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Possibility of freshwater red algae as bioindicator for water quality of streams in Nakhon Si Thammarat province, Thailand

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To study on diversity of freshwater red algae and water quality of five watershed area (Trang, Klong Klia, Kiriwong, Tapee, Klong Tha Ton**)** Nakhon Si Thammarat province, southern of Thailand, were conducted from February 2013 to January 2014. Samples were collected from 23 stream segment sites, which access by road area. Sixteen species in 8 genera of freshwater red algae *viz*., *Audouinella*, *Compsopogon, Batrachospermum, Kumanoa, Sirodotia, Thorea, Ballia* and *Caloglossa* were found. The majority of them were *Caloglossa ogasawaraensis* Okamura, *Compsopogon aeruginosus* Kützing and *Thorea clavata* Seto & Ratnasabapathy, respectively. The water quality was slightly different at each sampling site. Canonical Correspondence Analysis (CCA) was used to determine the relationship between the water quality and the present of stream red algae, in term of bio-monitoring. It was found that *Batrachospermum hypogynum* Kumano & Ratnsabapathy, *Kumanoa gibberosa* Necchi & Vis, indicated as oligotrophic status, whilst *Caloglossa ogasawaraensis* Okamura could be indicators of mesotrophic status, which were found as the dominant species in amount at Trang watershed were Pliu and Tan Tip site, in dry season. In addition, when the classification of water quality was based on trophic level by using by the Applied Algal Research Laboratory-Physical and Chemical Score (AARL-PC), the water quality were classified as oligotrophic and meso-eutrophic status.

Keywords: watershed, freshwater red algae, water quality, bio-monitoring

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Introduction

Using algae assemblages as indicators of water quality has a long traditional article, particularly in U.S.A. and Europe.The algae co-occur even though each species has a species niche based on its physical requirements and the constraints of the environment. There are many detailed descriptions of algae succession being correlated with changes in environmental parameters particularly, temperature, light, nutrients and mortality factors such as grazing (Eloranta and Kwandrans, 2004). Algae are involved in water pollution in a number of important ways. Due to the enrichment of inorganic phosphorus and nitrogen is responsible for the growth of algae in waste bodies. Research in the freshwater ecology of algae related to water is sparse and it is necessary of detailed studied for searching indicator species. Algae are one of the most rapid bio-indicator of water quality changes due to their short lifetime, instantaneous response to pollutants and easy to determine their numbers. Freshwater red algae characterize their environment in many ways owing to their different preferences variables (Eloranta and Kwandrans, 2004). In relation to the water quality, almost of them are often found in the clean to moderate quality of water with very few species being found in polluted water (Graham and Wilcox, 2000). In the rivers that bed is shallow, they are found mainly upstream and attached to solid substrate *e.g.* rock or cobble. They are also found in slow to fast flowing rivers or streams with low to high conductivity(Necchi,1993).In the Nordic countries, freshwater red algae are generally indicators of good quality (oliogotrophic status) (Eloranta and Kwandrans,2004). Some species of red algae from Khong river, Ping River and Thong Pha Phum National Park, Kanchanburi province of Thailand, were correlated with water quality changing and could be used for water quality indicator (Kunpradid and Peerapornpisal 2004; Peerapornpisal *et al*.,2004;Suphan *et al*.,2004).There have been few studies of freshwater red algae and the use of this group for water quality assessment is limited in Thailand. This study was carried out at stream of watershed, Nakhon Si Thammarat province, Thailand, where are an important watershed area for the surrounding villages and farms. The objectives of this research were: (1) to investigate the diversity of freshwater red algae and their relation to water quality in five watershed areas of Nakhon Si Thammarat province,Thailand and (2) to compare these data with the former report data, which the indicative species of these algae will be selected as bioindicators for assessment of water quality in Thailand**.**

Materials and methods

Study sites

The freshwater red algae samples were collected from 23 stream segments in 5 watershed area of Nakhon Si Thammarat Provinc**e**, southern part of Thailand, during February 2013 to January 2014. The study sites (Table 1) are located in Nakhon Si Thammarat province, which the climate in these areas is tropical, with well-demarcated rainy and dry seasons.

Table 1 Descriptions of the 23 sampling sites in watershed, Nakhon Si Thammarat province.

Name of watershed	Site description
Trang (TR)	Located in Thong Song district, compose of 6 stream segment sites, such as Thantip (TR1),Yong (TR2), Pliu (TR3), Nanpliu (TR4), Tarawarin (TR5) and Klongtapaetai (TR6)
KlongKlia (KK)	Located in Noppitum and Thasala district, compose of 9 stream segment sites, such as Pakklong (KK1), Klongyan(KK2), Monmod (KK3),Thepsana (KK4), Sunanta (KK5), Krungnang (KK6) Klongpot (KK7), Klonggun (KK8) and KlongKa (KK9)
Kiriwong (KRW)	Located in Lansaka district, compose of 4 stream segment sites, such as Wangbaipak (KRW1),Huaycheesuk (KRW2), Huayhang (KRW3) and Klonglumgna (KRW4)
Tapee (TP)	Located in Phipun district, compose of 2 stream segment sites, such as Wangrad (TP1) and Nannokann (TP2)
KlongThaTon (KTT)	Located in Sichon district, compose of 2 stream segment sites, such as Paitong (KTT1) and Wangdong (KTT2)

Sampling

The freshwater red algae were collected during the dry season (February and April), the early rainy (June and August: SW monsoon) and the heavy rainy season (October and December: NE monsoon). Species exploring were conducted along a transect line marked by permanent plots. The long-transect length surveyed is 10 m. per sampling site. For evaluation of seasonality quantitative methods (frequency) and for the distributional analysis qualitative (present or absence) used. For estimation of frequency and quantitative the transect length were divided into 10 equal parts (10 m. long-transect line) by a rope mark in 10 m. intervals, which stretched along the stream shores. Frequency of occurrence were took on the basis of the number of intervals in which a give species were present in relation to the ten samples.

Percentage cover on the stream bottom were evaluated in the same way and values were average to the whole transect (modified from Necchi, 1993).

Mean of the occurrence of algae	score
Not found	0
1 interval	1
2-3 intervals	2
4-6 intervals	3
7-8 intervals	4
9-10 intervals	5

Species identification was conducted according to Sheath (1984); Kumano (1993; 2002), Necchi and Vis (2012),Traichaiyaporn *et al*.,(2003;2004;2008;2012). Water temperature, conductivity and pH value were measured in the field using portable meters. Dissolved oxygen (DO) were also assessed in the field by the azide modification method Eaton *et al*.,(1995). Water turbidity was analyzed using a turbidity meter.

2.3 Data analysis

Statistical analyses were performed using software the multivariate statistical package (MVSP) for Windows. Diversity of freshwater (H') and evenness (E) were calculated according to the Shannon diversity (Brower *et al*., 1997). In order to identify interrelationships among sampling sites, cluster analysis using the percent similarity. The MVSP was used for Canonical Correspondence Analysis (CCA).The trophic status of water was evaluated from the main parameters such as DO, conductivity, ammonia-nitrogen, nitrate-nitrogen and soluble reactive phosphorus, by the Applied Algal Research Laboratory Physical and Chemical score (AARL PC score) (Peerapornpisal *et al*., 2004). For the cluster and CCA, the data was transformed to Log_{10} x+1 and the axes extracted by Kaiser's rule.

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Results and discussion

Water quality parameters

Nakhon Si Thammarat watershed is very important to Nakhon Si Thammarat, Surattanee and Trang province as it supplies freshwater need of the area. Mean water temperature varied from 24.55 to 26.20 ˚C. The velocity ranged between 2.70 to 82 $m.s^{-1}$. The turbidity ranged between 0.8.24 to 53.67 NTU, The total dissolved solid ranged between 0.81 to 58.9 $mg.L^{-1}$, the water conductivity, ranged between 12.44 to 46.68 $\mu s.cm^{-1}$. The pH average values of each sampling site were varied from 5.76 to 6.79. Most concurrent species were presented in slightly acid water. The dissolved oxygen ranged from 6.28 to 7.62 $mg.L^{-1}$. The acidity was ranged between 3.03 to 16.89 $mg.L^{-1}$as $CaCO_3$. The wide range of alkalinity was demonstrated, it was ranged from 5.62 to 142.98 $mg.L^{-1}$as $CaCO_3$. The wide range of hardness was demonstrated, it was ranged from 6.23 to 128.03 $mg.L^{-1}$as $CaCO_3$. Ammonium values varied from < 0.05 to 0.12 $mg.L^{-1}$.The trophic status varied from oligotrophic to meso-eutrophic status based on Wetzel (2001) and Lorraine and Vollenweider (1981) as shown in Table 2.

Table 2. Water quality by trophic status, species richness, diversity index and evenness of freshwater red algae taxa in each sampling sites.

Name of sites*	Trophic status (AARL-PC score)			Species richness	Shannon index	Evenness
	Dry season	Wet season (SW)	Wet season (NE)			
TR1	mesotrophic	mesotrophic	mesotrophic-eutrophic	6	2.21	0.91
TR2	mesotrophic	oligo-mesotrophic	oligo-mesotrophic	4	1.98	0.99
TR3	mesotrophic	oligo-mesotrophic	mesotrophic-eutrophic	4	2.10	0.96
TR4	mesotrophic	oligo-mesotrophic	mesotrophic	1	-	-
TR5	mesotrophic	oligo-mesotrophic	mesotrophic	1	-	-
TR6	oligo-mesotrophic	oligo-mesotrophic	oligo-mesotrophic	1	-	-
KK1	oligo-mesotrophic	oligotrophic	oligo-mesotrophic	3	1.53	0.96
KK2	oligo-mesotrophic	oligotrophic	oligo-mesotrophic	2	0.99	0.98
KK3	oligo-mesotrophic	oligotrophic	oligo-mesotrophic	1	-	-
KK4	oligo-mesotrophic	oligotrophic	oligotrophic	2	0.99	0.99
KK5	oligo-mesotrophic	oligotrophic	oligotrophic	2	0.72	0.72
KK6	oligo-mesotrophic	oligotrophic	oligotrophic	1	-	-
KK7	oligo-mesotrophic	oligotrophic	mesotrophic	1	-	-
KK8	oligo-mesotrophic	oligotrophic	mesotrophic	1	-	-
KK9	oligo-mesotrophic	oligotrophic	mesotrophic	1	-	-
KRW1	oligo-mesotrophic	oligotrophic	oligotrophic	1	-	0.91
KRW2	mesotrophic	mesotrophic	mesotrophic	4	1.83	0.76
KRW3	mesotrophic	mesotrophic	mesotrophic	2	0.77	-
KRW4	oligo-mesotrophic	oligotrophic	oligotrophic	1	-	-
TP1	oligo-mesotrophic	oligotrophic	oligotrophic	1	-	-
TP2	oligo-mesotrophic	oligotrophic	oligotrophic	1	-	-
KTT1	mesotrophic	oligotrophic	oligotrophic	1	-	-
KTT2	mesotrophic	oligotrophic	oligotrophic	2	1.0	1

*See Table 1, Materials and Methods for abbreviations

Freshwater red algae diversity and physico-chemical water parameters

A total of 16 red algae taxa were found in this study, belonging to 8 genera, *i.e. Audouniella, Compsopogon, Batrachospermum, Kumanoa, Sirodotia, Thorea, Ballia* and *Caloglossa*. A large number of red algae genera were *Kumanoa* (22 %). The Shannon diversity index, evenness and the number of red algae in each study sites are shown in Table 2. It is evident that TR1 site (Tantip), where 6 taxa were found, had the highest richness value with diversity index value of 2.21. As a result of the Shannon-Wiener, the diversity index was the highest in Tantip stream. It was followed by Pliu stream and Pakklong stream (Table 2).The analysis of the species diversity is used to explain the structure of community. It is known that the highest diversity of communities are composed of a lot of species and amount of algae. The richest species group is record as *Batrachospermum, Kumanoa* and *Sirodotia* (3 species), followed by *Thorea* (2 species) and *Audouniella, Ballia,Caloglossa* and *Compsopogon* (1 species) (Table 3). The frequency of occurrence of algae at all study sites is summarized in Table 3. *Caloglossa ogassawaraensis* and *Thorea clavata* as the dominant algae species, which found all seasons while, *Audouinella subtilis* and *Audouinella* sp.1 as were the rare species. Increment with temperature and nutrients was observed in dry season, correspondingly freshwater red algae population was increased at all study sites. During this study, maximum *Caloglossa ogassawaraensis* density was recorded in April 2013 at Thantip site which the highest value of nitrate (0.22 $mg.L^{-1}$) and soluble reactive phosphate (0.137$mg.L^{-1}$) were recorded.

Table 3. Summary of freshwater red algae taxa and frequency occurrence (%) in watershed of Nakhon Si Thammarat province.

	Taxa	**Frequency of occurrence (%)**
1	*Compsopogon aeruginosus*	83.33
2	*Audouninella subtilis*	16.67
3	*Audouninella* sp.1	16.67
4	*Batrachospermum hypogynum*	33.33
5	*Batrachospermum khaoluangensis*	50.00
6	*Batrachospermum* sp.1	50.00
7	*Kumanoa tagbagatenis*	33.33
8	*Kumanoa gibberosa*	66.66
9	*Kumanoa tiomanesis*	66.66
10	*Sirodotia huillensis*	50.00
11	*Sirodotia suceica*	50.00
12	*Sirodotia* sp.1	50.00
13	*Thorea clavata*	100
14	*Thorea siamensis*	50.00
15	*Ballia prieurii*	83.33
16	*Caloglossa ogassawaraensis*	100

The maximum algae density in Pliu stream was recorded in December 2013, nitrate and orthophosphate were also observed at maximum values and dominant species was *Compsopogon aeruginosus*.

The physico-chemical parameters are one of most influenced factor effects on the distribution of freshwater red algae. However, as evidenced by plots of freshwater red algae taxon numbers against levels of various physico-chemical parameters, the distribution of freshwater red algae taxa could be demonstrated on the different range of those physico-chemical parameters. Considering similarity analysis results eight groups were identified at 40 % similarity level. KlongKlia and Trang watershed were a big group (Fig 1).While, 2 sites of Klong Ta Ton was separate into 2 group.

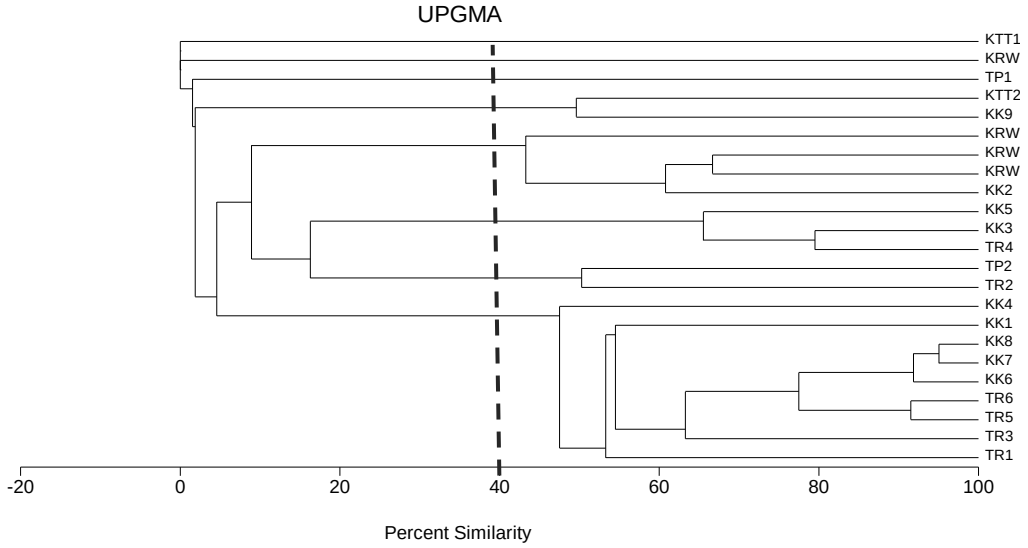

Fig. 1 Dendrogram for clustering of sampling site based on percent similarity.

The CCA analysis, showed a weak relationship between the diversity of freshwater red algae and environment factors. However, freshwater red algae distribution in this research could be separated into three groups according to water quality. It can be concluded that pH, nitrate-nitrogen (NO^-_3) and orthophosphate (PO^{-3}_4) were the chemical variables most strongly related to the abundance of *Caloglossa ogasawaraensis* (Co). The occurance of *Kumanoa tiomanesis* (Kt) was likely influenced by velocity (vel), total dissolved solid (tds). Alkalinity (alk) and hardness (har) were found to be the most influential factor on the distribution of *Compsopogon aeruginosus* (Ca), *Batrachospermum hypogynum* (Bh), *Sirodotia suecica* (Ss) *and Sirodotia* sp.1(Ssp). The occurrence of *Thorea siamensis* (Ts) and *Thorea clavata* (Tc) were likely influenced by dissolved oxygen (DO) (Fig 2). However, the dominant taxa found at the mesotrophic-eutrophic sites in dry season such as *Caloglossa ogasawaraensis* from Trang watershed were Pliu and Tan Tip site, and also found all seasons. Similary, *Caloglossa leprieurii* was found at Krabi province in water of moderated quality (Peerapornpisal *et al*., 2006). Thus, this species could possibly be used as bioindicators for mesotrophic status. On the other hand, the presence of rare species, such as *Batrachospermum hypogynum, Kumanoa tagbatensis, Audouinella subtilis* and *Audouinella* sp.1 could be used as oligotrophic status, which agree with (Suphan and Peerapornpisal, 2003) who reported that four species of *Batrachospermum* use for oligotrophic status of water quality in the area of the Golden Jubilee Thong Pha Phum Project. Thong Pha Phum District, Kanjanaburi province, Thailand. However, this research is only the screening and basic study of biomonitoring by freshwater red algae of Thailand. For the further detail study more sampling sites are needed in many watershed area.

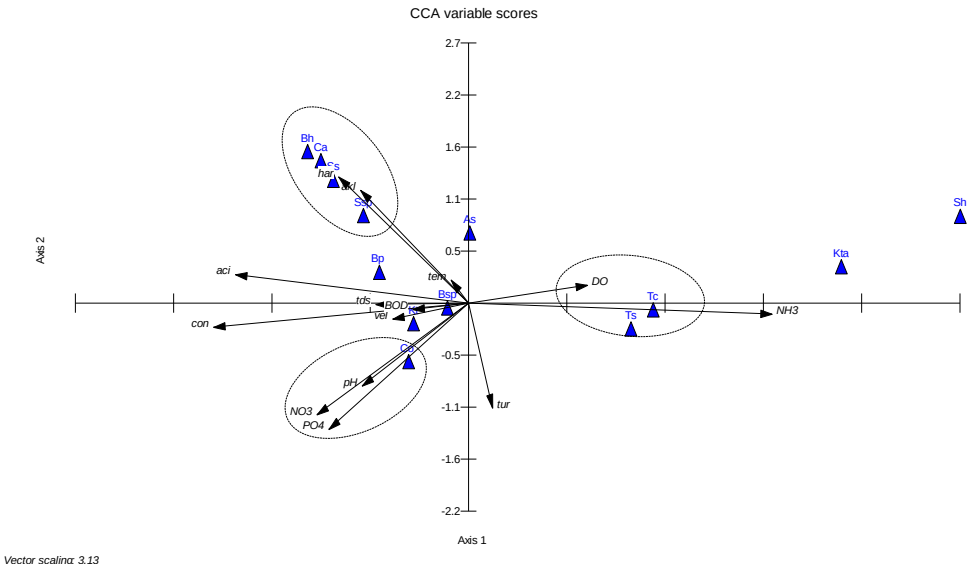

Fig. 2 Canonical correspondence analysis (CCA) of freshwater red algae distribution based on the correlation of environmental variables.

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