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Diversity and Habitat Characteristics of Freshwater Red Algae (Rhodophytes) in Some Water Resources of Thailand

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ABSTRACT: The freshwater red algae in some areas of the northern, central, western and southern regions of Thailand were investigated together with water quality and some ecological aspects. Five orders, 6 families, 9 genera and 26 species were found. The most diverse genus was *Batrachospermum* which had 9 species, followed by *Thorea, Bostrychia, Audouinella* and *Compsopogon* each with 3 species and *Nemalionopsis* with 2 species. Genera represented as 1 species only were *Sirodotia, Caloglossa* and *Compsopogonopsis*. Most of the freshwater red algae were observed in water of clean to moderate quality. However, some species were in the clean water e.g. *Batrachospermum boryanum* Sirodot, *B.gelatinosum* (Linnaeus) de Candolle and *B. macrosporum* Montagne but some species were in moderate to polluted water e.g. *Compsopogon coeruleus* (Balbis) Montagne and *Audouinella glomerata* Jao. The latter species had a wide tolerance range i.e. it could be found from clean to polluted water in as many as 15 different water resources.

Some species of freshwater red algae could be found in many regions but some species were detected only in one region, for example, *Batrachospermum nova-guineense* Kumano et John Stone, *Sirodotia huillensis* (Welwitsch ex West G.S West) Skuja, *Nemalionopsis shawii* Skuja , *Compsopogon minutus* Jao and *Compsopogonopsis fruticosa* (Jao) Seto were found in the northern region, *Batrachospermum boryanum* Sirodot and *B. gelatinosum* (Linnaeus) de Candolle were found in the western region and *B. diatyches* Entwisle, *B. iriomotense* Kumano, *Caloglossa leprieuril* (Montagne) G. Marteus, *Bostrychia moritziama* (Sonder) J. Agardh and *Bostrychia* sp.1 and *Bostrychia* sp. 2 were found in the southern region.

Batrachospermum iriomotense Kumano, *Batrachospermum* sp.1 and *Bostrychia moritziana* (Sonder) J. Agardh were found in a still water pond and *Batrachospermum nova-guineense* Kumano et John Stone grew well in strong sunlight with a distinct reddish appearance. Nineteen newly recorded species of freshwater red algae for Thailand resulted from this investigation.

KEYWORDS: Freshwater red algae, Rhodophytes, biodiversity, biomonitoring, *Batrachospermum*.

INTRODUCTION

Freshwater red algae are macroalgae which do not exist in great numbers compared with other freshwater macroalgae such as green or blue-green algae[1]. They are found mainly upstream in rivers where the river bed is shallow with solid substrate e.g. rock or cobble, and in slow to fast flowing streams or rivers with low to high conductivity[2]. They are also found in clean to moderate quality water, occasionally in polluted water[3], and in shady areas with comparatively low temperature, but sometimes at higher temperature[1].

Studies on freshwater red algae are relatively limited in the Americas, Europe, Australia and Asia. In Thailand, even less work has been done. Lewmanomont *et al.*[4] reported that West and West studied these algae in 1906 at Koh Chang , Trat Province and found *Batrachospermum macrosporum* Montagne. This was the first study of freshwater red algae in Thailand. Later, Peerapornpisal *et al.*[5] found *Batrachospermum moniliforme* Roth and *B. vugum* Agardh in Mae Sa Stream, Doi Suthep-Pui National Park, Chiang Mai Province. Kunpradid and Peerapornpisal[6] recorded two new species: *Compsopogon coeruleus* (Balbis) Montagne and *Nemalionopsis shawii* Skuja in Mae Sa Stream. Suphan[7] reported the presence of *Batrachospermum* spp. in many other Thai water bodies, i.e. Mae Sa, Mae Ping, Nan and Mekong Rivers as well as in the Thong Pha Phum National

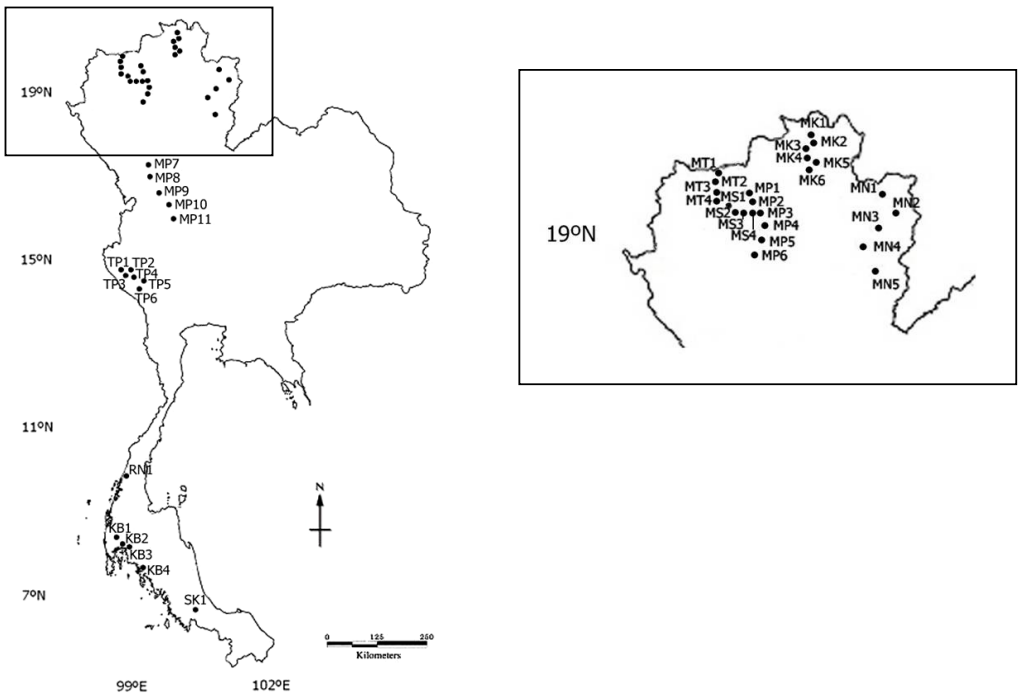

Fig 1. Map of Thailand showing the sampling sites in northern , central, western and southern regions.

Northern and central regions

Chiang Mai – Lamphun-Tak- Kamphaeng Phet - Nakhon Sawan

Mae Ping River: MP1- Ban Muang Na; MP2-Thung Khao Phuang; MP3- Fai Wang Hai; MP4-Kang Pan Tao; MP5-Mae Ho Phra; MP6-Ban Pa Dad; MP7- Had Nak; MP8-Ban Charoen Pattana; MP9- Ban Wang Chao; MP10- Ban Wang Yang; MP11- Ban Koh Moo; MP12- Kao-Liew

Chiang Mai

Mae Sa River MS1- Ban Kong Hae; MS2-Ban Kong Hae Bridge; MS3- Chollaprathan Bridge; MS4- Mae Rim Bridge

Mae Taeng River MT1-Mae Tang 2; MT2- Mae Tang 3; MT3 –Huay Mae Ban Luang; MT4-Huay Mae Plam

Chiang Rai

Mae Khum River MK1-Mae Slap1; MK2-Mae Slap 2; MK3- Huay Jai; MK4-Mae Pern Pa Miang; MK5- Mae Salong; MK6- Huay Mae Khang

Nan

Nan River MN1-San Charoen; MN2- Pang Sa; MN3- Ban Na Tao; MN4-Had Pha Khon; MN5- Pha Ya Phu Bridge

Western region

Kanchanaburi

Thong Pha Phum National Park

TP1- Huay Jok Kradin; TP2- Huay Etong; TP3- Huay Jok Tong; TP4- Huay Kayeng 1; TP5- Huay Kayeng 3; TP6-Tao Than Bridge

Southern region

Krabi

KB1- Sra Kaew Cave Pond; KB2 -Tha Pom Klong Song Nam; KB3- Klong Tarntip; KB4- Tha Tiaew Peat Land

Ranong RN1-Klong Kapur

Song Khla SK1- Ton Nga Chang Waterfall

Park, Kanchanaburi Province. All were new records for species in Thailand. Trichaiyaporn *et al.*[8,9] found *Batrachospermum cayennense* ex KÜtzing and *B. mahlacense* Kumano et Boden-Kerby, also new species records for Thailand. It may be assumed that nearly all the freshwater red algae found in Thailand are new records, further indicating the paucity of studies of these algae in Thailand.

This report presents the results of an investigation into the occurrence of freshwater red algae in the northern, western, central and southern regions of Thailand, in rivers, streams and tributaries, beginning from upstream in the Thong Pha Phum National Park to downstream and including ponds.

Materials and Methods

Study Areas

Northern and Central Regions:

Twelve sites on the Mae Ping River, from upstream in Chiang Mai Province to downstream in Nakhon Sawan Province, four sites on the Mae Sa River in Chiang Mai Province, four sites of the Mae Taeng River and its tributaries in Chiang Mai Province, six sites on the Mae Khum River and its tributaries in Chiang Rai Province, and five sites of Nan River, Nan Province, were investigated.

Western Region:

Six sites along small streams in Thong Pha Phum National Park, Kanchanaburi Province were studied.

Southern Region:

Four sites at Tha Pom Klong Song Nam, Tha Tiaew Peat Land, Klong Tarntip and Sra Kaew Cave Pond in Krabi Province, one site of Klong Kapur in Ranong Province and one site of Ton Nga Chang Waterfall in Song Khla Province were investigated (Fig.1).

The details of regions, provinces, water resources, study sites and abbreviations of each site are given in Fig. 1.

Samples were collected from rock, cobble, tree branches and artificial substrates in the water and fixed in 2.0% glutaraldehyde. Water quality in each sampling site was measured [temperature, current velocity, specific conductance, pH, DO, OD, nutrients (nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus)] according to APHA, AWWA, and WEF procedures[10]. Assessment of water quality in the terms of trophic level was according to Wetzel [11], Lorraine and Vollenweider [12] and the Guideline of Standard Surface Water Quality of Thailand [13].

The identification of freshwater red algae was carried out using the relevant books and publications.[14,15,16,17,18,19]. Photographs or drawings of the thalli and reproductive cells of each species were taken using a light microscope. Confirmation of species identity was made by the expert partners.

Results and Discussion

The identification of 26 species in 9 genera indicates the biodiversity of freshwater red algae in the investigated water resources. These species were in the Orders Batrachospermales, Thoreales, Ceramiales, Acrochaetiales and Compsopogonales. The names and illustrative figures of the 26 species, the water resources and the corresponding water quality assessments are shown in Table 1 and Figs. 2 and 3.

The genus with the most diversified species (up to 9) was *Batrachospermum*. This agrees with Kumano[19] who reported that *Batrachospermum* spp. are the most diverse within a single genus of freshwater red algae. The genera with 3 species were *Thorea, Bostrychia, Audouinella* and *Compsopogon*. The genera with 2 species were *Nemalionopsis* and those with 1 species were *Sirodotia, Caloglossa* and *Compsopogonopsis*.

The algae were found to be most abundant in the northern region, although this may have been due to the higher frequency of sampling and greater number of sampling sites in this area. The most prominent species was *Audouinella glomerata* Jao which was found in 15 water resources both in the northern and western regions. It was also found in water bodies with diverse qualities, from clean, moderate to polluted water, indicating a wide range of tolerance. *Audouinella cylindrica* Agardh was also found in 9 water resources in the northern and western regions and in waters of clean to moderate quality; this accords with two reports[2,20] that *Audouinella* is frequently found in general water resources .

Several species of freshwater red algae were found in the northern and western region but not in the southern region, including the two *Audouinella* species mentioned above. Moreover, *Batrachospermum macrosporum* Montagne, *B. vugum* Agardh and *Compsopogon coeruleus* (Balbis) Montagne were also found, indicating similar climate and ecohydrology in these two regions, particularly in Thong Pha Phum National Park and in some parts of the western region[7].

However, in this study, some species appeared only in a particular region. Those found only in the northern region were *Batrachospermum nova-guineense* Kumano et John Stone, *Sirodotia huillensis* (Welwitsch ex West G.S. West) Skuja, *Nemalionopsis shawii* Skuja, *Compsopogon minutus* Jao and *Compsopogonopsis fruticosa* (Jao) Seto. Those found only in the western region were *Batrachospermum boryanum* Sirodot and *B. gelatinosum* (Linnaeus) de Candolle. Those found only in the southern region were *B. diatyches* Entwisle, *B. iriomotense*

Table 1. Species of Freshwater red Algae in Some Water Resources of Thailand and Corresponding Habitat Characteristics.

Order	Family	Genus/Species	Water Resources	Water Quality
Batrachospermales	Batrachospermaceae	1. *Batrachospermum boryanum* Sirodot	TP1 (S)	Clean
		2. *Batrachospermum diatyches* Entwisle#	SK1 (S)	Clean
		3. *Batrachospermum gelatinosum* (Linnaeus) de Candolle	TP3 (S)	Clean
		4. *Batrachospermum iriomotense* Kumano#	*KB1 (P)	Clean-Moderate
		5. *Batrachospermum macrosporum* Montagne	TP1 (S)	Clean
			MS1 (S)	Clean
			MP1 (S)	Clean
			MN1 (S)	Clean
		6.*Batrachospermum nonocense* Kumano *et* Liao#	KB4 (S)	Clean-Moderate
		7.*Batrachospermum nova-guneense* Kumano *et* John Stone#	**MT1 (R)	ModerateModerate
			MT4 (S)	
			MK2 (R)	Clean-Moderate
		8. *Batrachospermum vugum* Agardh	TP1 (S)	CleanModerate
			MS4 (R)	
			MN1 (S)	Clean
		9.*Batrachospermum* sp. 1#	*KB1 (P)	Clean-Moderate
		10. *Sirodotia huillensis* (Welwitsch ex West G.S West) Skuja#	MK3 (S)	Moderate
			MK4 (S)	ModerateClean
			MS1 (S)	
			MS2 (S)	Moderate
			MS4 (R)	Moderate
			MP1 (S)	Clean
			MN1 (S)	Clean
		12.*Nemalionopsis* sp. 1#	MN1 (S)	Clean
		13.*Thorea* sp. 1#	KB3 (S)	Moderate
		14.*Thorea* sp. 2#	MN3(R)	Moderate
		15.*Thorea* sp. 3#	MP4 (R)	Moderate
Ceramiales	Ceramiaceae	16.*Caloglossa leprieurii* (Montagne) G. Marteus#	KB3 (S)	Moderate
			KB2 (S)	Moderate
			RN1(S)	Moderate
	Rhodomelaceae	17.*Bostrychia moritziana* (Sonder) J. Agardh#	KB1 (P)	Clean-Moderate
			*KB4 (S)	Clean-Moderate
		18. *Bostrychia* sp.1#	KB2 (S)	Moderate
		19. *Bostrychia* sp. 2#	KB2(S)	Moderate
Acrochaetiales	Acrochaetiaceae	20. *Audouinella cylindrica* Agardh#	TP1 (S)	Clean
			TP2 (S)	Clean
			TP3 (S)	Clean
			TP5 (S)	Moderate
			TP6 (S)	Moderate
			MP2 (S)	Clean-Moderate
			MN1 (S)	Clean
			MN2 (R)	Clean
			MN3 (R)	Moderate
		21.*Audouinella glomerata* Jao#	TP1 (S)	Clean
			TP2 (S)	Clean
			TP3 (S)	Clean
			TP5 (S)	Moderate
			TP6 (S)	Moderate
			MP1 (S)	Clean
			MP2 (S)	Clean-Moderate
			MP4 (R)	Moderate
			***MP6 (R)	Moderate-Polluted
			MP7 (R)	Moderate
			MN1 (S)	Clean
			MN2 (R)	Moderate

Table 1. Cont'd.

Order	Family	Genus/Species	Water Resources	Water Quality
			MN3 (R)	Moderate
			MN4 (R)	Moderate
			MN5 (R)	Moderate-polluted
		22.*Audouinella* spp.	TP2 (S)	Clean
			TP4 (S)	Clean-Moderate
			TP6 (S)	Moderate
			MP1 (S)	Clean
			MP3 (R)	Moderate
			MP5 (R)	Moderate
			MP9 (R)	Moderate
			MP10 (R)	Moderate
			MP11 (R)	Moderate
			MP12 (R)	Moderate
			MT1 (R)	Moderate
			MT2 (R)	Moderate
			MT3 (S)	Moderate
			MK1 (R)	Moderate
			MK2 (R)	Moderate
			MK4 (S)	Moderate
			MK5 (S)	Clean-Moderate
			MK6 (S)	Moderate
			KB2 (S)	Moderate
			KB4 (S)	Clean-Moderate
			KB3 (S)	Moderate
Compsopogonales	Compsopogonaceae	23.*Compsopogon minutus* Jao#	MK6 (S)	Moderate
			MK5 (R)	Clean-Moderate
		24.*Compsopogon coeruleus*	TP5 (S)	ModerateModerate
		(Balbis) Montagne#	TP6 (S)	
			MP3 (R)	Moderate
			MP4 (R)	Moderate
			***MP6 (R)	Moderate-Polluted
			MP7 (R)	Moderate
			MP8 (R)	Moderate
			MP9 (R)	Moderate
			MS2 (S)	Clean-moderate
			MS3 (R)	Moderate
			MS4 (R)	Moderate
			MN3(R)	Moderate
			MN4 (R)	Moderate
			MN5 (R)	Moderate-Polluted
		25.*Compsopogon* sp. 1#	MP8 (R)	Moderate
		26.*Compsopogonopsis fruticosa*	MT4 (S)	Moderate
		(Jao) Seto#	MT3 (S)	Moderate
			MT1 (R)	Clean-moderate

R=River, S = Stream, P=Pond
*Standing water
**Strong sunlight
***Polluted water all the year
#New record species in Thailand

Kumano, *Caloglossa leprieuril* (Montagne) G. Marteus, *Bostrychia moritziama* (Sonder) J. Agardh, *Bostrychia* sp.1 and *Bostrychia* sp. 2 .

In relation to the water quality, nearly all of the freshwater red algae were often found in the clean to moderate quality of water with very few species being found in polluted water. Some species were found only in clean water e.g. *B. boryanum* Sirodot, *B.diatyches* Entwisle, *B. gelatinosum* (Linnaeus) de Candolle and *B. macrosporum* Montagne .Those found in moderate to polluted water were the *Audouinella* spp.and *Compsopogon coeruleus* (Balbis) Montagne. Others were found in clean to moderate water which were in agreement with the report by Palmer[3]; thus, this study should be useful for biomonitoring to assess the water quality in both streams and ponds where freshwater red algae can grow.

Nearly all the freshwater red algae identified in this

research were found in running water, either fast or slow, both in rivers and streams. However, *Batrachospermum iriomotense* Kumano, *Batrachospermum* sp. 1 and *Bostrychia moritziana* (Sonder) J. Agardh were found in the standing water at the Sra Kaew Cave Pond, Krabi Province, which was a rare phenomenon. Generally, freshwater red algae are often found in shady areas[19] but in this research, they were found consistently in exposed location with strong sunlight at site MT1 on the Mae Teang River. They were *Batrachospermum nova–guineense* Kumano et John Stone which appeared as a distinct red color in great quantity. In this project, nineteen new record species of Thailand were found (Table 1).

ACKNOWLEDGEMENTS

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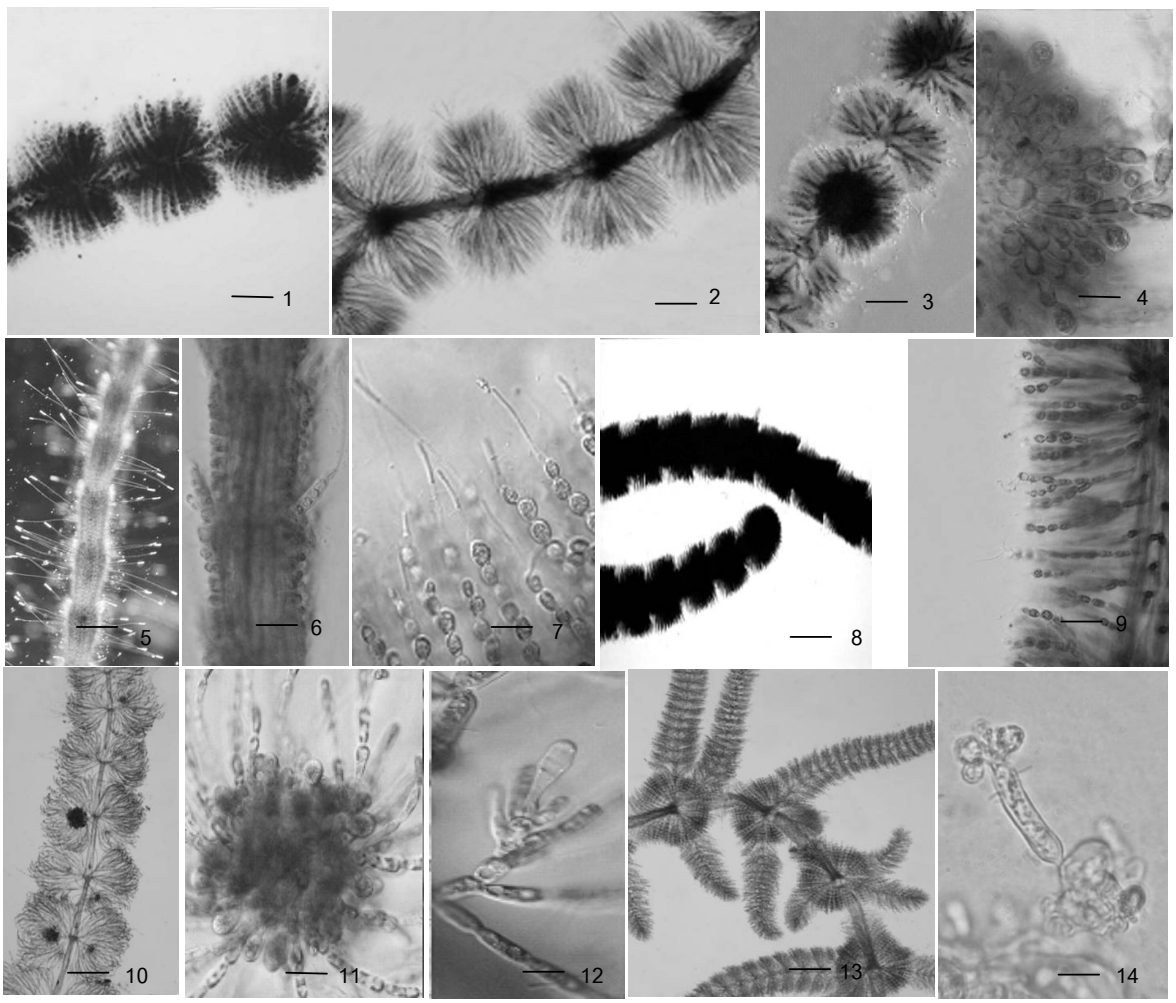

Fig 2. Freshwater red algae found in some water resources of Thailand. (1) *Batrachospermum boryanum* Sirodot, (2) *Batrachospermum gelatinosum* (Linnaeus) de Candolle, (3-4) *Batrachospermum iriomotense* Kumano, (5-6) *Batrachospermum diatyches* Entwisle, (7) *Batrachospermum macrosporum* Montagne, (8) *Batrachospermum vugum* Agardh, (9) *Batrachospermum nonocense* Kumano *et* Liao, (10-12) *Batrachospermum nova-guneense* Kumano *et* John Stone, (13-14) *Sirodotia huillensis* (Welwitsch ex Wet G.S West) Skuja. Scale bar = 100 μm (figs. 1-3, 5, 8, 10, 13); 20 μm (figs.4, 6, 9, 11); 10 μm (figs. 7, 12, 14).

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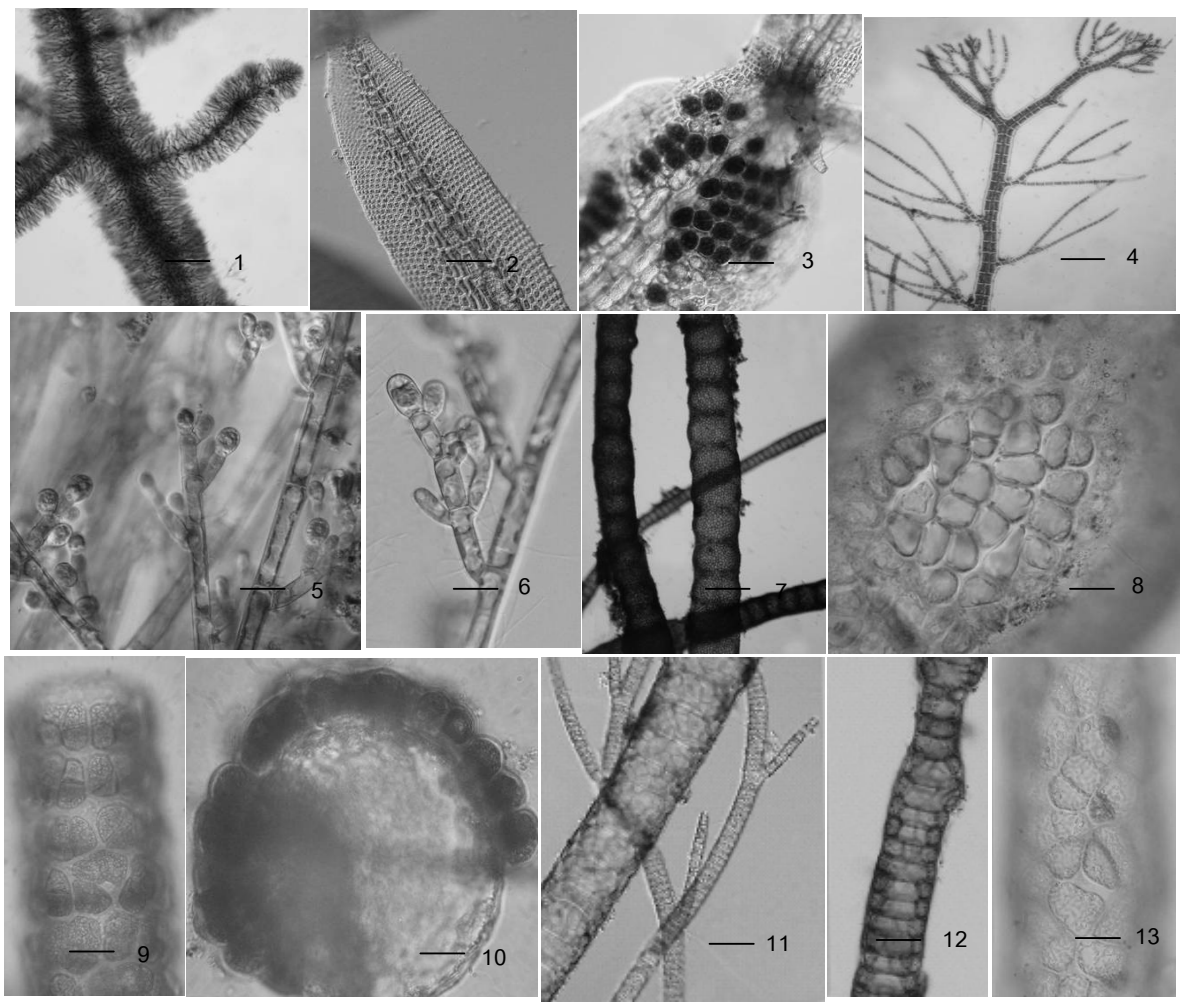

Fig 3. Freshwater red algae found in some water resources of Thailand (continued). (1) *Nemalionopsis shawii* Skuja, (2-3) *Caloglossa leprieurii* (Montagne) G. Marteus, (4) *Bostrychia moritziana*(Sonder) J. Agardh, (5) *Audouinella glomerata* Jao, (6) *Audouinella cylindrica* Agardh, (7-8) *Compsopogon coeruleus* (Balbis) Montagne, (9-10) *Compsopogon minutus* Jao, (11-13) *Compsopogonopsis fruticosa* (Jao) Seto. Scale bar = 100 μm (figs. 1, 2, 4, 7, 11); 20 μm (figs.3, 5, 8- 9, 13); 10 μm (figs. 6, 10).

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