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# Additions to the freshwater red algal flora of the Philippines

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## Abstract

This paper contributes to expanding the documented freshwater red algal flora of the Philippines, a country historically underrepresented in comparison to its Southeast Asian neighbours. It reports the discovery of four species previously unrecorded in the country's freshwater algal flora. These species were collected from clear, cool, fast-flowing streams within well-shaded, lowland rainforests in the provinces of Bataan and Cavite on Luzon Island. The newly identified species are *Audouinella cylindrica* C.-C.Jao, *Audouinella glomerata* C.-C.Jao, *Kumanoa montagnei* Entwisle, M.L.Vis, W.B.Chiasson, Necchi & A.R.Sherwood, and *Kumanoa tiomanensis* (S.Kumano & Ratnasabapathy) Necchi & M.L.Vis. The paper provides detailed descriptions of their morphological characteristics, habitats, and collection localities, alongside a key to the species of *Kumanoa* recorded in the country. This study highlights the ecological and taxonomic significance of these newly identified species and emphasizes the need for more extensive surveys to address biodiversity gaps in the region.

**Keywords:** distribution, diversity, freshwater, Luzon, Philippines, rhodophytes.

## Introduction

Expanding our understanding of the freshwater red algal flora in the Philippines is essential. In comparison, Thailand, which shares a similar research trajectory in freshwater red algae with the Philippines, has documented 26 species across nine genera (Peerapornpisal et al. 2006; Traichaiyaporn et al. 2008). Likewise, neighbouring Malaysia and Indonesia report 27 species, 13 of which are potential endemics, known only from type collections or specific localities within those countries (Johnston et al. 2014). Most freshwater red algal species in Southeast Asian freshwater habitats are typically confined to flowing waters, with few species recorded from lentic environments (Sheath & Hambrook 1990), and very rarely from polluted water bodies. These patterns highlight the unique and often restrictive habitat preferences of freshwater red algae across the region.

In contrast, the Philippines has documented only seven species across six genera (Skuja 1934; Krishnamurthy 1962; Liao & Largo 1985; Kumano & Liao 1987; Liao & Young 2000; Sherwood & Sheath 2003; Liu et al. 2004; Liao 2010; Vis et al. 2012; Linis & Vitug 2022). Among these are *Kumanoa tabagatenensis* (S.Kumano & Bowden-Kerby) M.L.Vis, Necchi, W.B.Chiasson & Entwisle, and *Kumanoa louisianae* (Skuja) Entwisle, M.L.Vis, W.B.Chiasson, Necchi & A.R.Sherwood, both within the family Batrachospermaceae, as currently defined by Ratnasabapathy & Kumano (1982b), Entwisle et al. (2009), and Vis et al. (2012). The only known Philippine specimen of *K. tabagatenensis* was initially

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identified as *Batrachospermum nonocense* S.Kumano & L.M.Liao from its type locality on Nonoc Island, Surigao del Norte Province (Kumano & Liao 1987). Meanwhile, *K. louisianae*, initially treated by Liao (2010) as *Kumanoa hirosei* (S.Kumano & Ratnasabapathy) L.M.Liao and later synonymized with *K. louisianae* by Vis & Necchi (2021), was first recorded downstream from Palogtoc Falls in Barangay San Roque, Bulusan, Sorsogon Province (Liu et al. 2004; Liao 2010).

Additionally, *Nemalionopsis shawii* Skuja, with its type locality in the Lamao Reserve, Bataan Province, is the generitype species of *Nemalionopsis* Skuja. It is now placed in the Thoreaceae in the new order Thoreales by Müller et al. (2002). In 1962, Krishnamurthy added two records of Philippine freshwater red algae: *Compsopogon caeruleus* (Balbis ex C.Agardh) Montagne and *C. aeruginosus* (J.Agardh) Kützing, both within in Compsopogonaceae, based on specimens collected by W.R. Shaw in 1911 and E.A. Quisumbing in 1929 from Palomar, Manila, and Los Baños (Liu et al. 2004). *Compsopogon aeruginosus* is now considered a synonym of *C. caeruleus* (Guiry 2021). Liao & Young (2000) and Sherwood & Sheath (2003) further documented two other species: *Thorea violacea* Bory from the Matutinao River in southwestern Cebu, and *Hildenbrandia angolensis* Welwitsch ex West & G.S.West from Sto. Niño Cold Spring on Camiguin Island. More recently, Linis & Vitug (2022) reported the presence of *Caloglossa fluviatilis* Krayesky, Fredericq & J.N.Norris (Delesseriaceae, Rhodophyta) from Mauban Creek in Morong Municipality, Bataan Province on Luzon.

During recent botanical surveys on the island of Luzon, the authors encountered ten populations of freshwater red algae in flowing streams. Morphological observations suggest that these populations belong to four species of red algae, all of which are new to the documented freshwater algal flora of the Philippines.

The limited number of documented species in the Philippines compared to neighbouring countries suggests potential under-sampling and highlights a significant gap in regional biodiversity data. The historical records underscore the early efforts and contributions to Philippine freshwater red algal diversity, yet they reveal a pressing need to conduct comprehensive and updated surveys, particularly in unexplored or understudied freshwater ecosystems.

## Materials and Methods

In 2022, specimens were collected from the provinces of Bataan and Cavite on Luzon Island, Philippines. These samples were obtained from clear, well-aerated, and moderately agitated streams at depths ranging from 20 to 60 cm. The collection sites were situated within ravines at elevations between 300 and 730 meters above sea level (masl), surrounded by tropical lowland rainforests with moderate litter layers on the forest floor.

For preservation and analysis, portions of the collected specimens were stored in 10% ethyl alcohol solutions to facilitate identification and morphological characterization. The remaining samples were prepared as dried herbarium vouchers, which were subsequently deposited at the University of the Philippines Los Baños (CAHUP) and the National Museum of the Philippines (PNH) herbaria.

To examine vegetative and reproductive structures, free-hand sections were prepared. Samples were briefly washed in tap water, then mounted in a solution of 50% sugar syrup in distilled water containing 10% formalin, enhancing the visibility of cytoplasmic content. Observations were conducted using an Amscope 20–80× compact multi-lens stereo microscope and a Harman XSZ-107BN binocular microscope, with imaging performed through an Amscope MU500 5MP USB microscope camera.

Species identification relied on diagnostic morphological characteristics referenced from key sources, including Jao (1941), Kumano (1978), Ratnasabapathy & Kumano (1982a), Ott (2009), Necchi et al. (2010), Necchi & Vis (2012), Johnston et al. (2014), and Guiry (2021). These references were instrumental in verifying the distinct morphological features of the specimens collected.

## New country records of freshwater red algae in the Philippines

Family **Acrochaetiaceae**

1) ***Audouinella cylindrica*** C.-C.Jao, *Sinensia* 12: 252 (1940).

*Audouinella cylindrica* is characterized by a bluish-green, hemispherical thallus (Fig. 1. A–D) that is macroscopic, reaching up to 7 mm in height. The thallus comprises both basal (repent) and vertical (erect) systems of filaments, consisting of barrel-shaped to cylindrical vegetative cells. The filaments of the basal system are loosely aggregated, shortly articulated, and irregularly branched. In contrast, the vertical filaments are radially arranged, with alternate branches (axes) in the upper parts, branching at angles of less than 25° from the vertical filaments. The vertical filaments are usually much elongated, terminating in obtuse or slightly attenuated apical cells. The cells of the vertical axes measure 11–14 µm in length and 5–12 µm in diameter, containing 2–4 plate-like chromatophores without pyrenoids. Monosporangia (7–9 µm in diameter and 13–18 µm in length) commonly occur on these filaments, each supported by a 1-cell pedicel, with 2–3 sporangia on each cell of the axial tips, mostly terminal but occasionally uni- or bilateral. Gametangia, carposporangia, and tetrasporangia have not been observed in this species.

**Specimen examined:** PHILIPPINES: Luzon Island, Province of Bataan, Municipality of Orani, Bakyas River, attached to the rocky bottom, submerged in fast-flowing water in a well-shaded lowland rainforest, 14°43’45.05”N, 120°24’01.05”E, 13 August 2022, *V.C. Linis & L.V. Vitug 5758-22* (CAHUP, PNH).

**Remarks:** *Audouinella cylindrica* represents the first of two clear records of freshwater species from this widespread genus in the Philippines as documented in this paper. The discovery *of A. cylindrica* on Luzon Island suggests that this species may have a broader distribution across Southeast Asia than previously documented.

Freshwater species of *Audouinella* have recently been categorized into two distinct groups: red-coloured and bluish species (Necchi et al. 1993a, b; Necchi & Zucchi 1995, 1997). The red-coloured species are understood to be independent organisms capable of producing gametangia, carposporangia, and tetrasporangia (Necchi et al. 1993a; Necchi & Zucchi 1995). In contrast, bluish species are often recognized as an alternate life-history phase of batrachospermalean taxa, known as the "Chantransia" stage, characterized by young gametophytes forming on certain filaments (Necchi & Zucchi 1997).

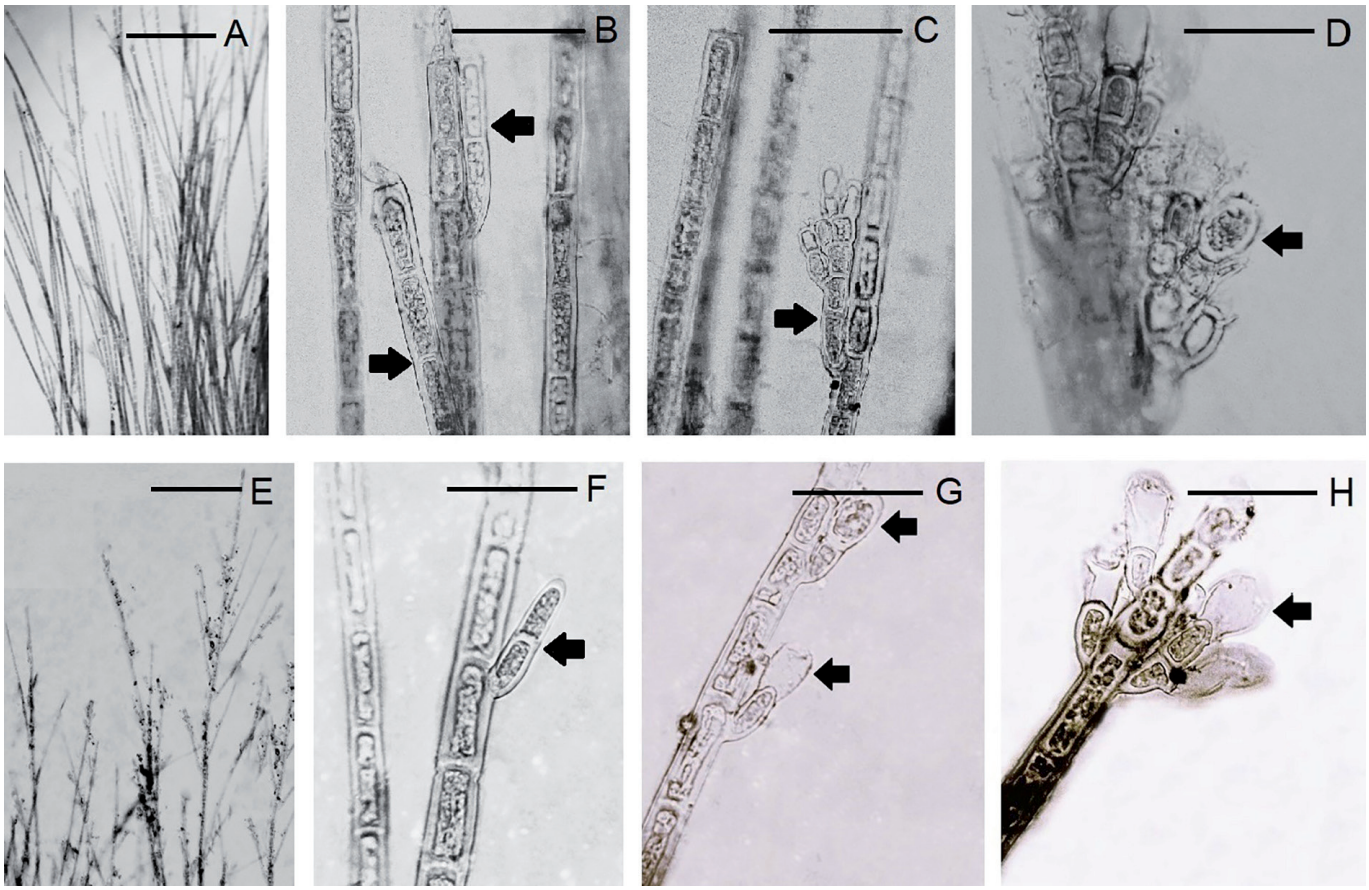


**Fig. 1. A–D.** *Audouinella cylindrica* C.-C.Jao. (A) General view showing vertical filaments bearing alternate branches (axes) in the upper parts. (B) Detail of the vertical filament. (C) Upper parts of the filaments showing branches with angles < 25° (arrowheads). (D) Detail of the filament showing monosporangia in fascicles (arrowheads). All from *V.C. Linis & L.V. Vitug 5758-22* (CAHUP). **E–H.** *Audouinella glomerata* C.-C.Jao. (E) General view showing vertical filaments bearing several alternate branches (axes). (F) Detail of the primary filament showing a branch with an angle < 25° (arrowhead). (G) Detail of a filament showing two monosporangial branches (arrowheads). (H) Several monosporangial branches, each with a short monosporangium (arrowheads). All from *V.C. Linis & L.V. Vitug 5760-22* (CAHUP). Scale bars represent 500 µm (A, E) and 100 µm (B, C, D, E, F, G).

Currently, *A. cylindrica* is classified within the bluish group, which calls for further study to clarify its unique taxonomic features, preferred environmental conditions, and geographic range. Additionally, this finding highlights the need for research on other underreported members of the *Audouinella* genus in Asia, to better understand their distribution and ecological roles.

2) ***Audouinella glomerata*** C.-C.Jao. *Sinensia* 12: 254, pl. 3, figs 18–20 (1941).

*Audouinella glomerata* features a black-blue thallus (Fig. 1. E–H) that is macroscopic, up to 4 mm in height. The thallus consists of basal (repent) and vertical (erect) systems of filaments. The basal system is an irregular prostrate mass of laterally branched, shortly articulated filaments. The vertical system comprises numerous primary filaments, with apices often terminating in delicate, elongated, hair-like cells. These filaments are densely pulvinate, with either few axes (branches) or unbranched. The few axes present are always extended and erect, rarely exhibiting ramuli (very short branchlets). The cells of the primary filaments and axes are cylindrical, measuring 15–36 µm in length and 7–9 µm in diameter, and contain 2–4 elliptic-discoid-shaped chromatophores, without pyrenoids. Ramuli with monosporangia are scattered, either opposite or rarely verticillate on the axes. Each ramulus consists of 1–3 cells, rarely exceeding three cells in length, and is much shorter than the primary filaments and axes. Monosporangia are found at the tips of each ramulus, supported by a 1-celled stalk, and consist of 1–4 cells (8–12 µm in diameter and 12–15 µm in length), arranged in a corymbose-glomerate pattern. Gametangia, carposporangia, and tetrasporangia have not been observed in this species.

**Specimens examined:** PHILIPPINES: Luzon Island, Province of Bataan, Municipality of Orani, Bakyas River, attached to boulders along the creek margin, submerged, well-shaded, rocky bottom, lowland rainforest, 750 masl, 14°43'46.79"N, 120°23'59.58"E, 13 August 2022, *V.C. Linis & L.V. Vitug 5757-22* (CAHUP, PNH);

Province of Bataan, Municipality of Limay, Lamao River, attached to boulders in a quieter part of the river, submerged, well-shaded, lowland rainforest, 303 masl, 14°30'45.82"N, 120°32'13.15"E, 21 August 2022, *V.C. Linis & L.V. Vitug 5759-22* (CAHUP, PNH); Lamao River, attached to boulders, submerged in slow-flowing water, well-shaded, lowland rainforest, 360 masl, 14°30'41.43"N, 120°32'04.76"E, 21 August 2022, *V.C. Linis & L.V. Vitug 5760-22* (CAHUP, PNH).

**Remarks:** *Audouinella glomerata* represents the second member of the genus *Audouinella* Bory documented in the Philippines in this study, following *A. cylindrica*. This finding suggests that *Audouinella* may have a broader geographical range than previously recognized. The specimen of *A. glomerata* was discovered in a rocky, bedrock-based stream on Luzon Island, heavily shaded by surrounding forest vegetation. Its presence in this shallow, moderately agitated stream—typically around 60 cm deep—indicates a high tolerance for various water qualities. Indeed, *A. glomerata* has been observed in water conditions ranging from clean to moderately polluted, suggesting a significant degree of ecological adaptability (Peerapornpisal et al. 2006).

Ott (2009) reclassified *Audouinella glomerata* into the genus *Pseudochantransia* based on its morphological features, although no evidence of sexual reproduction has been documented for this species. Earlier, Brand (1910) had split freshwater red algae traditionally grouped under *Chantransia* A.DC. into two genera: *Chantransia*, containing species with a full reproductive cycle and sexual reproduction, and *Pseudochantransia*, which included species reproducing solely through vegetative monospores. Subsequently, *Chantransia* was reconsidered as a form genus encompassing several species, distinguishing it from the genera *Audouinella* and *Ptilothamnion* Thuret (Vis et al. 2006).

It is now understood that *Chantransia* represents alternate life history stages (sporophyte stages) within the orders Batrachospermales and Thoreales (Müller et al.). Phylogenetic analyses have since confirmed that certain "chantransia" specimens, including members of *Audouinella* and *Ptilothamnion*, are indeed developmental phases of other red algae species rather than distinct entities (Necchi & Zucchi 1997; Chiasson et al. 2005; Kato et al. 2009; Necchi & Oliveira 2011; Han et al. 2021).

For now, the authors have chosen to treat the Philippine collection of *A. glomerata* as a distinct entity within *Audouinella*, as no sporophytic features have been observed in the material. Until sporophytic stages are identified, however, there remains the possibility that this species represents the "chantransia" phase of another red algal species. Further research—incorporating culture techniques or genetic analyses—will be necessary to determine whether *A. glomerata* is an independent species or merely a developmental stage of another red algal species. This investigation may shed light on the complex life cycles and taxonomic relationships within the genus *Audouinella* and its related genera.

Family **Batrachospermaceae**

1) ***Kumanoa montagnei*** Entwisle, M.L.Vis, W.B.Chiasson, Necchi & A.R.Sherwood. *Journal of Phycology* 45(3): 710 (2009).

The thallus of *Kumanoa montagnei* (Fig. 2. A–C; Fig. 3 A–F) is up to 4 cm in length and 200–300 µm in diameter. It features irregular branching and is slightly mucilaginous with an olive-green coloration. Whorls are distinct, globose, or ellipsoid, and are separated from each other, with internodes measuring 50–100 µm in length. The axial cells are cylindrical, 15–30 µm in diameter, and 40–170 µm in length. Primary fascicles (primary branchlets) are abundant, branching, and straight, consisting of 5–7(–8) cell layers originating from the pericentral cells. The cells of the primary fascicles are lanceolate-elliptical, fusiform, or ovoid, with terminal cells being barrel-shaped or cylindrical. Secondary fascicles (secondary branchlets) are common and vary in length, with some approaching the sizes of primary fascicles. Spermatangia are globose, 4–5 µm in diameter, and are located terminally on primary fascicles. Carpogonial branches arise from the pericentral cells at the base of the primary fascicles, measuring 10–20 µm in length. These branches are helically twisted and composed of 3–4 disc or barrel-shaped cells. The carpogonium has a base up to 5 µm in diameter, a tip 4–5 µm in diameter, and a length of 30–35 µm. The trichogyne is cylindrical, indistinctly pedicelled, and often bent at the base. Bracts are numerous and very short. Gonimoblasts are typically single or rarely two, globose or semi-globose, 50–60 µm in length, and are inserted in the center of the secondary fascicles. Carposporangia are ellipsoid or ovoid, measuring 8–9 µm in length and up to 7 µm in diameter.

**Specimen examined:** PHILIPPINES: Luzon Island, Province of Bataan, Municipality of Orani, Bakyas River, attached to rocks and pebbles, submerged, shaded, in the rocky bottom, lowland rainforest, 730 masl, 14°43'47.29"N, 120°23'59.28"E, 1 July 2022, *V.C. Linis & L.V. Vitug 5753-22* (CAHUP, PNH); Ibid, 1 July 2022, *V.C. Linis & L.V. Vitug 5754-22* (CAHUP, PNH).

**Remarks:** Our observations of Philippine specimens of *Kumanoa montagnei* reveal that, although they exhibit smaller whorl sizes, they are morphologically consistent with the original description of *Batrachospermum tortuosum* by Kumano (1978) from the type locality at Fort Iskander, Tasek Bera, Pahang, Malaysia. Both the Philippine and Malaysian specimens possess diminutive thalli with dense, compact carposporophytes, as well as smaller carposporangia (8–6 µm in diameter, 8.5–10.5 µm in length) and cylindrical carpogonia (5–6 µm in diameter, typically around 33 µm, occasionally up to 40 µm in length). Previously considered a doubtful species by Necchi & Vis (2012), *B. tortuosum* was later confirmed by Johnston et al. (2014) as a distinct taxon due to its characteristic twisted carpogonial branch, a defining feature of *Kumanoa*. Consequently, the new combination *Kumanoa tortuosa* (S.Kumano) E.T.Johnston, P.-E.Lim, & M.L.Vis was proposed. The synonymy of *K. tortuosa* with *K. montagnei* was subsequently confirmed by Vis & Necchi (2021).

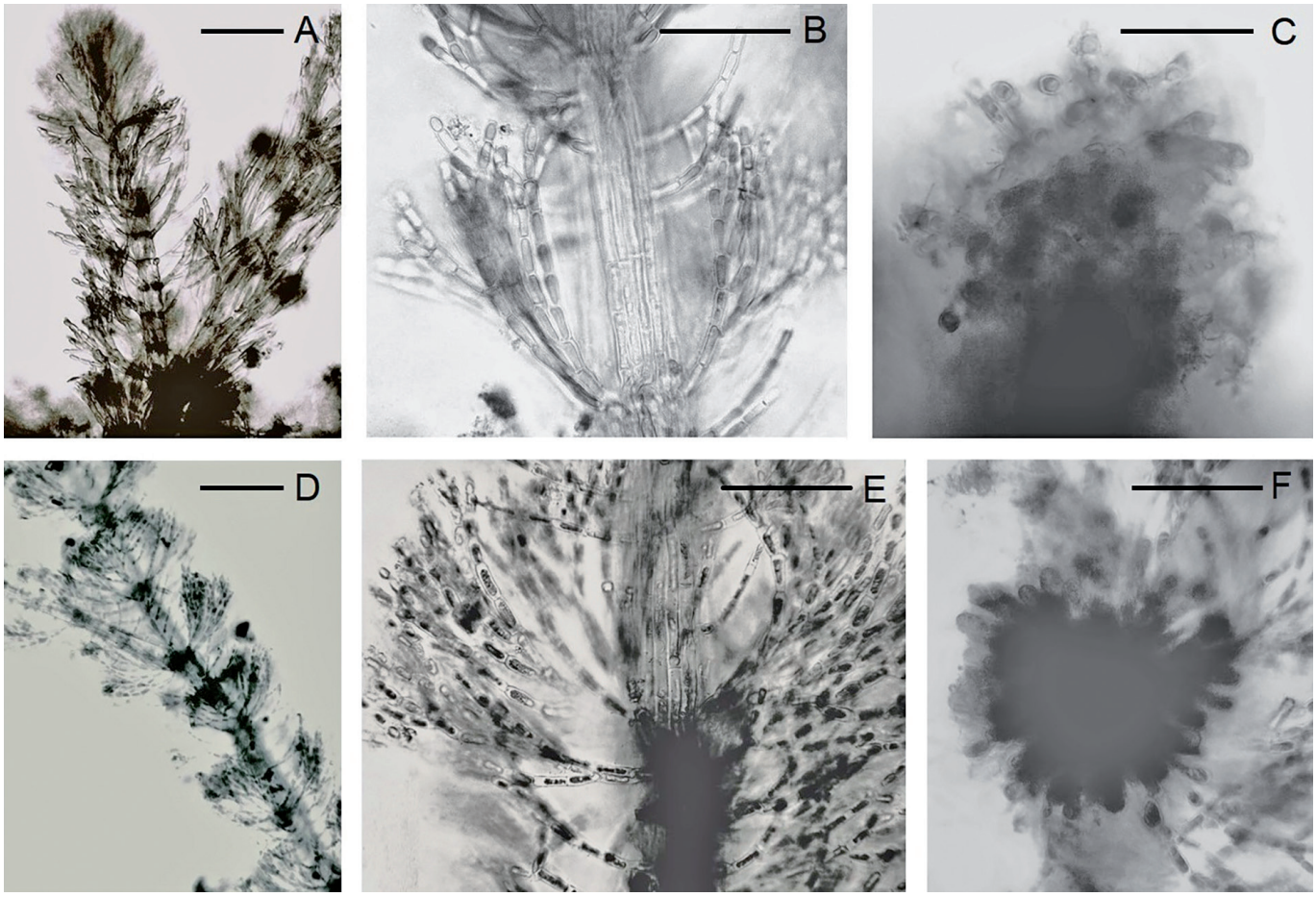


**Fig. 2. A–C.** *Kumanoa montagnei* Entwisle, M.L.Vis, W.B.Chiasson, Necchi & A.R.Sherwood. (A) General view of the thallus with confluent whorls. (B) Details of the whorls of primary fascicles with abundant branches composed of cylindrical cells. (C) Carposporangia terminal on a compactly agglomerated gonimoblast. All from *V.C. Linis & L.V. Vitug 5754-22* (CAHUP). **D–F.** *Kumanoa tiomanensis* (S.Kumano & Ratnabapathy) Necchi & M.L.Vis. (D) General view of the thallus with confluent whorls. (E) Details of the whorls of primary fascicles with sparse branching composed of cylindrical cells. (F) A young compactly agglomerated gonimoblast. All from *V.C. Linis & L.V. Vitug 5756-22* (CAHUP). Scale bars represent 500 µm (A, D), 100 µm (B, E), 25 µm (C), and 50 µm (F).

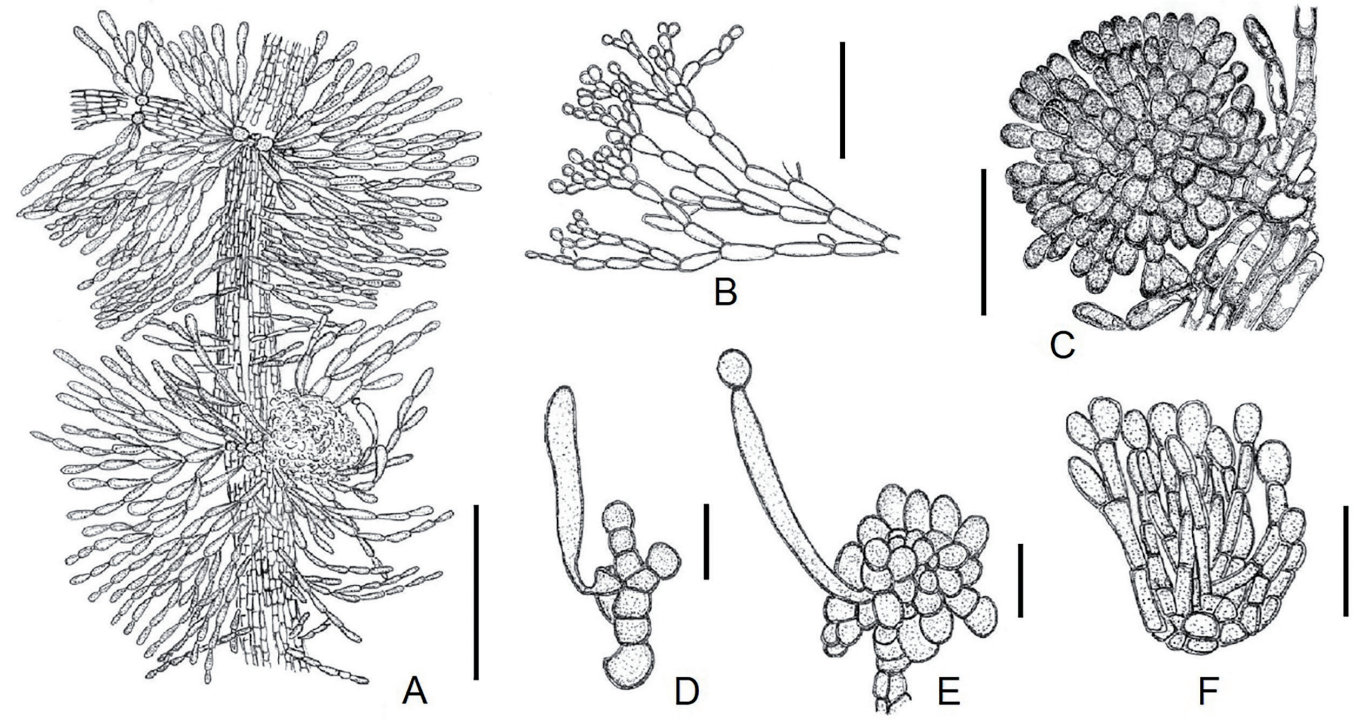


**Fig. 3. A–F.** *Kumanoa montagnei* Entwisle, M.L.Vis, W.B.Chiasson, Necchi & A.R.Sherwood. (A) Parts of a thallus shows the axial cells, cortical filaments, primary branchlets, secondary branchlets, and a gonimoblast. (B) Curved branchlets with spermatangia at the terminal ends. (C) A compactly agglomerated gonimoblast. (D–E) Carposporangium-bearing branches with bent trichogynes. (F) Carposporangia terminal on gonimoblast filaments. Scale bars represent 100 µm (A), 50 µm (B), 25 µm (C, F), and 10 µm (D, E). All drawn from *V.C. Linis & L.V. Vitug 5754-22* (CAHUP).

2) ***Kumanoa tiomanensis*** (S.Kumano & Ratnasabapathy) Necchi & M.L.Vis. *Bibliotheca Phycologica* 116: 66, pl. 24, figs 1–6 (2012).

The thallus of *Kumanoa tiomanensis* (Fig. 2. D–F; Fig. 4 A–F) reaches up to 6 cm in length and 200–300 µm in diameter. It exhibits a pseudo-dichotomous branching pattern and is slightly mucilaginous with a green hue. The whorls are barrel-shaped and touch each other in the mature parts of the thallus. The axial cells are cylindrical, measuring 35–60 µm in diameter and 95–320 µm in length. Primary fascicles (primary branchlets) are abundant, unilaterally branched, and curved, with 8–9 (occasionally up to 12) cell layers originating from the pericentral cells. The cells of the primary fascicles are cylindrical or barrel-shaped. The cortical filaments are well-developed. Secondary fascicles, which vary in length, are common and consist of 6–12 cell layers, with some approaching the size of the primary fascicles. These fascicles may be unbranched or dichotomously branched, covering the internodes. Spermatangia are globose, measuring 3–5 µm in diameter, and are terminal or lateral on secondary fascicles and rarely on primary fascicles. Carpogonial branches arise from the basal cells at the base of the primary fascicles, measuring 8–20 µm in length. These branches are helically twisted and composed of 5–7 disc or barrel-shaped cells. The carpogonium base is 3–5 µm in diameter, with the tip measuring 7–8 µm in diameter and 30–40 µm in length. The trichogyne is club-shaped. Bracts are sparse and short. Gonimoblasts are typically single or paired, globose or semi-globose, measuring 120–200 µm in length and 170–220 µm in diameter. They are inserted in the center of the secondary fascicles. Carposporangia are obovoid, measuring 10–15 µm in length and 7–11 µm in diameter.

**Specimens examined:** PHILIPPINES: Luzon Island, Province of Cavite, Municipality of Ternate, Mount Palay-Palay National Park, attached to rock along a small stream, well-shaded, rocky bottom, residual tropical lowland forest, 335 masl, 14°13’55.47”N, 120°39’24.43”E, 23 July 2022, *V.C. Linis & L.V. Vitug 5756-22* (CAHUP, PNH).

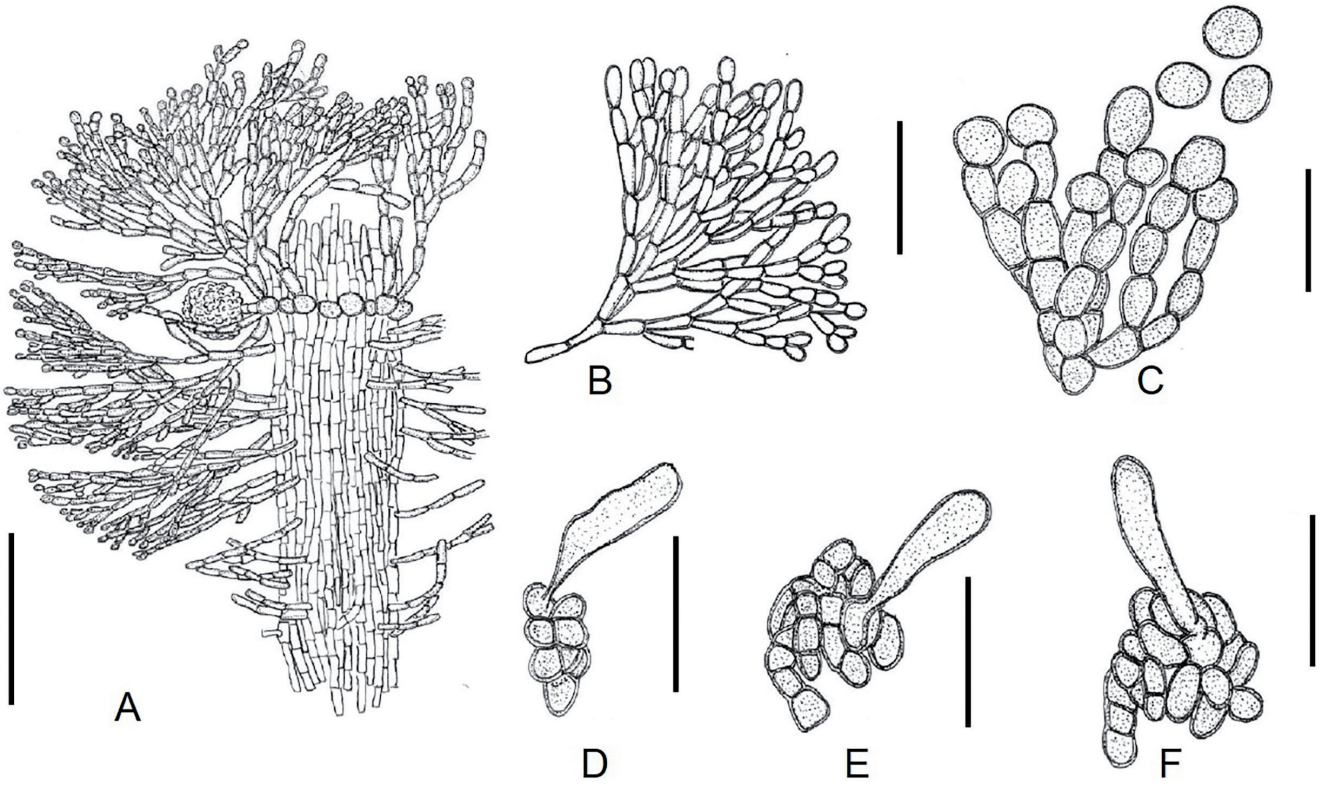


**Fig. 4. A–F.** *Kumanoa tiomanensis* (S.Kumano & Ratnabapathy) Necchi & M.L.Vis. (A) Parts of the thallus show the axial cells, cortical filaments, primary branchlets, secondary branchlets, and a gonimoblast. (B) Primary branchlets, curved and unilaterally branched. (C) Carposporangia terminal on gonimoblasts filaments. (D–F) Coiled carpogonium-bearing branches with mature trichogynes. Scale bars represent 100 µm (A), 50 µm (B), and 25 µm (C, D, E, F). All drawn from *V.C. Linis & L.V. Vitug 5756-22* (CAHUP).

**Remarks:** *Kumanoa tiomanensis*, previously identified as *Batrachospermum tiomanense* S.Kumano & Ratnasabapathy, was initially described from a holotype collected in Sungai Ayer Besar, Pulau Tioman, Malaysia (Ratnasabapathy & Kumano 1982a) and was later referenced by Kumano (2002) and Necchi & Vis (2012). This species was confirmed as morphologically distinct due to its twisted carpogonial branch, a defining feature of the genus *Kumanoa* (Johnston et al. 2014). The genus *Kumanoa* was established by T.J. Entwisle, M.L. Vis, W.B. Chiasson, Necchi, & A.R. Sherwood to reclassify species previously assigned to *Batrachospermum* sections *Hybrida* and *Contorta*, based on combined molecular and morphological data (Entwisle et al. 2009). Sequence analyses of the large subunit of ribulose-1,5-bisphosphate carboxylase/oxygenase (rbcL) and small subunit ribosomal RNA (SSU rDNA) genes consistently support *Kumanoa* as a monophyletic group within the Batrachospermales (Vis et al. 1998, 2005; Vis & Entwisle 2000). Additionally, species within this genus are identifiable by both molecular and morphological criteria (Necchi 1990).

The Philippine specimens of *Kumanoa tiomanensis*, though exhibiting slight variations in whorl sizes, are morphologically

consistent with the protologue (*Batrachospermum tiomanense*) and *B. omobodoense* S.Kumano & W.A.Bowden-Kerby, initially described from Palau, Micronesia (Kumano 2002). These specimens also share morphological traits with the Philippine congener *Kumanoa hirosei*, particularly in their compact, agglomerated gonimoblasts. However, they differ from *K. hirosei* in key features, such as the number of cells per carpogonium-bearing branch and fascicle, whorl dimensions, and trichogyne shape. To date, *K. tiomanensis* has not been subjected to molecular sequencing (Entwisle et al. 2009; Johnston et al. 2014; Vis et al. 2012), highlighting the need for a comprehensive re-evaluation of its taxonomic status based on combined morphological and molecular data.

## Discussion

The identification of *Audouinella cylindrica* and *A. glomerata* marks the first confirmed records of this genus in the Philippines. These findings suggest that these species may have a broader geographical range than previously recognized. However, since the identifications were made solely on the basis of morphological data, it remains possible that *A. cylindrica* and *A. glomerata* represent the "Chantransia" stages of other freshwater red algae within the orders *Batrachospermales* and *Thoreales*. To clarify their taxonomic status, further sampling and phylogenetic analyses using DNA sequence data are recommended.

The discovery of *Kumanoa montagnei* and *K. tiomanensis* increases the number of recognized *Kumanoa* species in the Philippines to four. Given that *Kumanoa* is particularly prevalent in tropical and subtropical regions, additional species are likely to be discovered and documented in the country. This expanded distribution reinforces the idea that the genus may be more diverse and widespread in Southeast Asia than previously understood.

Notably, *Kumanoa tiomanensis* has yet to undergo molecular sequencing, underscoring the need for a comprehensive re-evaluation of species validity and phylogenetic relationships for *K. tiomanensis* and other underexplored *Kumanoa* species. Such a re-evaluation, integrating both morphological and molecular evidence, would provide a clearer understanding of their evolutionary relationships. Meanwhile, a dichotomous key is provided below to highlight the diagnostic features of all *Kumanoa* species currently documented in the Philippines.

## Key to the four Philippine *Kumanoa* species

1. Thallus monoecious ..... 2
1: Thallus dioecious or trioecious ..... 3
2. Distal cells of primary fascicles fusiform to ellipsoidal; hairs present ..... *K. tabagatenensis*
2: Distal cells of primary fascicles otherwise ..... *K. louisianae*
3. Dioecious; primary fascicles straight and composed of ellipsoidal, fusiform or obovoidal cells ..... *K. montagnei*
3: Trioecious; primary fascicles curved, unilaterally branched and composed of cylindrical or barrel-shaped cells ..... *K. tiomanensis*

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## References

Brand F (1910) Uber Süsswasserformen von Chantransia (DC) Schmitz. *Hedwigia* 49: 107–118.

Chiasson WB, Sabo NJ, Vis ML (2005) Affinities of freshwater putative chantransia stages (Rhodophyta) from molecular and morphological data. *Phycologia* 44(2): 163–168. DOI

Entwisle TJ, Vis ML, Chiasson WB, Necchi Jr O, Sherwood AR (2009) Systematics of the Batrachospermales (Rhodophyta) – a synthesis. *Journal of Phycology* 45: 704–715. DOI

Guiry MD (2021) In Guiry MD, Guiry GM, *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. URL; searched on 10 October 2022.

Han J, Nan F, Feng J, Lü J, Liu Q, Liu X, Xie S (2021) Affinities of freshwater "Chantransia" stage algae (Rhodophyta) from China based on molecular and morphological analyses. *Journal of Oceanic Limnology* 39: 1063–1076. DOI

Jao C-C (1941) Studies on the freshwater algae of China VIII. A preliminary account of the Chinese freshwater Rhodophyceae. *Sinensia* 12: 245–289.

Johnston ET, Lim P-E, Buhari N, Keil EJ, Djawad I, Vis ML (2014) Diversity of freshwater red algae (Rhodophyta) in Malaysia and Indonesia from morphological and molecular data. *Phycologia* 53(4): 320–341. DOI

Kato A, Morita N, Hiratsuka T, Suda S (2009) Recent introduction of a freshwater red alga *Chantransia macrospora* (Batrachospermales, Rhodophyta) to Okinawa, Japan. *Aquatic Invasions* 4(4): 567–574. DOI

Krishnamurthy V (1962) The morphology and taxonomy of the genus *Compsopogon* Montagne. *Journal of the Linnean Society (Botany)* 58: 207–221. DOI

Kumano S (1978) Notes on freshwater red algae from west Malaysia. *Botanical Magazine Tokyo* 91: 97–107. DOI

Kumano S (2002) Freshwater red algae of the world. pp. 1–375. Biopress Limited: Bristol.

Kumano S, Bowden-Kerby WA (1986) Studies on the freshwater Rhodophyta of Micronesia I. Six new species of *Batrachospermum* Roth. *The Japanese Journal of Phycology* 34(2): 107–128.

Kumano S, Liao LM (1987) A new species of the section *Contorta* of the genus *Batrachospermum* (Rhodophyta, Nemalionales) from Nonoc Island, the Philippines. *Japanese Journal of Phycology* 35: 99–105.

Liao LM (2010) Nomenclatural notes on some Philippine species of freshwater red algae (Rhodophyta). *Philippine Journal of Systematic Biology* 4: 89–94.

Liao LM, Largo, DB (1985) A new record of freshwater Rhodophyta from the Philippines. In Proenca LAO, GM Hallegraeff (eds), *Proceedings of the 17th Annual Convention of Federal Institute of Marine and Freshwater Science*. pp. 29–30. International Society for the Study of Harmful Algae (ISSHA), Intergovernmental Oceanographic Commission of UNESCO.

Liao LM, Young, JG (2000) *Thorea* (Batrachospermales, Rhodophyta): A new addition to the freshwater algal flora of the Philippines. *Philippine Scientist* 37: 137–150.

Linis VC, Vitug LV (2022) *Caloglossa fluviatilis* (Delesseriaceae, Rhodophyta) from Bataan province, Luzon Island, Philippines, a new country record. *Telopea* 25: 385–389.

Liu SL, Wang WL, Liao LM (2004) *Batrachospermum hirosei* Ratnabapathy et Kumano, a freshwater red alga new to the Philippines. *Taiwania* 49: 141–147.

Müller KM, Sherwood AR, Pueschel CM, Gutell RR, Sheath RG (2002) A proposal for the new red algal order, the Thoreales. *Journal of Phycology* 38: 807–820. DOI

Necchi Jr O (1990) Revision of the genus *Batrachospermum* Roth (Rhodophyta, Batrachospermales) in Brazil. *Bibliotheca Phycologica* 84: 1–201.

Necchi Jr O, Oliveira MC (2011) Phylogenetic affinities of "Chantransia" stages in members of the Batrachospermales and Thoreales (Rhodophyta). *Journal of Phycology* 47(3): 680–686. DOI

Necchi Jr O, Sheath RG, Cole KM (1993a) Systematics of the freshwater *Audouinella* (Acrochaetiaceae, Rhodophyta) in North America. 1. The reddish species. *Archiv für Hydrobiologie, Algological Studies Supplements* 70: 11–28.

Necchi Jr O, Sheath RG, Cole KM (1993b) Systematics of the freshwater *Audouinella* (Acrochaetiaceae, Rhodophyta) in North America. 2. The bluish species. *Archiv für Hydrobiologie, Algological Studies Supplements* 71: 13–21.

Necchi Jr O, Vis ML (2012) Monograph of the genus *Kumanoa* (Rhodophyta, Batrachospermales). *Bibliotheca Phycologica* 116: 1–79. ISBN: 978-3-443-60043-3

Necchi Jr O, Vis ML, Oliveira MC (2010) Phylogenetic relationships in *Kumanoa* (Batrachospermales, Rhodophyta) species in Brazil with the proposal of *Kumanoa amazonensis* sp. nov. *Phycologia* 49(1): 97–103. DOI

Necchi Jr O, Zucchi MR (1995) Systematics and distribution of freshwater *Audouinella* (Acrochaetiaceae, Rhodophyta) in Brazil. *European Journal of Phycology* 30: 209–218. DOI

Necchi Jr O, Zucchi MR (1997) *Audouinella macrospora* (Acrochaetiaceae, Rhodophyta) is the Chantransia stage of *Batrachospermum* (Batrachospermaceae). *Phycologia* 36: 220–224. DOI

Ott FD (2009) *Handbook of the taxonomic names associated with the non-marine Rhodophycophyta*. pp. 1–969. J. Cramer: Stuttgart.

Peerapornpisal Y, Nualcharoen M, Suphan S, Kunpradid T, Inthasotti T, Mungmai R, Dhitisudh L, Sukchotiratana M, Kumano S (2006) Diversity and habitat characteristics of freshwater red algae (rhodophytes) in some water resources of Thailand. *ScienceAsia* 32, *Supplement* 1: 63–70. DOI

Ratnasabapathy M, Kumano S (1982a) Studies on freshwater red algae of Malaysia I. Some taxa of the genera *Batrachospermum*, *Ballia* and *Caloglossa*, are from Pulau, Tioman, West Malaysia. *Japanese Journal of Phycology* 30: 15–22.

Ratnasabapathy M, Kumano S (1982b) Studies on freshwater red algae of Malaysia II. Three species of Batrachospermum from Sungai Gombak and Sungai Pusu, Selangor, West Malaysia. *Japanese Journal of Phycology* 30: 119–124.

Sheath RG, Hambrook JA (1990) Freshwater ecology. In: Cole KM, Sheath RG (eds), *Biology of the Red Algae*. pp. 423–453. Cambridge University Press: Cambridge.

Sherwood AR, Sheath RG (2003) Systematics of the Hildenbrandiales (Rhodophyta): gene sequence and morphometric analyses of global collections. *Journal of Phycology* 39: 409–422. DOI

Skuja H (1934) VI. *Nemalionopsis shawi*, eine neue Gattung und Art der Helminthocladiaceen. *Untersuchungen über die Rhodophceen des Süßwassers. Beiheft zum Botanischen Centralblatt* 52B: 170–192.

Traichaiyaporn T, Khuantrairong T, Kumano S (2008) *Thorea siamensis* sp. nov. (Thoreaceae: Rhodophyta) from Thailand. *The Natural History Journal of Chulalongkorn University* 8: 27–33.

Vis ML, Chiasson WB, Sheath RG (2005) Phylogenetic relationships of *Batrachospermum* species (Batrachospermales, Rhodophyta) from coastal streams in French Guiana. *Phycologia* 44: 441–446. DOI

Vis ML, Entwisle TJ (2000) Insights into the phylogeny of the Batrachospermales (Rhodophyta) from rbcL sequence data of Australian taxa. *Journal of Phycology* 36:1175–1182. DOI

Vis ML, Entwisle TJ, West JA, Ott FD (2006) *Ptilothamnion richardsii* (Rhodophyta) is a Chantransia stage of *Batrachospermum*. *European Journal of Phycology* 41(1): 125–130. DOI

Vis ML, Necchi Jr O (2021) *Freshwater red algae: Phylogeny, taxonomy, and biogeography*. pp. 1–338. Springer Nature: Switzerland AG.

Vis ML, Necchi Jr O, Chiasson WB, Entwisle TJ (2012) Molecular phylogeny of the genus *Kumanoa* (Batrachospermales, Rhodophyta). *Journal of Phycology* 48(3): 750–758. DOI

Vis ML, Saunders GW, Sheath RG, Dunse K, Entwisle TJ (1998) Phylogeny of the Batrachospermales (Rhodophyta) inferred from rbcL and 18S ribosomal DNA gene sequences. *Journal of Phycology* 34: 341–350. DOI