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Diversity of Phytoplankton and Water Quality in Mae Suai Reservoir During the Rainy Season

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Abstract

The diversity of phytoplankton along with the water quality in the Mae Suai Reservoir, Chiang Rai province was studied from August to October 2016 (the rainy season). Specimens were collected from sites that were located in four different areas; the inlet area, the outlet area, a community area and the area that is used for agricultural purposes. A total of 39 genera of phytoplankton consisting of 52 species were obtained from the Mae Suai Reservoir. The dominant species were *Cosmarium moniliforme, Staurastrum* cf. *longibrachiatum*, *Pseudanabaena* sp., *Aulacoseira granulata, Frustulia* sp. and *Peridinium* sp. Notably, the dominant species were subject to change each month. The diversity index revealed that the highest values were recorded in October (3.41) and the lowest were recorded in August (3.27). The trophic status was classified as oligo-mesotrophic (September) to mesotrophic status (August and October). The physical and chemical factors affecting dominant phytoplankton species by canonical correspondence analysis (CCA) showed that *Pseudanabaena* sp. and *Aulacoseira granulata* had positive correlation with conductivity, BOD_5, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus (SRP). Nevertheless, *Frustaria* sp. had negative correlation to those parameters. *Staurastrum* cf. *longibrachiatum* and *Cosmarium moniliforme* had a negative correlation with DO.

Keywords: Phytoplankton, trophic status, water quality, Mae Suai Reservoir

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1. Introduction

Phytoplankton can be defined as free floating unicellular, filamentous and colonial organisms. They are important primary producers and form the basis of the aquatic food chain [1]. They are abundant in surface waters where sunlight and nutrients are readily available and where they can absorb carbon dioxide to produce oxygen through the process of photosynthesis. Phytoplankton can be found in bodies of water with a wide variety of water quality and are known to possess different physical and chemical requirements. Their tolerance levels determine the dominance of the species at different times and during different seasons [2]. The growth of phytoplankton among different species is likely to be limited by the available resources, including the nutrients that are present in the water body [1].

The study of the diversity of phytoplankton in relation to the water quality in Thailand has been continually studied from the past to the present. The checklist of algae found in Thailand is comprised of a report produced by Wongrat [3] that is compiled from 53 publications, listing 161 genera, 1,001 species, 287 varieties and 63 forms. Mae Suai Reservoir is a medium-sized reservoir (73 million cubic meters of water capacity) located in Chiang Rai Province in the northern part of Thailand, which has never been studied in terms of phytoplankton diversity. This location is a catchment reservoir for the Lum Nam Suai and serves as an agricultural resource. Lum Nam Suai is seventy kilometers long and flows through the agricultural area and community area, after which it gets released into the Mae Suai Reservoir. In addition, this reservoir is an important tourist attraction in Chiang Rai that also provides recreational and entertainment services all year round, such as providing locations for restaurants and raft rentals along the way. These activities have affected the water quality of the water body. Moreover, according to the Institute of Water Resources and Agriculture (Public Organization) [4], it was reported that the monthly rainfall in this reservoir varies widely during the course of the rainy season. The amount of rain resulted in the discharge of nitrogen and phosphorus from the agricultural and community activities into the reservoir and affected water quality and the phytoplankton diversity. The main objectives of this research study were to determine the relationship between the phytoplankton diversity and the water quality during the rainy season.

2. Materials and Experiment

2.1 Study Areas

Mae Suai Reservoir is a medium-sized reservoir and is a catchment reservoir for the Lum Nam Suai . The reservoir serves as an agricultural resource in this area. Most of the surrounding area is comprised of forests and agricultural plantation. In addition, this reservoir provides recreational and entertainment services all year round, such as providing locations for restaurants and raft rentals along the way. Water samples were collected from four sites within the Mae Suai Reservoir water body (19°68'20.15"N, 99°53'67.35"E); inlet, outlet, community area and agricultural area (Figure 1) during the course of the rainy season (from August to October, 2016).

2.2 Collection and identification of phytoplankton

Twenty liters of water samples from each station at the Mae Suai Reservoir were collected and filtered using a 10 µm mesh size plankton net. The samples were preserved by adding 0.7 mL of Lugol's solution to 100 mL of the sample [5]. The samples were observed under a light microscope and photographed using an Olympus Normaski microscope. The phytoplankton specimens were identified based on relevant characteristics such as color, cell-size, colony or filament, the shape of the chloroplast, the number and position of the flagella with or without the spine, as well as the details of the granular characteristics of the cell wall [6]. The assessment was conducted according to relevant literature, e.g.; Prescott [7]; Huber-Pestalozzi [8]; Hindák [9]; Komarek and Jankovska [10] and John et al. [6]; Lewmanomont [11]; Yamagishi and Kanetsuna [12]; Hirano [13-14].

Cell enumeration of the phytoplankton species was assessed by the Lackey drop method [15], which is a simple method that is used to obtain results when studying the density of plankton population. Dominance (Y) of a species was calculated by the following equation [16]:

$$Y = \frac{ni}{N} .fi$$

ni is the abundance of species i

fi is the occurrence frequency of species i

N is the total abundance

The occurrence frequency of a species refers to the proportion of the number of stations reporting its occurrence in the total number of the sampling stations. The dominant species was defined when $Y \geq 0.02$ [17].

Calculation of the diversity index was determined using Shannon's method [18]. Canonical correspondence analysis (CCA) [19] was used to find the relationship between certain physical and chemical factors and the phytoplankton. Comparison between parameters in each month was estimated by using ANOVA followed by post hoc Tukey's b test at $p<0.05$.

Figure 1 Map of study area;

1. Inlet area: that receives the water from Lum Nam Suai
2. Community area, 3. Outlet area: before being drained,
4. Agricultural area: the area used as an agricultural source

2.3 Determination of physico - chemical properties of water

A determination of the relevant physico - chemical properties of water in the reservoir was conducted at each sampling site. The conductivity was measured with a conductivity meter and dissolved oxygen (DO) was measured using the azide modification method [5]. Water samples were then collected at a depth of 30 centimeters from the surface of each collection site using polyethylene bottles, which were then kept in a cool box (5-7 °C) for later analysis in the laboratory.

Some chemical parameters were analyzed in the laboratory including biochemical oxygen demand (BOD) that was determined using the azide modification method. Additionally, nutrient content, particularly nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus (SRP), was assessed using the cadmium reduction method, nesslerization method and ascorbic method, respectively according to the protocol of Eaton et al. [5].

The trophic status of the water was classified according to the method of Peerapornpisal et al. [20].

3. Results and Discussion

3.1 Diversity of phytoplankton

A total of 3 9 genera of phytoplankton consisting of 52 species were found in the Mae Suai Reservoir. Each species shows difference of % relative abundance during each month (Table1). The relative abundance can be used to consider the dominant species [16]. The wide distribution of phytoplankton included five division groups consisting of Chlorophyta (52%), Bacillaliophyta (19%), Euglenophyta (12%), Pyrrophyta (10%), Cyanophyta (8%). All phytoplankton species found in the reservoir were acknowledged as common species that are typically found in standing fresh water throughout Thailand [21]. However, when compared to the species diversity with what has been previously reported, it was found to be same and different at some aspects. In this study, the amount of species was equal to the number of previously reported by Meesukko [22], who found 39 species of phytoplankton in the Kaeng Krachan Reservoir, Phetchaburi Province, in rainy season. Similarly to the Mae Suai one, those are open-air reservoir and supplies water for electricity generation, irrigation, transportation, tourism and fisheries. However, in comparison to the species diversity reported by Prasertsin and Peerapornpisal [23], it was found that the amount of species was lower (90 and 55 species in Nong Bua Reservoir and Chiang Saen Lake, Chiang Rai Province). Due to human activities of surrounding areas at the sampling sites, the effects on nutrient levels were different. Nitrate nitrogen, phosphorus were the most important nutrients often found to be the growth-limiting factors for algae and plants [1], [24- 25].

Table 1 Species and % relative abundance of phytoplankton in Mae Suai Reservoir, Chiang Rai Province, Thailand

Species	% Relative abundance		
	August	September	October
Division Cyanophyta			
Aphanocapsa sp.	2.89	2.44	2.15
Cylindrospermopsis raciborskii (Wolosz.) Seenayya & Subba Raju	0.96	1.97	1.69
Microcystis aeruginosa Kützing	1.68	0.18	0.61
Pseudanabaena sp.	12.52*	1.07	8.16*
Division Chlorophyta			
Botryococcus braunii Kützing	1.73	2.15	2.62
Closteriopsis sp.	2.16	1.18	0.77
Closterium sp.	2.64	1.79	0.31
Chlorella sp.	0.96	0.36	0.31
Coelastrum microsporum Nägeli	0.00	0.36	0.15
Coelastrum reticulatum (Dangeard) Senn	2.16	5.92	0.46
Cosmarium contractum var. *contractum* Kirchner	1.69	1.07	2.31
Cosmarium moniliforme (Turpin) Ralfs	5.30	10.04*	2.00
Cosmarium sp.	2.26	2.33	1.08
Dictyosphaerium granulatum Hindák	1.44	0.71	0.31
Dictlyosphaerium tetrachotomum Printz	0.96	0.89	0.92
Eudorina sp.	1.93	0.00	0.77
Golenkinia sp.	0.00	0.00	3.39
Gonium pectorale O.F.Müller	0.24	0.36	0.31
Monoraphidium contortum (Thuret) Komárková-Legnerová	0.96	0.54	2.28
Monoraphidium torile (West et G.S.West) Komàrkovà-Legnerovà	0.72	1.26	5.39
Netrium sp.	0.48	0.36	0.46
Oocystis sp.	2.64	0.54	0.61
Pediastrum duplex var. *duplex* Meyen	0.00	0.36	2.00
Pediastrum simplex var. *simplex* Meyen	0.24	0.36	0.15
Scenedesmus sp.	1.92	2.33	2.00
Staurastrum gutwinskii Ralfs	1.68	2.65	0.46
Staurastrum cf. *longibrachiatum (*Borge) Gutwinski	2.89	9.69*	1.23

Species	% Relative abundance		
	August	September	October
Staurastrum smithii Teiling	2.41	2.15	2.00
Staurastrum sp.	1.44	0.00	0.00
Staurodesmus convergens (Ehrenberg ex Ralfs) Teiling	0.94	4.66	2.77
Tetraedron sp.	0.48	0.36	1.23
Division Euglenophyta			
Euglena gracilis Klebs	0.00	2.69	3.39
Lepocinclis oxyuris (Schmarda) Marin & Melkonian	0.00	0.00	1.08
Phacus orbicularis f. *communis* Popova	0.00	0.36	0.77
Phacus ranula Pochmann	0.00	0.36	0.31
Trachelomonas hispida (Perty) F. Stein	0.00	0.18	0.15
Trachelomonas volvocina Ehrenberg	2.40	2.69	3.23
Division Bacillariophyta			
Aulacoseira granulata			
Ehrenberg (Simonsen)	12.27*	8.52*	8.90*
Achnanthes sp.	0.56	1.07	1.23
Cyclotella sp.	2.40	1.07	0.46
Cymbella sp.	2.40	3.13	4.15
Diatomella sp.	1.44	2.51	3.39
Encyonema sp.	0.72	0.54	0.15
Frustulia sp.	1.44	9.33*	8.16*
Gomphonema gracile Ehrenberg	0.24	0.36	0.15
Navicula sp.	0.96	1.79	1.85
Pinularia sp.	1.20	2.51	2.77
Division Pyrrhophyta			
Ceratium brachyceros Daday	0.24	0.18	0.46
Ceratium furcoides (Levander) Langhans	0.72	0.36	0.46
Ceratium hirundinella (O.F. Müller) Dujardin	0.72	0.00	0.31
Peridiniopsis sp.	1.69	1.26	0.77
Peridinium sp.	12.28*	5.02	8.96*

Note: * = Dominant species

According to Shannon's diversity index, the values of phytoplankton in Mae Suai Reservoir revealed few variations during different months; the highest value was recorded in October (diversity index 3.41, evenness 0.59) followed by September (diversity index 3.33, evenness 0.59) and August (diversity index 3.27, evenness 0.60), respectively (Table 2). These results was similar to the report of Khuantrairong and Traichaiyaporn [26] that the number of species and density of phytoplankton was low in the rainy season (August when loading of suspended solids from agricultural area led to high turbidity and low water transparency [27]. These factors were therefore also likely to control the phytoplankton growth [28], resulting in the reduced phytoplankton density in the rainy season [26]. The results agreed with the report by Ariyadej et al. [29] that high concentration of total phosphorus, high turbidity and low water transparency were not suitable conditions for phytoplankton growth.

Table 2 Shannon's diversity index, evenness and amount of phytoplankton presented in the Mae

Shannon's diversity index	**August**	**September**	**October**
Diversity index	3.27	3.33	3.41
Evenness	0.60	0.59	0.59
Amount of species	44	47	51

3.2 Water quality and physico-chemical properties

Certain differences in the values of the physico-chemical parameters of the Mae Suai Reservoir in each sampling sites were revealed during the months of August and October (Table 3). The overall conductivity was found to be between 124 and 154 µS/cm at all sampling sites which was normal for general water resources, meaning that the water was livable for living organisms and suitable for human consumption as it did not exceed the quality standard (<300 µS/cm) of surface water [30]. The value of the dissolved oxygen (DO) was between 6.23 and 8.57 mg/L. Therefore, all sampling sites met the standards of the surface water quality for general water resources (2 mg/L) [30]. The highest and lowest value was found at site 4 in October and August respectively. The BOD was between 1.53 and 2.20 mg/L. The highest value occurred in August at site 1, while the lowest value was recorded in September at site 2. The results showed that it did not exceed the standard of surface water [30]. The amounts of nutrients such as nitrate- nitrogen, ammonia nitrogen and soluble reactive phosphorus were between 0.13 - 1.33 mg/L, 0.05 - 0.45 mg/L and 0.07 - 0.89 mg/L, respectively. The highest value occurred in August at site 1, while the lowest value was recorded in September at site 2. The level of nitrate - nitrogen and ammonia nitrogen found at all site did not exceed the values of Thailand's prescribed surface water quality standards [30]. When compared the physico-chemical parameters among the sampling sites, the values of conductivity, the amounts of nitrate nitrogen and ammonia nitrogen were significant different ($p<0.05$) in august. All of those parameters were high in the inlet area (site 1), followed by the agricultural area (site 4). Both site 1 and site 4 were most commonly associated with the discharge of effluents from agricultural fertilizers and wastewater runoff from community into the reservoir [31]. At site 1, the slow running water containing organic matter was discharged into the water and became an important source of algal nutrients since an aerobic decomposition of organic matter resulted in the release of phosphate, nitrate and other nutrients [1] into the water though out communities. In the month of September, the values of DO, BOD, ammonia nitrogen and soluble reactive phosphorus among all sites were significantly different ($p<0.05$). All of those parameters were high in inlet area (site 1) followed by agricultural area (site 4). In the month of October, there was significant difference in BOD and ammonia nitrogen ($p<0.05$).

The water quality was classified as oligo-mesotrophic to mesotrophic status (Table 4). This was likely due to the fact that different activities took place at different locations along the reservoir. Mae Suai Reservoir is an open, medium-sized reservoir catchment of the Lum Nam Suai River which is seventy kilometers long and flows through large agricultural areas. The relevant conditions had an effect on various water quality parameters including nutrient loading and BOD [26]. During the course of this study, the frequent rainfall occurred during the month of August. The extensive amount of rain resulted in the discharge of nitrogen and phosphorus from the soil, along with the discharge of agricultural fertilizers and wastewater from community into the water body [32]. Phosphorus and nitrogen presented in natural waters are usually found in the form of orthophosphates (PO_4^{3-}) and nitrates (NO_3^-), which are the most important nutrients for the growth of plants and algae [1]. The orthophosphate and nitrate contents recorded in this study were similar to those reported by Liu et al. [33], indicating that TN, NO_3-N and phosphate under heavy rainfall conditions were higher than what was measured under conditions of moderate amounts of rainfall. Moreover, the influence of these activities also resulted in higher BOD levels. The value of BOD was recorded in a range of 2.5 -5.0 mg/L, indicating that it was β-mesosaprobic [5]. During the months of September and October, a lower amount of rain resulted in lower conductivity, BOD and nutrient values than what were recorded in the month of August (Table 3). This finding was similar to the results recorded by Liang et al., [34] who indicated that the concentrations of ammonium nitrogen and phosphate in the catchment area were low during the periods of lower amount of rainfall.

3.3 Correlations

The dominant species of phytoplankton in the Mae Suai Reservoir changed during each month (Figure 2). In August, the dominant species were *Pseudanabaena* sp., *Aulacoseira granulata* , Ehrenberg (Simonsen) and *Peridinium* sp. In September, the dominant species were *Cosmarium moniliforme* (Turpin) Ralfs, *Staurastrum* cf. *longibrachiatum* (Borge) Gutwinski, *Aulacoseira granulata* Ehrenberg (Simonsen) and *Frustulia* sp., and in October, the dominant species were *Pseudanabaena* sp., *Aulacoseira granulata* Ehrenberg (Simonsen), *Frustulia* sp. and *Peridinium* sp. (Figure 3). These results showed that *Peridinium* was the dominant species in August and October which the water quality was classified as mesotrophic status, similar to the report of Wetzel [1], who reported that *Peridinium* was usually presented in medium nutrient-rich or mesotrophic lakes. According to Suravit [35], *Peridinium* app. and *Trachelomonas* spp. were found to be the dominant species in Ratchaprapa reservoir in the southern Thailand which was indicated to be in mesotrophic status.

In September, *Cosmarium moniliforme* (Turpin) Ralfs, *Staurastrum* cf. and *longibrachiatum* (Borge) were dominant. These species were found to be dominant species in poor to moderate nutrient reservoirs, thus they could be used as bioindicators to assess water quality in the oligo-mesotrophic status [1], [36]. Besides, these results were similar to the report of Khuantrairong and Traichaiyaporn [26], who reported that Chrysophytes contributed the highest phytoplankton density in the rainy season with *Aulacosiera granulata* as a dominant species.

The relationship between the dominant species and the physical and chemical characteristics of the water body is shown in the results of the CCA plot (Figure 4). It was found that *Pseudanabaena* sp. (Pseu) and *Aulacoseira granulata* (Ehrenberg) Simonsen (Aula_gra) had a positive correlation with conductivity, $BOD_{5,}$ nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus (SRP). In this result explain that the nutrient were essential for all living organisms and is a common growth limiting factor for phytoplankton in lakes and reservoirs necessary which the algae especially blue green algae group were increase when the increase of phosphate–phosphorus which algae group can store excess phosphorus in polyphosphate granules when there is a high phosphate–phosphorus concentration, then the phytoplankton can divide several times while the external phosphate–phosphorus reserves are depleted [37]. *Staurastrum* cf. *longibrachiatum* (Borge) Gutwinski (Stau_long) and *Cosmarium moniliforme* (Turpin) Ralfs had a negative correlation with DO. Additionally, *Frusturia* sp. had a negative correlation with conductivity, BOD5, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus (SRP).

Table 3 The physico - chemical factors and other parameters of each sampling site in Mae Suai Reservoir

Parameters	**August**				**September**				**October**			
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Conductivity (µS/cm)	154.0b	150.3a	151.3a	152.4ab	126.9a	124.0a	124.0a	125.0a	126.4a	126.0a	126.2a	126.0a
DO (mg/L)	6.63a	6.30a	6.24a	6.23a	6.68b	6.34a	6.37a	6.70b	8.50a	8.13a	8.50a	8.57a
BOD (mg/L)	3.20a	2.63a	3.00a	3.00a	2.20b	1.53a	1.57a	1.90a	3.03b	2.20a	2.41ab	2.50ab
Nitrate nitrogen (mg/L)	1.33c	0.46a	0.66ab	1.10bc	0.37a	0.13a	0.16a	0.23a	1.21a	0.44a	0.56a	0.89a
Ammonia nitrogen (mg/L)	0.45b	0.10a	0.14a	0.32a	0.22b	0.05a	0.06a	0.12a	0.40b	0.13a	0.17ab	0.23ab
Soluble reactive phosphorus (mg/L)	0.89a	0.42a	0.45a	0.65a	0.20b	0.07a	0.10ab	0.12ab	0.79a	0.36a	0.46a	0.70a

Table 4 The physico - chemical factors and trophic status in Mae Suai Reservoir

Parameter	August	September	October
Conductivity (µS/cm)	152 ± 1.56a	125 ± 1.37b	126 ± 0.18c
DO (mg/L)	6.3 ± 0.19ab	6.5 ± 0.19ab	8.4 ± 0.20c
BOD (mg/L)	3.0 ± 0.24a	1.8 ± 0.31b	2.5 ± 0.35c
Nitrate nitrogen (mg/L)	0.90 ± 0.40a	0.22 ± 0.11b	0.78 ± 0.35ac
Ammonia nitrogen (mg/L)	0.25 ± 0.16a	0.11 ± 0.08b	0.23 ± 0.12ac
Soluble reactive phosphorus (mg/L)	0.60 ± 0.22a	0.12 ± 0.06b	0.58 ± 0.20ac
Trophic status	**Mesotrophic**	**Oligotrophic - mesotrophic**	**Mesotrophic**

Note: Data are expressed as the mean ± standard deviation (SD) of four replicates. Different letters (a, b and c) represent the statistical comparisons between groups in each row by using ANOVA and post hoc Tukey's b test ($p<0.05$).

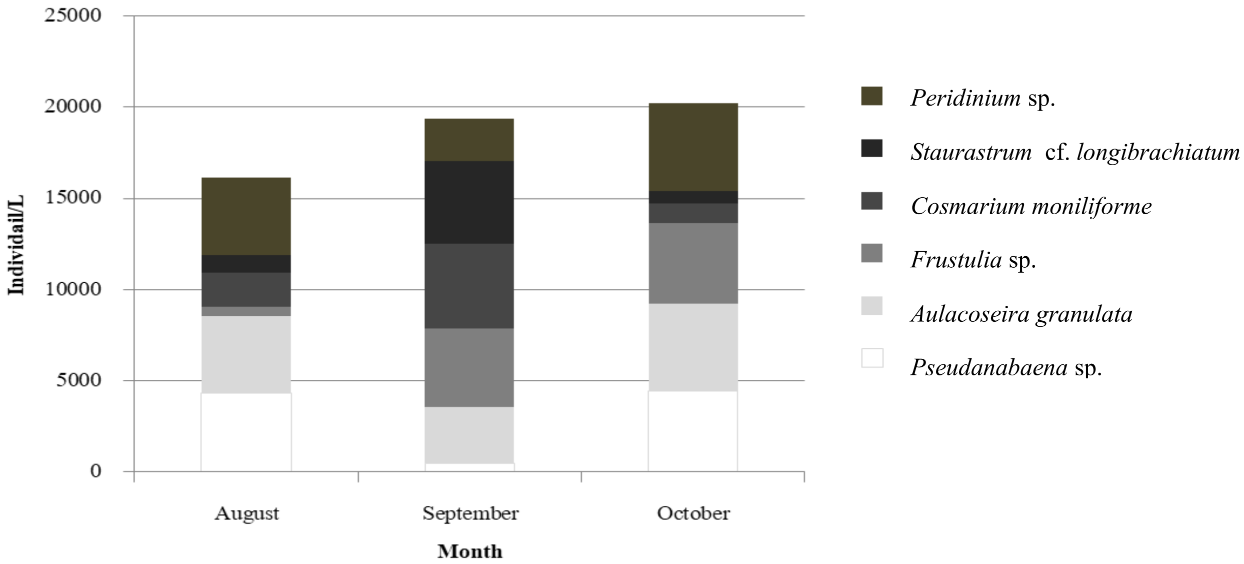
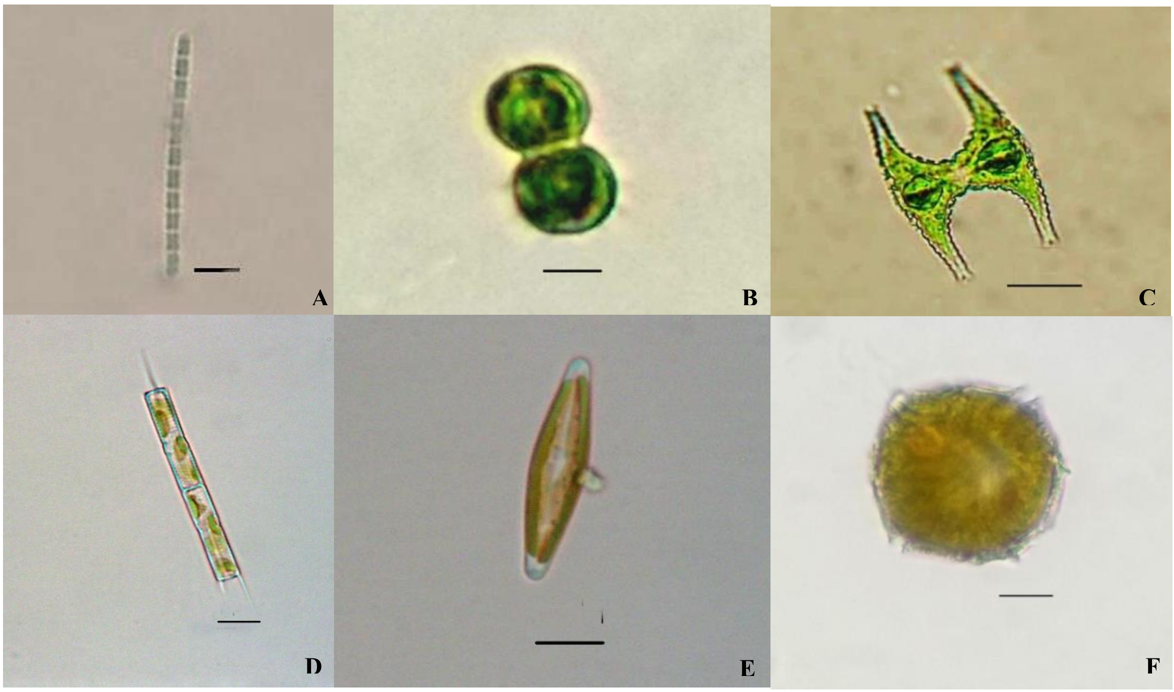


Figure 2 Bar chart presenting the dominant species of phytoplankton during the months of August, September and October 2016



Scale bar = 10 µm

Figures 3 (A)-(F) Light microscopic photographs of phytoplankton dominant species from August to October 2016: A. *Pseudanabaena* sp., B. *Cosmariummoniliforme* (Turpin) Ralfs C. *Staurastrum* cf. *longibrachiatum* (Borge) Gutwinski, D. *Aulacoseira granulata* Ehrenberg (Simonsen) E. *Frustulia* sp. F. *Peridinium* sp.

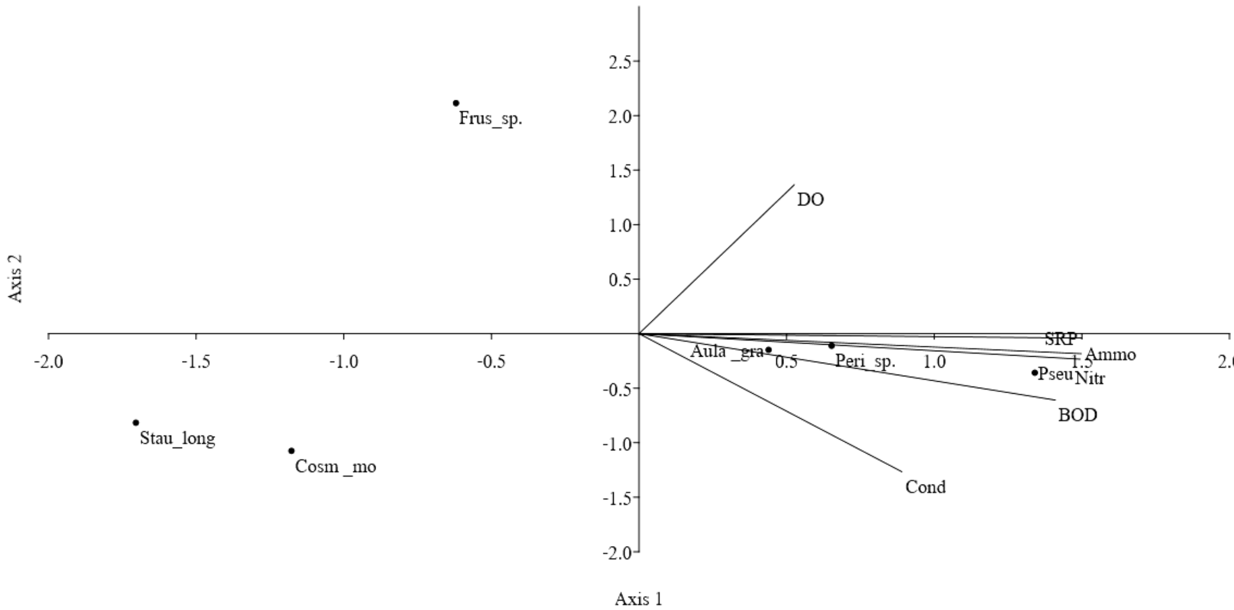


Figure 4 Canonical Correspondence Analysis (CCA) of the physico-chemical parameters and the phytoplankton presented in the water bodies revealed a correlation between the physico-chemical parameters and the dominant species of phytoplankton in the Mae Suai Reservoir Reservoir (Eigenvalues percentage of axis 1 = 83.83, axis 2 = 16.

4. Conclusions

A total of 39 genera of phytoplankton consisting of 52 species were found in Mae Suai Reservoir during the course of the rainy season. The diversity index revealed that the highest and lowest values were presented in October and September, respectively. The trophic status of the water body was classified as oligo-mesotrophic (September) to mesotrophic status (August and October). The canonical correspondence analysis (CCA) was used to evaluate the relationship between physical and chemical factors and the dominant species of phytoplankton. The results showed that *Pseudanabaena* sp. and *Aulacoseira granulata* had positive correlation with conductivity, BOD_5, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus (SRP). Nevertheless, *Frustaria* sp. had negative correlation to those parameters. *Staurastrum* cf. *longibrachiatum* and *Cosmarium moniliforme* had a negative correlation with DO.

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