การตรวจติดตามคุณภาพน้ำและชุมชนแพลงก์ตอนพืชในสระเก็บน้ำพระราม 9 จ.ปทุมธานี ภายหลังเหตุการณ์น้ำท่วมใหญ่ในปี พ.ศ.2554

Water Quality Monitoring and Phytoplankton Communities in the Rama IX Lake, Pathumthani Province after Flood Disaster in 2011

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สาขาวิชาชีววิทยา คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยเทคโนโลยีราชมงคลธัญบุรี

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บทคัดย่อ

การตรวจติดตามคุณภาพน้ำและชุมชนแพลงก์ตอนพืชในสระเก็บน้ำพระราม 9 จ.ปทุมธานี ซึ่งเกิดเหตุการณ์น้ำท่วมใหญ่ในช่วงเดือนกรกฎาคมถึงเดือนพฤศจิกายน พ.ศ. 2554 โดยทำการเก็บตัวอย่างน้ำและแพลงก์ตอนพืชทุกเดือนหลังเหตุการณ์น้ำท่วม ตั้งแต่เดือนธันวาคม พ.ศ. 2554 ถึงเดือนพฤศจิกายน พ.ศ. 2555 ในบริเวณ 2 จุดเก็บตัวอย่าง จากข้อมูลค่าความเป็นกรด-ด่าง ปริมาณออกซิเจนที่ละลายในน้ำ ไนเตรท-ไนโตรเจน แอมโมเนีย-ไนโตรเจน ปริมาณแบคทีเรียกลุ่มโคลิฟอร์มทั้งหมด และปริมาณแบคทีเรียกลุ่มฟีคัลโคลิฟอร์ม สามารถจัดคุณภาพน้ำทั้ง 2 จุดเก็บตัวอย่างให้อยู่ในประเภท 2-3 โดยสามารถนำน้ำไปอุปโภคและบริโภคได้ทั้งที่ต้องผ่านการฆ่าเชื้อโรคตามปกติ และผ่านกระบวนการปรับปรุงคุณภาพน้ำทั่วไปก่อน ชุมชนแพลงก์ตอนพืชที่จุดเก็บตัวอย่างที่ 1 พบแพลงก์ตอนพืชทั้งหมด 7 ดิวิชัน 81 สปีชีส์ ส่วนจุดเก็บตัวอย่างที่ 2 พบทั้งหมด 7 ดิวิชัน 79 สปีชีส์ โดยพบว่า *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju, *Pseudanabaena limnetica* (Lemmermann) Komárek และ *Trachelomonas volvocina* (Ehrenberg) Ehrenberg มีความสัมพันธ์เชิงบวกกับปริมาณฟอสเฟตที่ละลายในน้ำ และเมื่อประเมินคุณภาพน้ำตามระดับสารอาหารร่วมกับแพลงก์ตอนพืชที่เป็นชนิดเด่น พบว่าคุณภาพน้ำในทั้ง 2 จุดเก็บตัวอย่าง สามารถจัดอยู่ในระดับสารอาหารปานกลางได้ โดยพบ *Peridiniopsis cunningtonii* Lemmermann และ *Trachelomonas volvocina* (Ehrenberg) Ehrenberg เป็นแพลงก์ตอนพืชชนิดเด่น ยกเว้นในช่วงเดือนธันวาคม พ.ศ. 2554 ถึงเดือนมกราคม พ.ศ. 2555 พบว่า *C. raciborskii, P. limnetica* และ *P. cunningtonii* เป็นแพลงก์ตอนพืชชนิดเด่นที่สามารถบ่งชี้คุณภาพน้ำให้อยู่ในระดับสารอาหารปานกลางถึงระดับสารอาหารสูงได้

คำสำคัญ : ชุมชนแพลงก์ตอนพืช ระดับสารอาหารปานกลาง สระเก็บน้ำพระราม 9

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Abstract

This study was focused on the monitoring of water quality and phytoplankton communities in the Rama IX Lake, Pathumthani Province which was affected by the flood disaster during July and November 2011. After flood crisis, water samples and phytoplankton were collected monthly from December 2011 to November 2012 at 2 sampling sites. The amount of pH, DO, NO_3-N, NH_3-N, Total Coliform Bacteria and Fecal Coliform Bacteria, the water quality in both sampling sites were classified in category 2-3 that is suitable for household consumption after proper process of water treatment. From the study on phytoplankton communities, 81 species in 7 divisions of phytoplankton were found in sampling site 1; and 79 species in 7 divisions, in sampling site 2. It was found that *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju, *Pseudanabaena limnetica* (Lemmermann) Komárek and *Trachelomonas volvocina* (Ehrenberg) Ehrenberg had a positive correlation with soluble reactive phosphorus. With regard to the trophic level and the dominant species of phytoplankton, the water in both sampling sites could be classified as mesotrophic status which found that *Peridiniopsis cunningtonii* Lemmermann and *Trachelomonas volvocina* (Ehrenberg) Ehrenberg were a dominant species, except in December 2011 to January 2012, *C. raciborskii, P. limnetica and P. cunningtonii* were a dominant species which indicator water in Rama IX Lake was in mesotrophic to eutrophic status.

Keywords : phytoplankton communities, mesotrophic status, Rama IX Lake

Introduction

From July to November 2011, the flood crisis occurred in Thailand. The beginning of the flood was at the end of July triggered by 'Nock-ten' tropical storm and soon spread through the provinces of Northern, Northeastern and Central Thailand. Fifty-six provinces were declared flood disaster zone and over 20,000 square kilometers of farmland was damaged. (Emergency Operation Center for Flood, 2012) The Rama IX Lake was also affected from flood from October 23, 2011 to November 21, 2011, and the water quality as well as phytoplankton communities was severely affected (Plangklang, 2012). The Rama IX Lake is a man-made lake with the capacity of about 16,100,000 cubic meters. It is one of His Majesty's Royal Projects to provide water supply for the public and for the people in Pathumthani Province (Irrigation North Rangsit, 1998). The lake also supplies water for agriculture to grow rice and vegetables during the dry season (Pongswat, 2002). Especially, the water from the Rama IX Lake is used to produce water supply in Rajamangala University of Technology Thanyaburi (RMUTT) and it is important that the water is suitable for consumption by RMUTT personal and students. After the flood, researchers had realized the degree of seriousness of the problem concerning the water quality in the Rama IX Lake. Therefore, monitoring water quality in the Rama IX Lake after flood disaster is essential. Presently, there are several parameters to monitor water quality such as physico-chemical and biological parameters (Eaton *et al*., 2005). One of the organisms successfully used for monitoring standing water is phytoplankton - a biological assessment (Phillips *et al*., 2013). Phytoplankton can be found around the world (Suphan & Peerapornpisal, 2007 ; Pekoh, 2002 ; Pongswat, 2002) because of its high potential richness and sensitivity to environmental factors (Reynolds, 2006). There are many advantages in using phytoplankton to monitor water quality of the resources for it is easy to get sampling, inexpensive and it creates minimal impact on resident biota (Quevauviller *et al*., 2008). Phytoplankton can be used as a good bio-indicator of water quality (Sommer *et al*., 1986) because it responds quickly and predictably to changes in nutrient status (Murphy *et al*., 2002).

The objectives of this research are to conduct a study on phytoplankton communities as bio-indicator with the physical and chemical factors to determine the trophic status and water quality of the Rama IX Lake for 12 months after the flood crisis from December 2011 to November 2012.

Materials and Methods

1. Study area & Sample sites

The Rama IX Lake is located at 14° 02´ latitude and 100° 44´ N longitude (Pongswat, 2002) in Amphur Khlong Luang and Amphur Thanyaburi, Pathumthani Province. The lake is located 40 meters above sea level. The Rama IX Lake is a big lake with two connecting parts. The first part covers an area of about 1,264 km^2 with the capacity of about 6,000,000 cubic meters. The second part covers an area of about 2,864 km^2 with the capacity of about 11,100,000 cubic meters (Irrigation North Rangsit, 1998). Water samples were collected from 2 sampling sites and investigated every month for 12 months from December 2011 to November 2012. At sampling site 1, the deepest point of the Rama IX Lake which can be used to represent of this lake (Wetzel, 1975). The water sample was collected at the depth of 1 meter from the surface and at the depth of every 5 meters until reaching the bottom of the lake (Pongswat, 2002 ; Pekkoh, 2002). Depending on the depth of water in each month, the methods of water sample collection should be collected from vertically regions because of phytoplankton will move in a vertical migration into the deep areas of the water depending on the penetration of light into the water (Lorenzen, 1963). At sampling site 2, where the raw water pumping station of RMUTT, the water was collected at the depth of 1 and 4 meters from the surface. At the depth of 4 meters, which is located of water pipe to be drawn to produce water supply in RMUTT (Figure 1).

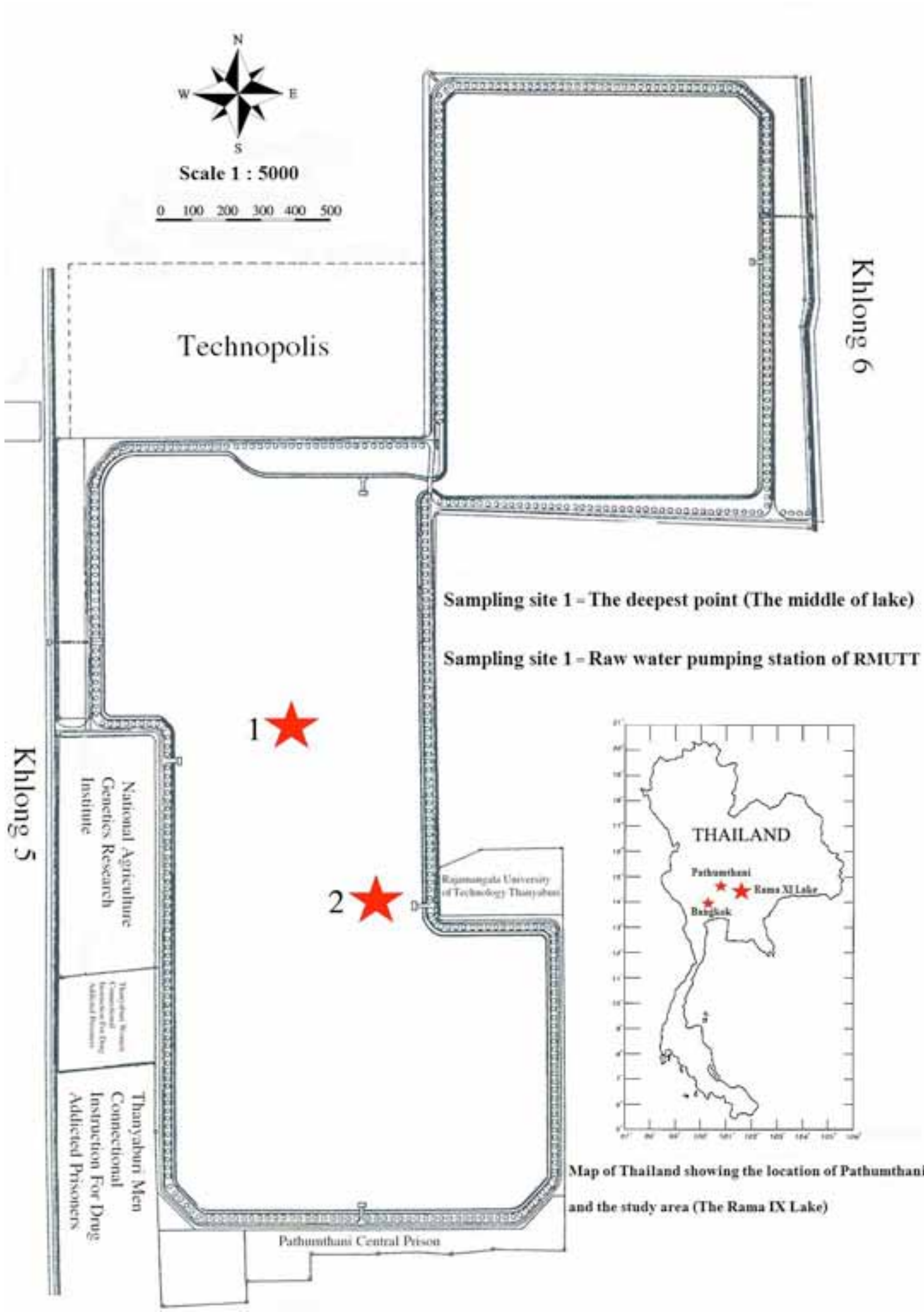

Figure 1 Map of the Rama IX Lake showing the location of the sampling sites.

2. Physico-chemical and biological parameters

The methods employed in conducting the study at sampling sites and in the laboratory according to Standard methods for the examination of water and wastewater (Eaton *et al*., 2005). The methods adopted for water quality analysis are listed in Table 1. The water quality that conducted at sampling sites were water temperature, Conductivity and pH. For the variable were analyzed in the laboratory such as the quantity of Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Alkalinity, Nitrate nitrogen (NO_3-N), Ammonia nitrogen (NH_3-N), Total phosphorus (TP) and Soluble reactive phosphorus (SRP), Total and Fecal Coliform Bacteria, while Chlorophyll a concentration was determined according to Nusch (1980).

3. Analysis of phytoplankton

For phytoplankton analysis, phytoplankton were collected by using two techniques. Firstly, phytoplankton were collected for identification at sampling site 1 (the deepest point) by sweeping the plankton net (mesh size 10 μm) which was pulled up vertically to the surface. The water sample from the plankton net was placed into an approximately 100 ml dark glass bottle (Verlencar & Desai, 2004). Secondly, phytoplankton were collected to assess the number of phytoplankton by using a water sampler. The water samples at the deepest point of sampling site 1 were collected at the depth of 1 meter from surface and at every 5 meters until reaching the bottom of the lake. At sampling site 2, the water was collected at the depths of 1 and 4 meters, respectively. Immediately after collection, all water samples were preserved in a 2 ml of Lugol's solution per 100 ml of sample (Throndsen, 1978). For counting and estimating phytoplankton biovolume, the samples were sedimented for 48 hrs. (APHA, AWWA, & WPCF, 1999) and studied with an Olympus inverted microscope using the Utermöhl method (UtermÖhl, 1958). Phytoplankton biovolume was estimated for individual species by assigning a geometric shape similar to the shape of each phytoplankton species (Rott, 1981). Taxonomic identifications were made according to Komárek & Anagnostidis (1998, 2005), Komárek & Fott (1983), Komárek

Table 1 Methods for physico-chemical and biological analysis (Eaton *et al*., 2005).

Variable	Methods of analysis
Physico-chemical variable:	
Water temperature (°C) & Conductivity (μS/cm)	Electrical conductivity method by conductivity meter
pH	Electrometric method by pH meter
Dissolved oxygen; DO (mg/L)	Azide modification method
Biochemical oxygen demand; BOD (mg/L)	5 Days incubation and azide modification method
Alkalinity (mg/L as $CaCO_3$)	Phenolphthalein Methyl-Orange Indicator method
Nitrate nitrogen; NO_3-N (mg/L)	Cadmium Reduction method
Ammonia nitrogen; NH_3-N (mg/L)	Nesslerization method
Total phosphorus; TP (mg/L)	Persulfate Digestion method
Soluble reactive phosphorus; SRP (mg/L)	Ascorbic Acid method
Biological variable:	
Total and Fecal Coliform Bacteria (MPN/100 mL)	Multiple Tube method
Chlorophyll a (μg/L)	Spectrophotometric method (Nusch, 1980)

et al. (2002), Krammer & Lange-Bertalot (1988, 1991), Huber-Pestalozzi (1950, 1983) and Smith (1950).

4. Statistical Analysis

The computer statistical package Microsoft and SPSS for Window Version 15.0 were used to perform the following statistical analysis: Analysis of water quality in terms of physical, chemical and biological parameters and phytoplankton biovolume at each depth of the lake by using Analyzed of variance (ANOVA) to find the difference, then Duncan's multiple range test to find any pair of mean exhibits the difference. The T-test was used to compare the differences of the means of two sampling sites, which both of ANOVA and T-test were tested normality distribution assumption successfully (Table 2).

The dominant species were analyzed by Principal Component Analysis (PCA), to find the dominant species of phytoplankton from the biovolume of phytoplankton through the year of study. Water quality data and the dominant species of phytoplankton were analyzed with Canonical Correspondence Analysis (CCA), to determine the relationship between physico-chemical water quality and dominant species. The PCA and CCA were done by using multivariate statistical package (MVSP) software.

Results and Discussion

Physico-Chemical and Biological Parameters

The physico-chemical and biological parameters at 2 sampling sites of the Rama IX Lake are presented in Table 3. The values of pH at both sampling sites was normal for general water resources which meant the water was livable for living organisms and suitable for human consumption (Kodchasanee, 1996) which did not exceed the standards of surface water (National Environmental Board, 1994). The conductivity was found to be in the range of 548.00-590.00 µS/cm. This conductivity value was considered to be rather low compared with 1,080-1,360 µS/cm in the research done at the same sampling site by Pongswat (2002) during the years 2000-2001. The lower value of conductivity was caused by excessive water coming into the lake during the flood, diluting ions of Ca^{2+}, Mg^{2+}, SO_4^{2-} and HCO_3^- present in the water (Duangsawasdi & Somsiri, 1985). The alkalinity values at both sampling sites were in range 10-200 mg/L, which was in line with alkalinity of natural water source (Kodchasanee, 1996).

The values of DO at both sampling sites in December 2011 were found to be lower than the standards of surface water which 6.0 mg/L caused by the great floods. In highly polluted water the amount of oxygen is very low (Loigu & Leisk, 1996). While, BOD values in both sampling sites were at the highest in December 2011, which higher than the standard value 1.5 mg/L that effected from the effluents during the microbial degradation of its organic content (Able, 1989). The results showed that the quality of water was not suitable for living organisms in the water (APHA, AWWA, & WPCF, 1992). After December 2011, the DO values were found to increase month by month and not lower than the said standard. This shows that the water quality is better than December 2011 and suitable for living organisms in the water (National Environmental Board, 1994).

NO_3-N and NH_3-N were found at both sampling sites with the amount not exceeding 5.0 mg/L and 0.5 mg/L respectively, which is the standards quality of surface water (National Environmental Board, 1994). The values of nutrients such as NO_3-N, NH_3-N, total phosphorus and soluble reactive phosphorus were found to be higher in relation to the depth of the water. The statistical test revealed significant differences ($p<0.05$) at different depth levels of lake (Table 4). Ariyadej *et al*. (2004) found that in Banglang Reservoir, Yala Province, nitrate and ammonia gradually increased in the line with the depth of the water. In this study, the amount of Total Coliform Bacteria and Fecal Coliform Bacteria found at both sampling sites did not exceed standards quality of surface water (National Environmental Board, 1994) which were 5,000 MPN/100 mL and 1,000 MPN/100 mL, respectively. Therefore, the

Table 2 Tests of Normality by using Kolmogorov-Smirnov of physico-chemical and biological variable in 2 sampling sites of the Rama IX Lake (December 2011 to November 2012).

Site	Depth (m)	Tests of Normality																							
		Kolmogorov-Smirnov																							
		Water temp		pH		Conductivity		Alkalinity		DO		BOD		NO_3-N		NH_3-N		TP		SRP		Chlorophyll a		Bivolume	
		Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.	Statistic	Sig.
1	1	.189	.200	.241	.054	.220	.112	.129	.117	.160	.200	.364	.000	.134	.200	.224	.178	.242	.051	.230	.079	.219	.116	.115	.200
	5	.202	.189	.145	.200	.228	.085	.148	.200	.115	.200	.388	.000	.204	.180	.209	.122	.212	.141	.212	.141	.194	.200	.152	.200
	10	.169	.200	.120	.200	.171	.200	.236	.063	.201	.195	.302	.003	.148	.200	.218	.121	.363	.000	.363	.000	.198	.200	.131	.200
	15	.141	.200	.174	.200	.205	.173	.226	.092	-	-	.343	.000	.136	.200	.238	.059	.276	.012	.276	.012	.206	.170	.165	.200
	20	.232	.200	.225	.200	.163	.200	.267	.142	-	-	.244	.200	.259	.171	.277	.111	.385	.002	.385	.002	.228	.200	.185	.200
2	1	.153	.200	.132	.200	.133	.200	.232	.072	.235	.066	.354	.000	.159	.200	.220	.114	.191	.200	.198	.200	.109	.200	.124	.200
	4	.158	.200	.157	.200	.155	.200	.120	.200	.200	.198	.339	.000	.173	.200	.228	.085	.201	.193	.195	.188	.196	.181	.191	.200

Sampling site 1 : The deepest point of the Rama IX Lake, Sampling site 2 : Raw water pumping station of RMUTT (- = no data) Variable of water temperature, pH, conductivity, alkalinity, DO, NO_3-N, NH_3-N, chlorophyll a and biovolume were normality distribution assumption, excepted BOD, TP and SRP were not normally distributed because of these factor had effected by flood crisis. These variables were highest at December 2011. After the time, these variables decreased month by month. Thus, they were not normally distributed. Then, All variable were analyzed using by ANOVA to find the difference.

Table 3 Mean and Standard Deviation (SD) of physico-chemical and biological variable measured in 2 sampling sites from the Rama IX Lake (December 2011 to November 2012).

Variable (Unit)	Sampling site 1					Sampling site 2	
	1 meter	5 meters	10 meters	15 meters	20 meters	1 meter	4 meters
Water Temperature (°C)	29.51 ± 0.06	28.45 ± 0.08	28.16 ± 0.09	28.23 ± 0.04	28.59 ± 0.08	29.49 ± 0.05	29.18 ± 0.06
pH	8.53 ± 0.02	8.22 ± 0.02	7.88 ± 0.04	7.79 ± 0.07	7.82 ± 0.05	8.53 ± 0.01	8.39 ± 0.01
Conductivity (µS/cm)	572.70 ± 0.24	573.00 ± 0.74	577.10 ± 1.48	580.00 ± 1.02	7.82 ± 1.64	8.53 ± 0.47	8.39 ± 1.34
Alkalinity (mg/L as $CaCO_3$)	80.40 ± 1.14	81.25 ± 0.81	85.90 ± 8.53	87.68 ± 3.98	88.96 ± 4.01	81.88 ± 1.13	83.04 ± 0.51
DO (mg/L)	6.92 ± 0.48	4.29 ± 0.30	1.55 ± 0.22	0.34 ± 0.01	0.32 ± 0.05	7.33 ± 0.44	6.12 ± 0.22
BOD (mg/L)	8.58 ± 0.49	8.42 ± 0.25	9.62 ± 0.90	10.23 ± 0.56	10.81 ± 0.41	8.92 ± 0.38	8.38 ± 0.26
NO_3-N (mg/L)	0.30 ± 0.05	0.22 ± 0.06	0.28 ± 0.05	0.47 ± 0.06	0.56 ± 0.05	0.30 ± 0.06	0.32 ± 0.04
NH_3-N (mg/L)	0.08 ± 0.01	0.08 ± 0.02	0.30 ± 0.03	0.43 ± 0.03	0.78 ± 0.05	0.08 ± 0.01	0.06 ± 0.01
TP (mg/L)	0.03 ± 0.01	0.05 ± 0.01	0.09 ± 0.01	0.20 ± 0.01	0.39 ± 0.02	0.03 ± 0.01	0.06 ± 0.01
SRP (mg/L)	0.03 ± 0.01	0.05 ± 0.01	0.09 ± 0.01	0.19 ± 0.01	0.38 ± 0.01	0.03 ± 0.01	0.05 ± 0.02
Chlorophyll a (µg/L)	7.87 ± 1.45	6.69 ± 1.18	6.25 ± 2.01	3.27 ± 0.98	1.61 ± 0.84	7.00 ± 1.12	6.78 ± 0.95
Total Coliform Bacteria (MPN/100 mL)	14.43 ± 0.02	-	-	-	-	19.25 ± 0.01	-
Fecal Coliform Bacteria (MPN/100 mL)	15.33 ± 0.01	-	-	-	-	15.88 ± 0.02	-

Sampling site 1 : The deepest point of the Rama IX Lake, Sampling site 2 : Raw water pumping station of RMUTT, - : Non detected.

Table 4 Average values of physico-chemical and biological variable in each levels of depth in sampling site 1: The deepest point of the Rama IX Lake (December 2011 to November 2012).

Depth (m)	variable											
	Wt	pH	Cond.	Alk.	DO	BOD	NO_3-N	NH_3-N	TP	SRP	Chl a	Biovol.
1	29.51^{b}	8.53^{c}	572.70^{a}	80.40^{a}	6.92^{d}	8.58^{a}	0.30^{a}	0.08^{a}	0.03^{a}	0.03^{a}	7.87^{d}	4267.09^{d}
5	28.45^{ab}	8.22^{b}	573.00^{a}	81.25^{a}	4.29^{c}	8.42^{a}	0.22^{a}	0.08^{a}	0.08^{ab}	0.07^{a}	6.69^{d}	4161.80^{d}
10	28.16^{a}	7.88^{a}	577.10^{a}	85.90^{a}	1.55^{b}	9.62^{a}	0.28^{a}	0.30^{ab}	0.09^{ab}	0.09^{a}	6.25^{c}	2181.50^{c}
15	28.23^{a}	7.79^{a}	580.00^{a}	87.68^{a}	0.34^{a}	10.23^{a}	0.47^{b}	0.43^{b}	0.20^{b}	0.19^{ab}	3.27^{b}	746.96^{b}
20	28.59^{a}	7.82^{a}	579.40^{a}	88.96^{a}	0.32^{a}	10.81^{a}	0.56^{b}	0.78^{c}	0.39^{c}	0.38^{b}	1.61^{a}	354.77^{a}

Averages within a column followed by the same letter were not difference by Duncan's Multiple Range test (Wt : Water temperature, Cond. : Conductivity, Alk. : Alkalinity, Chl a : Chlorophyll a, Biovol. : Biovolume).

water from the Rama IX Lake can be used for raw water in water supply.

Species composition

In the examination of the phytoplankton communities from both sampling sites, they were classified into 7 divisions and a total of 81 species and 79 species of phytoplankton were identified (Appendix ; Table 5). In sampling site 1, the Chlorophyta was the most abundant species with 32.10%. There were 27.17% species of Euglenophyta, 19.76% of Cyanophyta, 9.87% of Bacillariophyta, 4.93% of Pyrrhophyta were found, Cryptophyta had 3.70% and Chrysophyta had 2.46%. Similarly in sampling site 2, the Chlorophyta was the richest in species with 31.65%. Euglenophyta was found to have 22.79%, Cyanophyta - 20.26%, Bacillariophyta - 13.92%, Pyrrhophyta - 5.06%, Cryptophyta - 3.79% and Chrysophyta - 2.53%, respectively (Figure 2). In sampling sites 1 and 2 were found the highest species of phytoplankton in Division Chlorophyta. According to Charzykowskie Lake in Poland (Wiśniewska & Luścińska, 2012) and Mae Ngat Somboonchol Reservoir in Chiang Mai Province (Proongkiat, 1999) were found that the highest species of algae was in Division Chlorophyta. It was shown that there are an abundance of nitrate and phosphorus in the water when the Chlorophyta was the richest in water (Proongkiat, 1999).

In sampling site 1, the highest phytoplankton biovolume was found at the depth of 1 meter ranging from 780.34-12,347.78 $mm^3.m^{-3}$ (The average was 4,267.09 $mm^3.m^{-3}$). At sampling site 2, phytoplankton biovolume ranged from 1,051.49-13,903.18 $mm^3.m^{-3}$ (The average was 4,967.10 $mm^3.m^{-3}$). The highest value of phytoplankton biovolume at both sampling sites was found in December 2011 to January 2012 due to the inflow of nutrients, organic and inorganic matters into the lake during the great floods causing algae bloom (Talling, 1962 ; Wetzel, 1975). In the study of phytoplankton biovolume at different depths of sampling site 1, the biovolume stratification at 1 meter from water surface tended to be higher than those at lower depths (Figures 3). It was found that 31.35% at the depth of 1 meter followed by at the depth of 5 meters and 10 meters representing 30.54% and 20.15%, respectively. The percentages of phytoplankton biovolume were low at the depth of 15 and 20 meters with 12.49% and 5.47%, respectively (Figure 4). The finding showed significant differences ($p<0.05$) in the amount of biovolume in each depth of the lake because light is an essential factor for photosynthesis of phytoplankton. When the sunlight is able to penetrate through the water surface, phytoplankton will grow well and therefore increase the phytoplankton biovolume (Shirota, 1966). Likewise at sampling site 2, the phytoplankton biovolume at the depth of 1 meter was higher than that at 4 meters (Figure 5) but there were no significant differences ($p>0.05$). Comparing the amount of phytoplankton biovolume and chlorophyll a at the depth of 1 meter at both sampling sites, there were no significant differences ($p>0.05$) because of these sampling sites had the same physico-chemical variable. Therefore, the amount of phytoplankton biovolume and chlorophyll a were not different (Pekoh, 2002).

Both sampling sites had the same dominant species such as *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju followed by, *Peridiniopsis cunningtonii* Lemmermann, *Pseudanabaena limnetica* (Lemmermann) Komárek and *Trachelomonas volvocina* (Ehrenberg) Ehrenberg, respectively. In this research, *C. raciborskii, P. limnetica* and *P. cunningtonii* had the highest biovolume in both sampling sites after flood disaster during December 2011 and January 2012 which indicator water in Rama IX Lake was in mesotrophic to eutrophic status. However, *C. raciborskii* can be found in every specified depth of the lake because *C. raciborskii* is tolerant to low light availability and is able to assimilate and store phosphorus and to fix atmospheric nitrogen (Padisák, 1997) and very common in the tropical zone with an optimum temperature growth rate above 25°C

Appendix

Table 5 The phytoplankton communities in the Rama IX Lake (December 2011 to November 2012) (+ : found, - : not found).

Division/Species name	Sampling site		Division/Species name	Sampling site	
	1	2		1	2
Cyanophyta			Chlorophyta		
Arthrospira platensis (Nordstedt) Gomont	+	+	*Acanthosphaera zachariasii* Lemmermann	+	+
Aphanizomenon sp.	+	+	*Botryococcus braunii* Kützing	+	+
Aphanocapsa elachista West & G.S.West	+	+	*Chlamydomonas* sp.1	+	+
Aphanothece smithii J.Komárková-Legnerová & G.Cronberg	+	+	*Chlorella vulgaris* Beyerinck [Beijerinck]	+	+
Chroococcus globosus (Elenkin) Hindák	+	+	*Coelastrum microporum* Nägeli	+	+
C. limneticus Lemmermann	+	+	*C. pseudomicroporum* Korshikov	+	+
Coelomoron pusillum (Van Goor) Komárek	+	+	*C. sphaericum* Nägeli	+	+
Cylindrospermopsis philippinensis (Taylor) Komárek	+	+	*Cosmarium bioculatum* Brébisson ex Ralfs	+	+
C. raciborskii (Woloszynska) Seenayya & Subba Raju	+	+	*Crucigeniella crucifera* (Wolle) Komárek	+	+
Dolichospermum sp.	+	+	*Dictyosphaerium pulchellum* H.C.Wood	+	+
Merismopedia punctata f. arctica Kosinskaja	+	+	*Monoraphidium arcuatum* (Korshikov) Hindák	+	+
Microcystis aeruginosa (Kützing) Kützing	+	+	*M. contortum* (Thuret) Komárková-Legnerová	+	+
Oscillatoria limosa C.Agardh ex Gomont	+	+	*M. griffithii* (Berkeley) Komárková-Legnerová	+	+
Planktolyngbya limnitica (Lemmermann) J.Komárková-Legnerová & G.Cronberg	+	+	*M. irregulare* (G.M.Smith) Komárková-Legnerová	+	+
			Oocystis naegelii A.Braun	+	+
Pseudanabaena galeata Böcher	+	+	*Pandorina morum* (O.F.Müller) Bory de Saint-Vincent	+	+
P. limnetica (Lemmermann) Komárek	+	+	*Pediastrum simplex* Meyen	+	+
Pyrrhophyta			*Scenedesmus acuminatus* (Lagerheim) Chodat	+	+
Ceratium furcoides (Levander) Langhans	+	+	*S. armatus* (R.Chodat) R.Chodat	+	+
Gymnodinium sp.	+	+	*Spirogyra* sp.	+	-
Peridiniopsis cunningtonii Lemmermann	+	+	*Staurastrum perundulatum* Grönblad	+	+
Peridinium sp.1	+	+	*Tetraedron incus* (Teiling) G.M.Smith	+	+
Euglenophyta			*T. minimum* (A.Braun) Hansgirg	+	+
Euglena acus (O.F.Müller) Ehrenberg	+	+	*Tetrastrum staurogeniiforme* (Schröder) Lemmermann	+	+
E. charkowiensis D.O.Svirenko	+	-	*Treubaria setigera* (W.Archer) G.M.Smith	+	+
E. limnophila Lemmermann	+	+	*Volvox* sp.	+	+
E. minima Francé	+	+	Bacillariophyta		
E. proxima P.A.Dangeard	+	+	*Aulacoseira granulata* (Ehrenberg) Simonsen	-	+
E. velata G.A.Klebs	+	+	*Cocconeis pediculus* Ehrenberg	+	+
Lepocinclis fusiformis (H.J.Carter) Lemmermann	+	-	*Cyclotella meneghiniana* Kützing	+	+
L. glabra Drezepolski	+	-	*Eunotia multiplastidica* S.Mayama	-	+
Phacus curvicauda Svirenko	+	+	*Fragilaria crotonensis* Kitton	-	+
P. longicauda (Ehrenberg) Dujardin	+	+	*F. ulna var. acus* (Kützing) Lange-Bertalot	+	+
P. pleuronectes (O.F.Müller) Nitzsch ex Dujardin	+	+	*Gyrosigma macrum* (W.Smith) J.W.Griffith & Henfrey	+	+
P. pyrum (Ehrenberg) W.Archer	+	-	*Gyrosigma* sp.	+	+
Strombomonas borysteniensis (Roll) Popowa	+	+	*Navicula* sp.	+	+
S. fluviatilis (Lemmermann) Deflandre	+	+	*Nitzschia palea* (Kützing) W.Smith	+	+
S. verrucosa (E.Daday) Deflandre	+	+	*N. reversa* W.Smith	+	+
Trachelomonas bernardinensis Vischer	+	+	Chrysophyta		
T. dybowskii Drezepolski	+	+	*Isthmochloron gracile* (Reinsch) Skuja	+	+
T. hispida (Perty) F.Stein	+	+	*Mallomonas splendens* (G.S.West) Playfair	+	+
T. intermedia P.A.Dangeard	+	+	Cryptophyta		
T. mucosa Svirenko	+	+	*Chroomonas* sp.	+	+
T. volvocina (Ehrenberg) Ehrenberg	+	+	*Cryptomonas* sp.	+	+
T. volvocinopsis Svirenko	+	+	*Rhodomonas* sp.	+	+

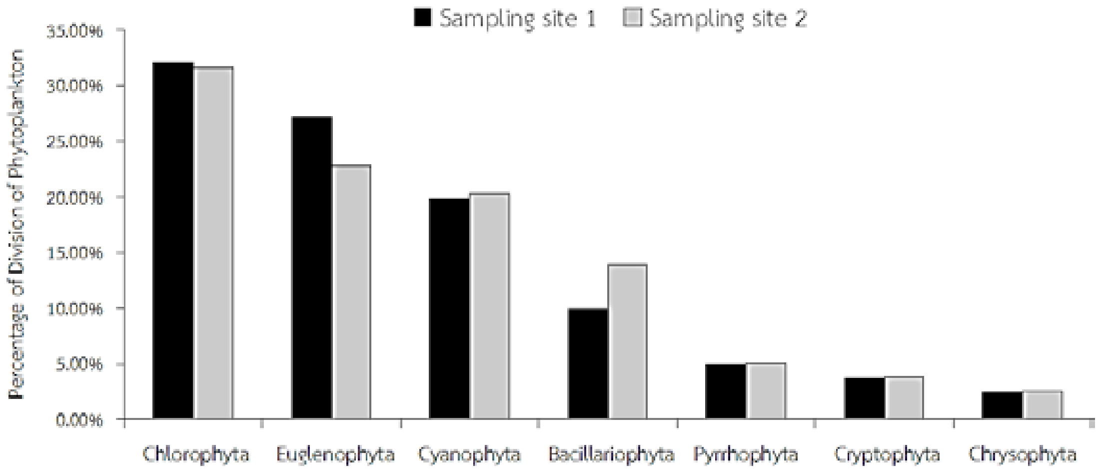

Figure 2 The percentage of the species in each division in sampling site 1: The deepest point of the Rama IX Lake and sampling site 2: Raw water pumping station of RMUTT.

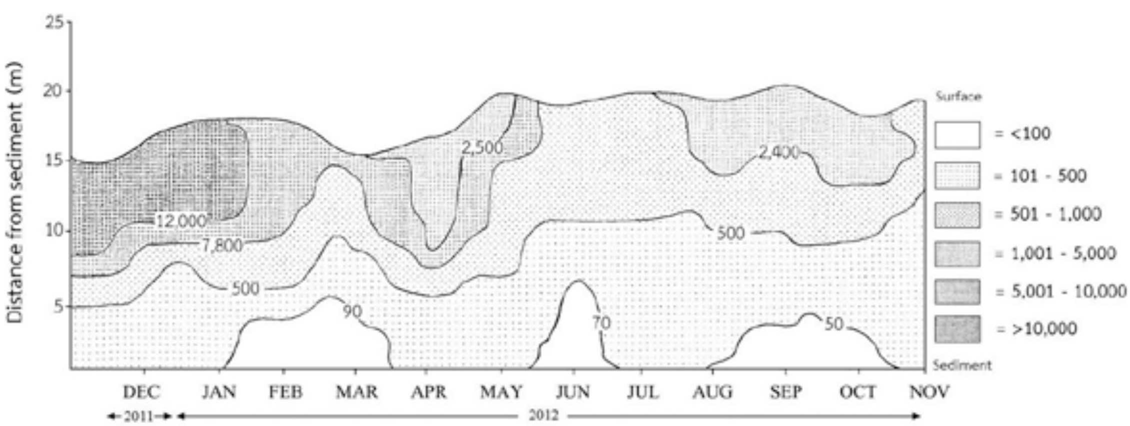

Figure 3 The different water levels of the biovolume ($mm^3.m^{-3}$) in sampling site 1: The deepest point of the Rama IX Lake (December 2011 to November 2012).

(Chiswell *et al*., 1997). Walsby (1992) reported that *C. raciborskii* has gas vacuoles which is nitrogen gas. Thus, it can be sink to the lower levels or float up to the surface of the lake.

After flood period from February to November 2012, it was found that *P. cunningtonii* which is dinoflagellate and *T. volvocina* were a dominant species in both sampling sites of the Rama IX Lake and indicated as mesotrophic status. According to Suravit (1996), who found *Peridinium* app. and *Trachelomonas* spp. were to be the dominant species in Ratchaprapa reservoir in southern, Thailand and indicated as mesotrophic status. Therefore, the dominant species of phytoplankton can be used to indicator the trophic status in the Rama IX Lake.

Water quality

The water quality of both sampling sites was classified based on the surface water quality standards of Thailand set by the Notification National Environment Board (1994). Some deciding parameters used were pH, DO, NO_3-N, NH_3-N, Total Coliform Bacteria and Fecal

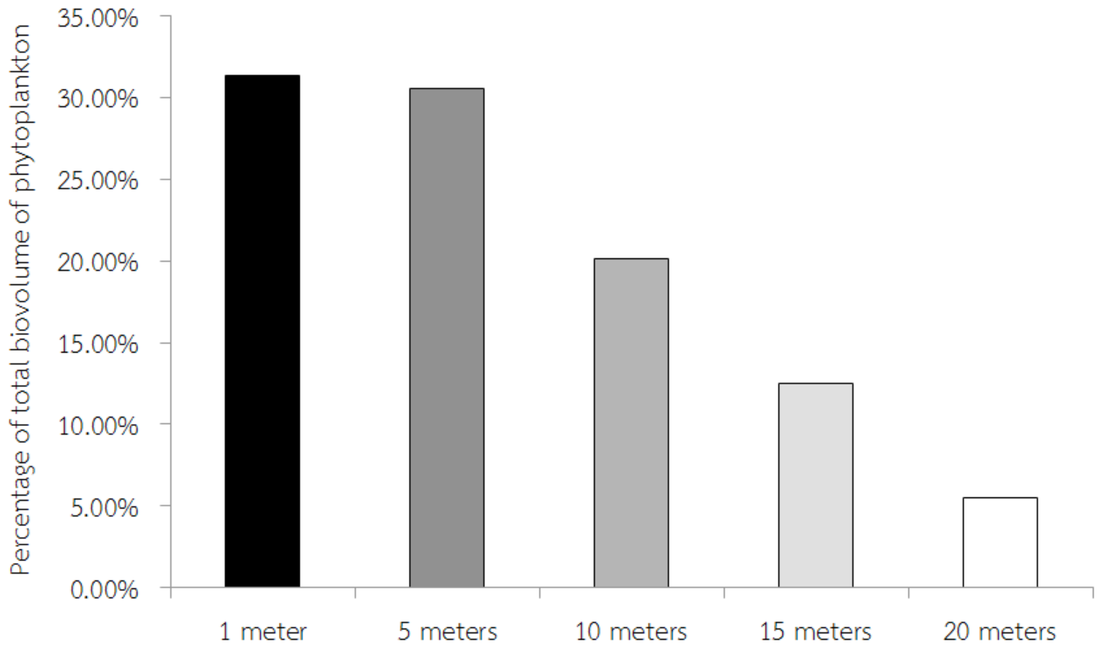

Figure 4 The percentage of total biovolume of phytoplankton in various depths at sampling site 1: The deepest point of the Rama IX Lake.

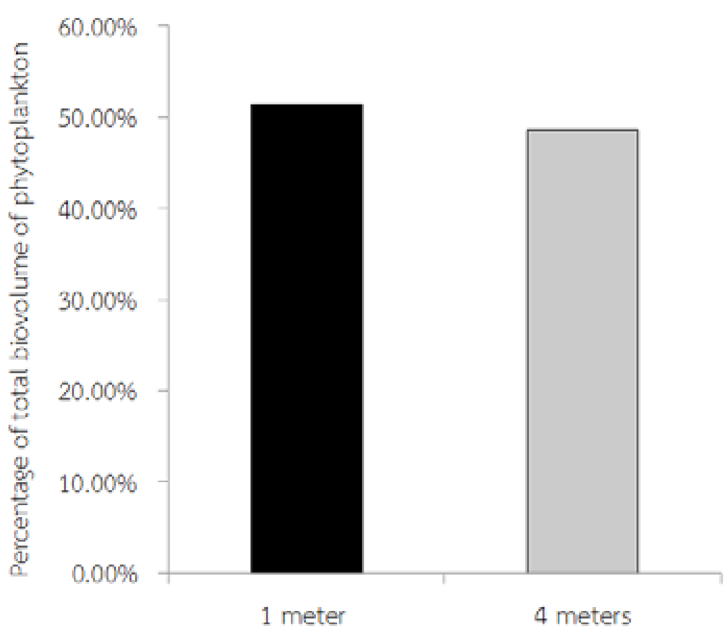

Figure 5 The percentage of total biovolume of phytoplankton in various depths at sampling site 2: Raw water pumping station of RMUTT.

Table 6 The classification of trophic status in each month from December 2011 to November 2012 in the Rama IX Lake.

Sampling Site	Standard	variable	The classification of trophic status in each month of the Rama IX Lake											
			2011	2012										
			Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	Lampart & Sommer (1993)	Total phosphorus (mg/L)	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
		Chlorophyll a (µg/L)	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
		Biovolume ($mm^3.m^{-3}$)	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	Reynoids (1980)	Dominant species	Meso-Eutrophic	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
2	Lampart & Sommer (1993)	Total phosphorus (mg/L)	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
		Chlorophyll a (µg/L)	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
		Biovolume ($mm^3.m^{-3}$)	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
	Reynoids (1980)	Dominant species	Meso-Eutrophic	Meso-Eutrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic

Sampling site 1 : The deepest point of the Rama IX Lake, Sampling site 2 : Raw water pumping station of RMUTT

Coliform Bacteria. The water in both sampling sites could be placed in the second to third category. It could be suitable for household consumption after being properly treated.

The classification of trophic status of the water quality at both sampling sites in the Rama IX Lake was based on the variable of total phosphorus, chlorophyll a, phytoplankton biovolume and the dominant species of phytoplankton set by Lampert & Sommer (1993) and Reynoids (1980). The finding showed that the water quality in the Rama IX Lake could be classified as mesotrophic status, except in December 2011 to January 2012, the months after the great flood; the water was in mesotrophic to eutrophic status (Table 6).

Relationship between phytoplankton and physico-chemical and biological parameters

The results of CCA to find the relationship between physico-chemical and biological variable as well as the dominant species of phytoplankton were shown in Figures 6 and 7. At sampling sites 1 and 2, *C. raciborskii, P. limnetica* and *T. volvocina* had a positive correlation with soluble reactive phosphorus (SRP). Similar report on this correlation also found by Burkholder *et al*. (2008), Pooarlai (1999) and Malaiwan (2010) who found that *C. raciborskii* showed a positive correlation with soluble reactive phosphorus in the water because phosphorus is main nutrient phytoplankton require to thrive. It functions as one of the major players in the process of photosynthesis, nutrient transport and energy transfer. Phosphorus also effects the phytoplankton's structure at a cellular level (Clark *et al*., 1977). And according to Sommer (1989) reported that these phytoplankton need to use high amounts of phosphorus for growth. Therefore, the amount of these species increased with relation to higher soluble reactive phosphorus in the water. In addition, *P. cunningtonii* was found to have a positive correlation with NO_3-N at sampling site 2. Those species can use nitrate-nitrogen for growth, which nitrogen is essential for phytoplankton to synthesis amino acid of proteins and nucleic acids (Darley, 1982).

Conclusion

The water quality of both sampling sites in the Rama IX Lake from December 2011 to November 2012 after flood disaster could be placed in the second to third category based on the defined standards for surface water quality (1994). Water in the Rama IX Lake is suitable for household consumption when it was property treated. The phytoplankton communities was represented by 7 divisions 81 species which were found in sampling site 1 and 7 divisions 79 species were found in sampling site 2. With regard to the trophic level based on the amount of total phosphorus, chlorophyll a, phytoplankton biovolume and the dominant species of phytoplankton, the water in both sampling sites of the Rama IX Lake could be classified as mesotrophic status, except in December 2011 to January 2012 could be classified into mesotrophic to eutrophic status.

Acknowledgement

The researchers would like to thank Rajamangala University of Technology Thanyaburi for giving the grant to conduct this research study.

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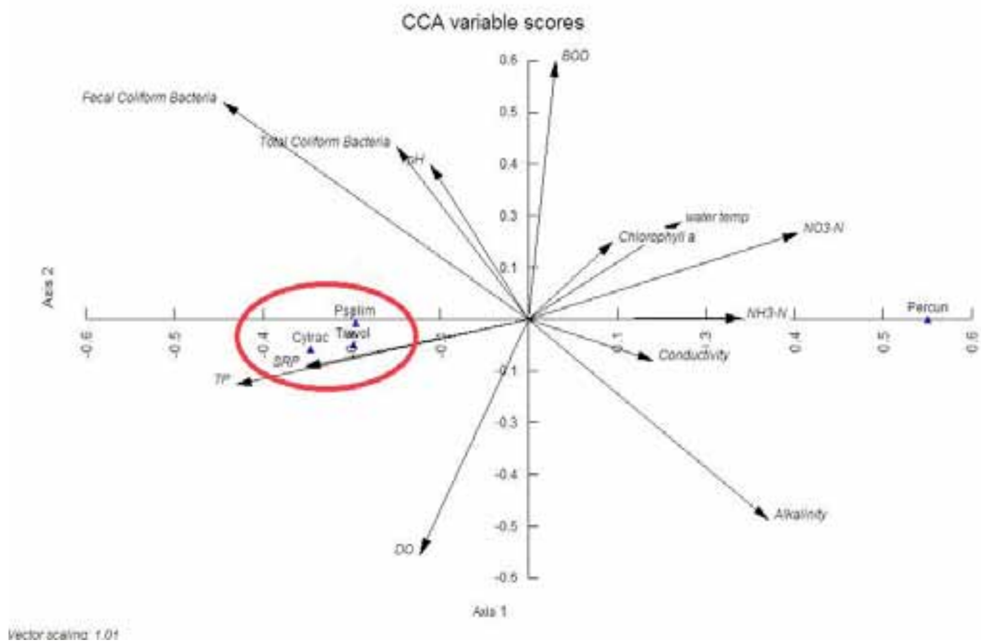

Figure 6 The percentage of total biovolume of phytoplankton in various depths at sampling site 1: The deepest point of Rama IX Lake.

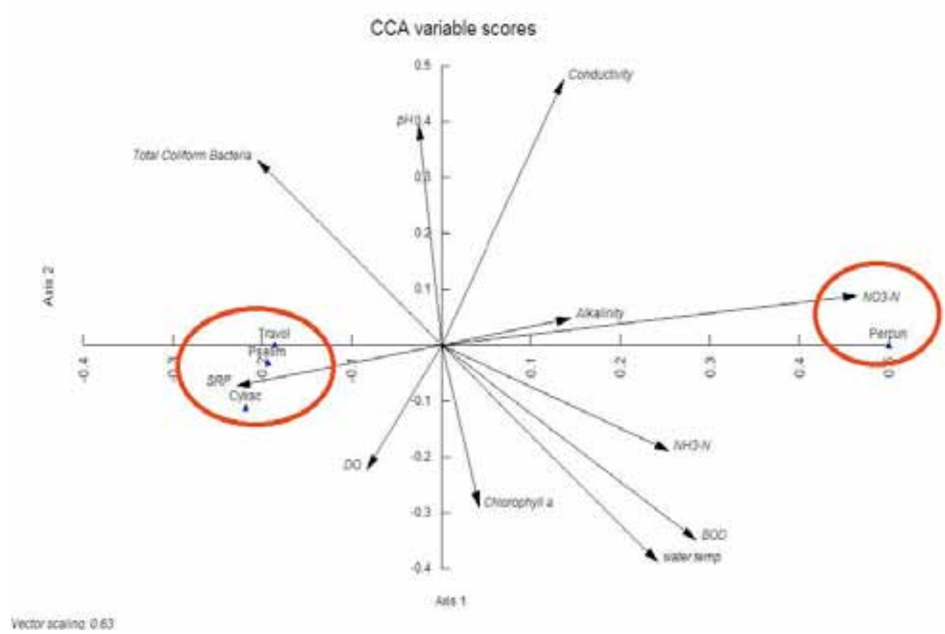

Figure 7 The percentage of total biovolume of phytoplankton in various depths at sampling site 2: Raw water pumping station of RMUTT.

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