol represents the new species discovered from the mangrove environment.

List of cyanobacterial species	Habitat	References
Chroococcales - Aphanothecaceae		
<i>Aphanothece bullosa</i> (Meneghini) Rabenhorst 1865	Epiphytic	Bano and Siddiqui, 2007

<i>Aphanothece castagnei</i> (Kutzing) Rabenhorst 1865	Epipsammic	Branco et al., 1996
	Mangrove environment	Branco et al., 2003
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001
	Mangrove environment	Joseph and Saramma, 2016
<i>Aphanothece elabens</i> (Brebisson ex Meneghini) Elenkin 1938	Mangrove environment	Mohammed and Al-Shehri, 2015
<i>Aphanothece microscopica</i> Nageli 1849	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epizoic	Bano and Siddiqui, 2007
<i>Aphanothece nidulans</i> P.Richter 1884	Epiphytic	Saifullah et al., 1997
	Epiphytic, Coastal waters of Mangrove environment	Bano and Siddiqui, 2007
<i>Aphanothece pallida</i> (Kutzing) Rabenhorst 1863	Epiphytic	Ram and Shamina, 2015
	Mangrove environment	Ram and Shamina, 2017
<i>Aphanothece saxicola</i> Nageli 1849	Mangrove environment	Dhargalkar, 1994
	Epiphytic	Branco et al., 1996
<i>Aphanothece stagnina</i> (Sprengel) A.Braun 1863	Epiphytic	Silva, 1991
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001
	Planktic	Sen and Naskar, 2003
	Epilithic	Bano and Siddiqui, 2007
Chroococcales - Chroococcaceae		
<i>Chondrocystis dermochroa</i> (Nageli ex Kutzing) Komarek and Anagnostidis 1995 (=) <i>Gloeocapsa dermochroa</i> Nägeli ex Kützing 1849	Mangrove environment	Joseph and Saramma, 2016
<i>Chroococcus cohaerens</i> (Brebisson) Nageli 1849	Epizoic, Epilithic, Edaphic, Coastal waters of mangrove environment	Bano and Siddiqui, 2007
	Mangrove environment	Joseph and Saramma, 2016
<i>Chroococcus dispersus</i> (Keissler) Lemmermann 1904	Epiphytic	Bano and Siddiqui, 2007
<i>Chroococcus giganteus</i> West 1892	Mangrove Swamps	Hussain and Khoja,

		1993
<i>Chroococcus gomontii</i> Nygaard 1926	Epiphytic	Bano and Siddiqui, 2007
<i>Chroococcus hansgirgii</i> Schmidle 1900	Epiphytic, Epilithic	Lambert et al., 1989
	Epiphytic	Steinke et al., 2003
	Epiphytic	Bano and Siddiqui, 2007
<i>Chroococcus indicus</i> Zeller 1873	Epiphytic, Edaphic	Bano and Siddiqui, 2007
<i>Chroococcus macrococcus</i> (Kutzing) Rabenhorst 1863	Mangrove Swamps	Hussain and Khoja, 1993
	Epiphytic, Mangrove swamps	Bano and Siddiqui, 2007
<i>Chroococcus major</i> Komarek and Komakova-Legnerova 2007	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Chroococcus membraninus</i> (Meneghini) Nageli 1849	Epiphytic	Branco et al., 1996
<i>Chroococcus minor</i> (Kutzing) Nageli 1849	Epiphytic	Silva 1991
	Epiphytic	Branco et al., 1996
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epilithic, Epizoic	Bano and Siddiqui, 2007
	Planktic	Nedumaran et al., 2008
	Mangrove environment	Mohammed and Al-Shehri, 2015
	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Chroococcus minutus</i> (Kutzing) Nageli 1849	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Sudha 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Epilithic, Edaphic, Rockpool waters of mangrove environment	Bano and Siddiqui, 2007
	Epiphytic	Boopathi, 2011
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Mohammed and Al-Shehri, 2015

	Mangrove environment	Joseph and Saramma, 2016
<i>Chroococcus montanus</i> Hansgirg 1893	Epiphytic, Epizoic	Bano and Siddiqui, 2007
	Epiphytic	Boopathi, 2011
	Mangrove environment	Joseph and Saramma, 2016
<i>Chroococcus obliterated</i> Richter 1885	Epiphytic	Leon-Tejera et al., 2011
	Epiphytic	Perez-Estrada et al., 2012
<i>Chroococcus pallidus</i> Nageli 1849	Epilithic	Bano and Siddiqui, 2007
<i>Chroococcus schizodermaticus</i> West 1892	Rockpool waters of mangrove environment	Bano and Siddiqui, 2007
<i>Chroococcus spelaeus</i> Ercegovic 1925	Mangrove Swamps	Hussain and Khoja, 1993
<i>Chroococcus tenax</i> (Kirchner) Hieronymus 1892	Mangrove Swamps, Epilithic	Hussain and Khoja, 1993
	Epiphytic	Bano and Siddiqui, 2007
	Planktic	Nedumaran et al., 2008
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Joseph and Saramma, 2016
<i>Chroococcus turgidus</i> (Kützing) Nageli 1849	Mangrove environment	Coppejans and Gallin, 1989
	Epiphytic	Lambert et al., 1989
	Mangrove environment	Hussain and Khoja, 1993
	Mangrove environment	Dhargalkar, 1994
	Epiphytic	Steinke et al., 2003
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Edaphic, Coastal waters of mangrove environment	Bano and Siddiqui, 2007
	Planktic	Nedumaran et al., 2008
	Mangrove environment	Silambarasan et al., 2012
	Mangrove	Sakthivel and

	environment	Kathiresan, 2013
	Mangrove environment	Shamina et al., 2014
	Mangrove environment	Mohammed and Al-Shehri, 2015
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Ramamurthy and Abhinand, 2016
	Mangrove environment	Ram and Shamina, 2017
<i>Chroococcus turgidus</i> var. <i>maximus</i> Nygaard 1926	Epiphytic	Silva, 1991
<i>Chroococcus turicensis</i> (Nageli) Hansgirg 1887	Mangrove environment	Hussain and Khoja, 1993
<i>Chroococcus varius</i> A.Braun 1876	Mangrove environment	Silambarasan et al., 2012
<i>Chroococcus westii</i> J.B.Petersen 1923	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
<i>Cyanobacterium cedrorum</i> (Sauvageau) Komarek, J.Kopecky and Cepak 1999 (=) <i>Synechococcus cedrorum</i> Sauvageau 1892	Mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Bhuvaneswari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Cyanosarcina spectabilis</i> (Geitler) Kovacic 1988 (=) <i>Myxosarcina spectabilis</i> Geitler 1933	Epiphytic	Zaib-Un-Nisa et al., 2000
	Epiphytic, Epizoic, Epilithic, Edaphic, Rockpool water, mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Gloeocapsa aeruginosa</i> Kutzing 1843	Planktic	Sen and Naskar, 2003
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
<i>Gloeocapsa calcarea</i> Tilden 1898	Epiphytic	Bano and Siddiqui, 2007
	Mangrove environment	Bhuvaneswari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Gloeocapsa compacta</i> Kutzing 1847	Epiphytic, Epilithic	Bano and Siddiqui,

		2007
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Gloeocapsa decorticans</i> (A.Braun) P.Richter 1930	Epipsammic	Sen and Naskar, 2003
<i>Gloeocapsa gelatinosa</i> Kutzing 1843	Epiphytic, Epizoic, Epilithic, Edaphic, mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Joseph and Saramma, 2016
<i>Gloeocapsa granosa</i> (Berkeley) Kutzing 1847	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
<i>Gloeocapsa kuetzingiana</i> Nageli ex Kutzing 1849	Planktic	Sen and Naskar, 2003
	Edaphic	Bano and Siddiqui, 2007
<i>Gloeocapsa livida</i> (Carmichael) Kutzing 1847	Mangrove environment	Joseph and Saramma, 2016
<i>Gloeocapsa punctata</i> Nageli 1849	Epilithic	Sen and Naskar, 2003
	Epizoic	Bano and Siddiqui, 2007
	Mangrove environment	Barman et al., 2015
<i>Gloeocapsa quaternata</i> Kutzing 1846	Mangrove environment	Joseph and Saramma, 2016
<i>Gloeocapsa rupestris</i> Kutzing 1847	Epipsammic	Sen and Naskar 2003
	Mangrove environment	Joseph and Saramma, 2016
<i>Gloeocapsa sanguinea</i> (C.Agardh) Kutzing 1843	Mangrove environment	Hussain and Khoja, 1993
<i>Gloeocapsa stegophila</i> (Itzigsohn) Rabenhorst 1863	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Mohammed and Al-Shehri, 2015
<i>Gloeocapsopsis crepidinum</i> (Thuret) Geitler ex Komarek 1993	Mangrove Swamps, Epilithic	Hussain and Khoja, 1993
	Epiphytic	Zaib-Un-Nisa et al.,

		2000
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Epilithic, Edaphic	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Joseph and Saramma, 2016
<i>Gloeocapsopsis pleurocapsoides</i> (Novacek) Komarek and Anagnostidis ex Komarek 1993	Epiphytic	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Gloeothece fuscolutea</i> (Nageli ex Kutzing) Nageli 1849	Epiphytic	Bano and Siddiqui, 2007
<i>Gloeothece palea</i> (Kutzing) Nageli 1849	Epipsammic	Branco et al., 1996
	Epizoic	Bano and Siddiqui, 2007
<i>Gloeothece rhodochlamys</i> Skuja 1949	Epizoic	Bano and Siddiqui, 2007
<i>Gloeothece rupestris</i> (Lyngbye) Bornet 1880	Epiphytic	Branco et al., 1996
	Epiphytic, Epizoic	Bano and Siddiqui, 2007
	Epiphytic	Zaib-Un-Nisa et al., 2000
<i>Gloeothece samoensis</i> Wille 1913	Epiphytic, Epizoic, Epilithic, Edaphic, Rockpool water, coastal waters of mangrove environment	Bano and Siddiqui, 2007
<i>Lightfootiella montana</i> (Lightfoot) Hasler, Pentecost, Jahodarova, Dvorak et Pouluckova 2018 (=) <i>Anacystis montana</i> (Lightfoot) Drouet and Daily 1952	Epiphytic	Rodriguez and Stoner, 1990
Chroococcales - Cyanothrichaceae		
<i>Johannesbaptistia pellucida</i> (Dickie) W.R.Taylor and Drouet 1938	Mangrove environment	Coppejans and Gallin, 1989
	Mangrove Swamps	Hussain and Khoja, 1993
	Epiphytic	Selvakumar and Sundararaman, 2001
	Planktic	Sen and Naskar, 2003

	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epilithic	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Joseph and Saramma, 2016
Chroococcales - Entophysalidaceae		
<i>Entophysalis conferta</i> (Kutzing) Drouet and Daily 1948 (=) <i>Chlorogloea conferta</i> (Kutzing) Setchell and N.L.Gardner 1918	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
<i>Entophysalis granulosa</i> Kutzing 1843	Epipsammic	Potts and Whitton, 1980
	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Sakthivel and Kathiresan, 2013
Chroococcales - Gomphosphaeriaceae		
<i>Gomphosphaeria aponina</i> Kutzing 1836	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Ramamurthy and Abhinand, 2016
<i>Gomphosphaeria aponina</i> var. <i>multiplex</i> Nygaard 1926	Microbial mat	Hussain and Khoja, 1993
Chroococcales - Microcystaceae		
<i>Microcystis aeruginosa</i> (Kutzing) Kutzing 1846	Planktic	Nedumaran et al., 2008
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Bhuvaneshwari and Muruganandam, 2016
	Mangrove environment	Kumar et al., 2017
	Mangrove environment	Priya et al., 2019
<i>Microcystis bengalensis</i> Banerjee 1936	Planktic	Sen and Naskar, 2003
<i>Microcystis flosaquae</i> (Wittrock) Kirchner 1898	Mangrove environment	Ramamurthy and Abhinand, 2016
<i>Microcystis halophila</i> var. <i>macrococca</i> (Hansgirg) P.C.Silva 1996 (=) <i>Aphanocapsa litoralis</i> var. <i>macrococca</i> Hansgirg 1893	Mangrove environment	Hussain and Khoja, 1993

<i>Microcystis lamelliformis</i> Holsinger 1954	Mangrove environment	Ramamurthy and Abhinand, 2016
<i>Microcystis orissica</i> West 1911	Mangrove environment	Joseph and Saramma, 2016
<i>Microcystis protocystis</i> W.B.Crow 1923	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Microcystis pulverea</i> (H.C.Wood) Forti 1907	Mangrove environment	Ramamurthy and Abhinand, 2016
<i>Microcystis robusta</i> (H.W.Clark) Nygaard 1925	Epiphytic	Selvakumar and Sundararaman, 2001
	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Microcystis smithii</i> Komarek and Anagnostidis 1995 (= <i>Aphanocapsa pulchra</i> (Kutzing) Rabenhorst 1865)	Planktic	Sen and Naskar, 2003
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic	Boopathi, 2011
<i>Microcystis viridis</i> (A.Braun) Lemmermann 1903	Edaphic	Bano and Siddiqui, 2007
Chroococcales - Stichosiphonaceae		
* <i>Stichosiphon mangle</i> L.H.Z.Branco, S.M.F.Silva, and C.L.Sant'Anna 1995	Epiphytic	Branco et al.,1994
	Epiphytic	Branco et al.,1996
<i>Stichosiphon sansibaricus</i> (Hieronymus) F.E.Drouet and W.A.Daily 1956	Mangrove environment	Sen and Naskar, 2003
	Mangrove environment	Ramamurthy and Abhinand, 2016
Chroococciopsidales – Chroococciopsidaceae		
<i>Chroococciopsis cubana</i> Komarek and Hindak 1975	Epiphytic	Branco et al., 1996
<i>Chroococciopsis indica</i> Desikachary 1959	Epiphytic	Zaib-Un-Nisa et al., 2000
	Epiphytic, Epizoic, Edaphic, mangrove swamps	Bano and Siddiqui, 2007
Gloeobacterales - Gloeobacteraceae		
<i>Gloeobacter violaceus</i> Rippka, J.B.Waterbury and Cohen-Bazire 1974 (= <i>Gloeotheca linearis</i> Nageli 1849)	Mangrove environment	Ramamurthy and Abhinand, 2016

Synechococcales – Chamaesiphonaceae		
<i>Chamaesiphon confervicola</i> A.Braun 1864 (=) <i>Chamaesiphon curvatus</i> Nordstedt 1878	Epiphytic	Sen and Naskar, 2003
<i>Chamaesiphon sideriphilus</i> Starmach 1929	Mangrove environment	Ramamurthy and Abhinand, 2016
Synechococcales – Coelosphaeriaceae		
<i>Coelosphaerium dubium</i> Grunow 1865	Mangrove environment	Joseph and Saramma, 2016
<i>Coelosphaerium kuetzingianum</i> Nageli 1849	Epiphytic	Bano and Siddiqui, 2007
	Epiphytic	Boopathi, 2011
Synechococcales – Heteroleibleiniaceae		
<i>Heteroleibleinia gardneri</i> (Geitler) Anagnostidis and Komarek 1988 (=) <i>Lyngbya gardneri</i> Geitler 1932	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Epilithic, Edaphic, coastal waters	Bano and Siddiqui, 2007
	Epiphytic	Boopathi, 2011
<i>Heteroleibleinia infixa</i> (Fremy) Anagnostidis and Komarek 1988 (=) <i>Lyngbya infixa</i> Frémy 1932	Coastal waters of mangrove environment	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Heteroleibleinia mesotricha</i> (Skuja) Anagnostidis and Komarek 1988 (=) <i>Lyngbya mesotricha</i> Skuja 1949	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Heteroleibleinia willei</i> (Setchell and N.L.Gardner) Guiry and D.M.John 2021 (=) <i>Lyngbya nordgaardii</i> Wille 1919 (=) <i>Leibleinia nordgaardii</i> Anagnostidis and Komárek 1988	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Branco et al.,1997
	Epiphytic, Epilithic, Edaphic, Rockpool waters of mangrove environment	Bano and Siddiqui, 2007
	Mangrove environment	Joseph and Saramma, 2016
<i>Heteroleibleinia chaetomorphae</i> (Iyengar and Desikachary) Anagnostidis and Komarek 1988 (=) <i>Lyngbya chaetomorphae</i> Iyengar and Desikachary 1944	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic	Boopathi, 2011
	Mangrove environment	Sakthivel and Kathiresan, 2013
<i>Heteroleibleinia kuetzingii</i> (Schmidle) Compere 1985 (=) <i>Lyngbya kuetzingii</i> Schmidle 1897	Among other algae	Potts, 1980
	Epiphytic	Branco et al.,1997

Synechococcales – Leptolyngbyaceae		
* <i>Euryhalinema mangrovii</i> Chakraborty et Mukherjee 2019	Epipsammic	Chakraborty et al., 2019
<i>Leibleinia epiphytica</i> (Hieronymus) Compere 1985 (=) <i>Lyngbya epiphytica</i> Hieronymus 1898	Microbial mat	Hussain and Khoja, 1993
<i>Leibleinia subtilis</i> (Holden) Anagnostidis and Komarek 1988	Epiphytic	Perez-Estrada et al., 2012
* <i>Leptolongatus litoralis</i> Chakraborty et Mukherjee in Chakraborty 2019	Epipsammic	Chakraborty et al., 2019
<i>Leptolyngbya africana</i> (Lemmermann) Anagnostidis and Komarek 1988 (=) <i>Phormidium africanum</i> Lemmermann 1911	Mangrove swamps	Bano and Siddiqui, 2007
<i>Leptolyngbya angustissima</i> (West and G.S.West) Anagnostidis and Komarek 1988 (=) <i>Phormidium angustissimum</i> West and G.S.West 1897	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Mangrove environment	Joseph and Saramma, 2016
<i>Leptolyngbya cebennensis</i> (Gomont) I.Umezaki and M.Watanabe 1994 (=) <i>Phormidium cebennense</i> Gomont 1899	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Epilithic, Edaphic, rock pool water	Bano and Siddiqui, 2007
<i>Leptolyngbya crosbyana</i> (Tilden) Anagnostidis and Komarek 1988 (=) <i>Phormidium crosbyanum</i> Tilden 1909	Epiphytic	Rodriguez and Stoner, 1990
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001
<i>Leptolyngbya foveolarum</i> (Gomont) Anagnostidis and Komarek 1988 (=) <i>Phormidium foveolarum</i> Gomont 1892	Epiphytic, Epizoic, Epilithic, Edaphic, coastal waters	Bano and Siddiqui, 2007
	Mangrove environment	Barman et al., 2015
	Mangrove environment	Joseph and Saramma, 2016
<i>Leptolyngbya fragilis</i> (Gomont) Anagnostidis and Komarek 1988 (=) <i>Phormidium fragile</i> Gomont 1893	Microbial mat	Hussain and Khoja, 1993
	Mangrove environment	Dhargalkar, 1994
	Epiphytic	Saifullah et al., 1997
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001
	Epiphytic	Sen and Naskar, 2003
	Mangrove environment	Sudha, 2005

	Mangrove environment	Sudha et al., 2007
	Epilithic	Bano and Siddiqui, 2007
	Epiphytic	Nedumaran et al., 2008
	Epiphytic	Boopathi, 2011
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Mohammed and Al-Shehri, 2015
	mangrove environment	Ramamurthy and Abhinand, 2016
<i>Leptolyngbya lagerheimii</i> (Gomont ex Gomont) Anagnostidis and Komarek 1988 (=) <i>Lyngbya lagerheimii</i> Gomont ex Gomont 1892	Epiphytic	Branco et al., 1997
	Epilithic	Bano and Siddiqui, 2007
<i>Leptolyngbya laminosa</i> (Gomont ex Gomont) Anagnostidis and Komárek 1988 (=) <i>Phormidium laminosum</i> Gomont ex Gomont 1892	Epiphytic	Bano and Siddiqui, 2007
<i>Leptolyngbya nostocorum</i> (Bornet ex Gomont) Anagnostidis and Komarek 1988 (=) <i>Plectonema nostocorum</i> Bornet ex Gomont 1892	mangrove environment	Joseph and Saramma, 2016
<i>Leptolyngbya perelegans</i> (Lemmermann) Anagnostidis and Komarek 1988 (=) <i>Lyngbya perelegans</i> Lemmermann 1899	Mangrove environment	Branco et al., 1997
	Mangrove environment	Branco et al., 2003
	Epiphytic	Bano and Siddiqui, 2007
<i>Leptolyngbya polysiphoniae</i> (Fremy) Anagnostidis 2001 (=) <i>Lyngbya polysiphoniae</i> Frémy 1930	Epiphytic	Bano and Siddiqui, 2007
<i>Leptolyngbya purpurascens</i> (Gomont ex Gomont) Anagnostidis and Komarek 1988 (=) <i>Phormidium purpurascens</i> Gomont ex Gomont 1892	Mangrove environment	Branco et al., 2003
	Mangrove environment	Joseph and Saramma, 2016
<i>Leptolyngbya tenuis</i> (Gomont) Anagnostidis and Komarek 1988 (=) <i>Phormidium tenue</i> Gomont 1892	Mangrove environment	Branco et al., 1997
	Epiphytic	Zaib-Un-Nisa et al., 2000
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Rockpool water, Coastal pool water	Bano and Siddiqui, 2007
	Epiphytic	Nedumaran et al., 2008

	Epiphytic	Boopathi 2011
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Mohammed and Al-Shehri, 2015
	Mangrove environment	Barman et al., 2015
	Mangrove environment	Ahmed et al., 2016
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Priya et al., 2019
<i>Leptolyngbya terebrans</i> (Bornet and Flahault ex Gomont) Anagnostidis and Komarek 1988 (=) <i>Plectonema terebrans</i> Bornet and Flahault ex Gomont 1892	Mangrove environment	Hussain and Khoja, 1993
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Priya et al., 2019
<i>Leptolyngbya valderiana</i> (Gomont) Anagnostidis and Komarek 1988 (=) <i>Phormidium valderianum</i> Gomont 1892	Epiphytic, Epizoic, Epilithic, Edaphic, rock pool water, coastal waters	Bano and Siddiqui, 2007
	Epiphytic	Boopathi, 2011
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Barman et al., 2015
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Ramamurthy and Abhinand 2016
<i>Phormidesmis mollis</i> (Gomont) Turicchia, Ventura, Komarkova and Komarek 2009 (=) <i>Phormidium molle</i> Gomont 1892	Mangrove environment	Hussain and Khoja, 1993
	Epiphytic	Branco et al., 1997
	Epiphytic	Zaib-Un-Nisa et al., 2000
	Mangrove environment	Branco et al., 2003

	Epiphytic	Bano and Siddiqui, 2007
	Mangrove environment	Shamina et al., 2014
	Epiphytic	Ram and Shamina, 2015
	Mangrove environment	Joseph and Saramma, 2016
	Mangrove environment	Ram and Shamina, 2017
<i>Planktolynghya limnetica</i> (Lemmermann) Komarkova-Legnerova and Cronberg 1992 (=) <i>Lynghya limnetica</i> Lemmermann 1898	Mangrove environment	Ram and Shamina, 2017
<i>Planktolynghya minor</i> (Geitler and Ruttner) Komarek and Cronberg 2001	Mangrove environment	Barman et al., 2015
<i>Stenomitos frigidus</i> (F.E.Fritsch) Miscoe and J.R.Johansen 2016 (=) <i>Leptolynghya frigida</i> (F.E.Fritsch) Anagnostidis and Komárek 1988	Mangrove environment	Barman et al., 2015
Synechococcales – Merismopediaceae		
<i>Aphanocapsa stagnalis</i> (Lemmermann) Belyakova 2004 (=) <i>Microcystis stagnalis</i> (Lemmermann) Lemmermann 1903	Mangrove environment	Joseph and Saramma, 2016
<i>Aphanocapsa roeseana</i> De Bary in Rabenhorst 1870	Epiphytic	Ram and Shamina, 2015
	Mangrove environment	Ram and Shamina, 2017
<i>Aphanocapsa bififormis</i> A.Braun 1879	Edaphic	Bano and Siddiqui, 2007
	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Priya et al., 2019
<i>Aphanocapsa brunnea</i> (A.Baun ex Kützing) Nägeli 1849	Mangrove environment	Joseph and Saramma, 2016
<i>Aphanocapsa conferta</i> (West and G.S.West) Komarkova-Legnerova and Cronberg 1994 (=) <i>Aphanocapsa elachista</i> var. <i>conferta</i> West and G.S.West 1912	Epiphytic	Lambert et al., 1989
	Epiphytic	Phillips et al., 1994
	Epiphytic	Phillips et al., 1996
	Epiphytic	Steinke et al., 2003
<i>Aphanocapsa grevillei</i> (Berkeley) Rabenhorst 1865	Mangrove Swamps, Epilithic	Hussain and Khoja, 1993
	Epiphytic	Ram and Shamina, 2015
	Mangrove environment	Ram and Shamina, 2017
<i>Aphanocapsa koordersii</i> K.M.Strom 1923	Epiphytic	Selvakumar and

		Sundararaman, 2001
<i>Aphanocapsa litoralis</i> Hansgirg 1892 (=) <i>Microcystis litoralis</i> (Hansgirg) Aboal 1988	Mangrove Swamps	Hussain and Khoja, 1993
	Epiphytic	Saifullah et al., 1997
	Epiphytic	Selvakumar and Sundararaman, 2001
	Planktic, Epipsammic	Sen and Naskar, 2003
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic, Epizoic, Epilithic, Coastal waters of Mangrove environment	Bano and Siddiqui, 2007
	Epiphytic	Nedumaran et al., 2008
	Epiphytic	Leon-Tejera et al., 2011
	Epiphytic	Perez-Estrada et al., 2012
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Bhuvaneswari and Muruganandam, 2016
	Mangrove environment	Joseph and Saramma, 2016
Mangrove environment	Priya et al., 2019	
<i>Aphanocapsa muscicola</i> (Meneghini) Wille 1919 (=) <i>Aphanocapsa montana</i> Cramer 1862	Epiphytic, Epilithic	Lambert et al., 1989
	Epiphytic	Steinke et al., 2003
<i>Aphanocapsa reinboldii</i> (Richter) Komarek and Anagnostidis 1995 (=) <i>Microcystis reinboldii</i> (Richter) Forti 1907	Epipsammic	Potts, 1980
<i>Aphanocapsa rivularis</i> (Carmichael) Rabenhorst 1865	Epiphytic, Rockpool waters of mangrove environment	Bano and Siddiqui, 2007
<i>Eucapsis minuta</i> F.E.Fritsch 1912	Mangrove environment	Joseph and Saramma, 2016
<i>Limnococcus limneticus</i> (Lemmermann) Komarkova, Jezberova, O.Komarek and Zapomelova 2010 (=) <i>Chroococcus limneticus</i> Lemmermann 1898	Coastal waters of mangrove environment	Bano and Siddiqui, 2007
<i>Merismopedia convoluta</i> Brebisson ex Kutzing 1849	Epiphytic, Mangrove swamps	Bano and Siddiqui, 2007
	Microbial mat,	Hussain and Khoja,

	Mangrove Swamps, Pelagic	1993
<i>Merismopedia elegans</i> A.Braun ex Kutzing 1849	Mangrove Swamps	Hussain and Khoja, 1993
	Edaphic, Mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Shamina et al., 2014
	Mangrove environment	Ram and Shamina, 2017
<i>Merismopedia glauca</i> (Ehrenberg) Kutzing 1845	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
	Epiphytic, Epizoic, Epilithic, Edaphic, coastal water, mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Barman et al., 2015
	Mangrove environment	Ramamurthy and Abhinand, 2016
<i>Merismopedia litoralis</i> (Oersted) Rabenhorst 1865	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
<i>Merismopedia minima</i> G.Beck 1897	Epiphytic, Epilithic	Bano and Siddiqui, 2007
	Mangrove environment	Barman et al., 2015
<i>Merismopedia tenuissima</i> Lemmermann 1898	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
	Epipsammic	Sen and Naskar, 2003
	Epiphytic, Edaphic	Bano and Siddiqui, 2007
<i>Merismopedia tranquilla</i> (Ehrenberg) Trevisan 1845 (=) <i>Merismopedia punctata</i> Meyen 1839	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Branco et al., 1996
	Epiphytic	Bano and Siddiqui, 2007
	Mangrove environment	Barman et al., 2015
<i>Synechocystis aquatilis</i> Sauvageau 1892	Epiphytic	Zaib-Un-Nisa et al., 2000
	Mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Barman et al., 2015

	Mangrove environment	Joseph and Saramma, 2016
<i>Synechocystis pevalekii</i> Ercegovic 1925	Epiphytic	Zaib-Un-Nisa et al., 2000
	Epiphytic, Epizoic, Epilithic, Edaphic, Rockpool water, coastal water, mangrove swamps	Bano and Siddiqui, 2007
	Mangrove environment	Sakthivel and Kathiresan, 2013
	Mangrove environment	Barman et al., 2015
	Mangrove environment	Bhuvanewari and Muruganandam, 2016
	Mangrove environment	Ramamurthy and Abhinand, 2016
	Mangrove environment	Priya et al., 2019
<i>Synechocystis salina</i> Wislouch 1924	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Joseph and Saramma, 2016
Synechococcales – Oculatellaceae		
<i>Drouetiella lurida</i> (Gomont) Mai, J.R.Johansen and Pietrasiak 2018 (=) <i>Phormidium luridum</i> Gomont 1892	Epiphytic	Bano and Siddiqui, 2007
<i>Dasygloea lamyi</i> (Gomont ex Gomont) Senna and Komarek 1998 (=) <i>Schizothrix lamyi</i> Gomont ex Gomont 1892	Planktic	Sen and Naskar, 2003
Synechococcales – Schizotrichaceae		
<i>Schizothrix arenaria</i> Gomont 1892	Epiphytic	Lambert et al., 1989
	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Branco et al., 1997
<i>Schizothrix calcicola</i> Gomont 1892	Epiphytic	Potts, 1980
	Epipsammic	Potts and Whitton, 1980
	Microbial mat, Mangrove Swamps	Hussain and Khoja, 1993
<i>Schizothrix telephoroides</i> Gomont 1890	Epiphytic	Selvakumar and Sundararaman, 2001
Synechococcales – Synechococcaceae		
<i>Leemermanniella obesa</i> M.T.P.Azevedo, C.A.Souza and M.Menezes 1999	Epiphytic	Branco et al., 1997
	Mangrove	Nogueira and

(=) <i>Leibleinia pellucida</i> (I.Umezaki) I.Umezaki and M.Watanabe	environment	Ferrieira-Correia, 2001
<i>Synechococcus elongatus</i> (Nageli) Nageli 1849	Epiphytic	Branco et al., 1996
	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Epiphytic	Bano and Siddiqui, 2007
	Mangrove environment	Silambarasan et al., 2012
	Mangrove environment	Joseph and Saramma, 2016
* <i>Synechococcus moorigangaii</i> Singh and Bhadury 2019	Planktic	Singh and Bhadury, 2019
Synechococcales – Trichocoleusaceae		
<i>Trichocoleus acutissimus</i> (N.L.Gardner) Anagnostidis 2001 (=) <i>Microcoleus acutissimus</i> N.L.Gardner 1927	Mangrove environment	Sudha, 2005
	Mangrove environment	Sudha et al., 2007
	Mangrove environment	Shamina et al., 2014
<i>Trichocoleus tenerrimus</i> (Gomont) Anagnostidis 2001 (=) <i>Microcoleus tenerrimus</i> Gomont 1892	Mangrove Swamps	Hussain and Khoja, 1993
	Mangrove environment	Branco et al., 1997
	Mangrove environment	Nogueira and Ferrieira-Correia, 2001

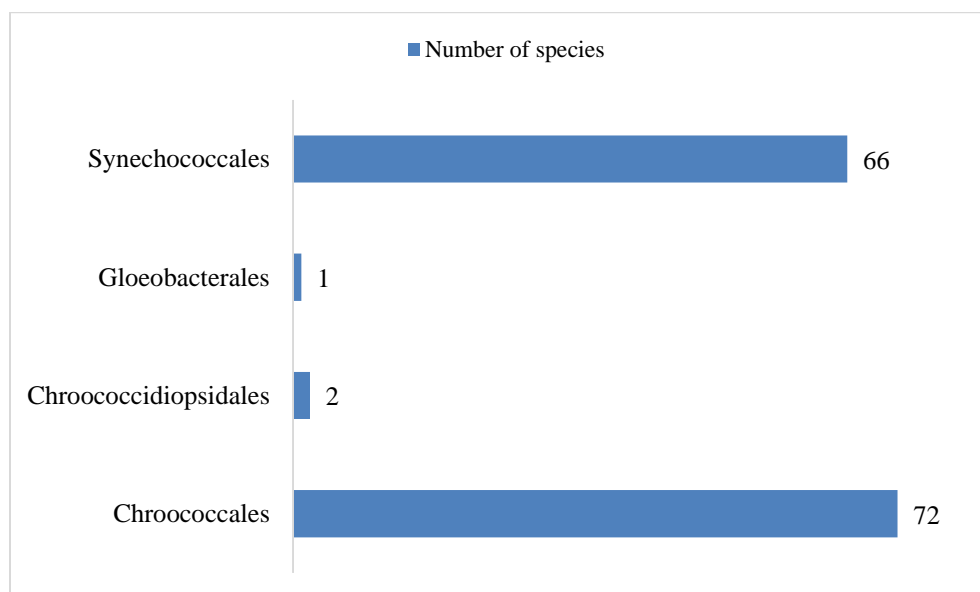


Figure 1: Graphical representation with number of species from the mangrove-associated cyanobacteria according to order.

Studies on the biodiversity of coccoid cyanobacteria from the mangrove environments had started in the 1980s (Potts, 1980; Potts and Whitton, 1980). Research on mangrove-associated cyanobacterial diversity has become increasingly focused since 1990, and there has been a large increase in biodiversity research over the last few decades, although no taxonomic studies have been published in 2020.

The greatest diversity was found in the 'mangrove environment' and epiphytic form (Table 2). Even though planktic cyanobacterial flora has been extensively investigated, it has a low diversity when compared to mangrove ecosystems according to this study. However, the following cyanobacterial species commonly occur as planktic: *Aphanocapsa litoralis*, *Aphanothece stagnina*, *Chroococcus minor*, *Chroococcus tenax*, *Chroococcus turgidus* and *Gloeocapsa aeruginosa*.

It is very difficult to check the validity while considering the misspelt species name, genus abbreviations in the literature and improper author citations are missing in publications. Therefore, the authors should write the species name and its respective author citation properly.

Several traditional Chroococcales genera were confirmed as non-cyanobacterial organisms, eg. *Cyanotheca* Pascher 1914 (type: Caulobacteria) and *Dactylococcopsis* Hansgirg 1888 (type: Green algae) and they were removed from the revised classification system of cyanobacteria (Komarek and Anagnostidis, 1998). But the genus *Dactylococcopsis* was included under the order Chroococcales (family: Chroococcaceae) with 31 species names in the database (<https://www.algaebase.org/>) at present as well as 22 infraspecific names. Of the species names, 17 have been labelled as taxonomically accepted based on the literature under the species name. Thus, the inclusion of this genus is the subject of controversy.

Some researchers reported the occurrence of *Synechococcus cedrorum* from the mangrove environments and it is currently known as *Cyanobacterium cedrorum*. According to recent taxonomic revision (Guiry and Guiry, 2021; Hauer and Komarek, 2021), the genus *Cyanobacterium* is currently regarded as an invalid genus and suggested for further investigation (Tuji et al., 2021). Thus, the entity of this species name is taxonomically uncertain. Many Cyanobacterial species lack gene sequence information. Despite the current method (Komarek et al., 2014) it depicts phylogeny for cyanobacteria because many morphologically similar taxa are polyphyletic and their taxonomy is a particularly vexing topic.

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Author Contributions

Arun T Ram: Contributed substantially to the conception and design of the work, literature collection, preparation of the checklist and interpretation of data for the work.

Tessy Paul P: Contributed substantially to the conception and design of the work, literature collection, and revised the manuscript.

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The authors declare no conflict of interest.

Data and materials availability

All data associated with this study are present in the paper.

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