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Comparison of phytoplankton diversity and succession between two small man-made lakes in Serdang, Selangor

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Abstract: Information on the relations between phytoplankton communities and the environment is limited for the man-made lakes in Malaysia. This paper presents the results of a study on the diversity and seasonal succession of phytoplankton in Seri Serdang Lake and Faculty of Engineering Lake conducted between November 2013 and February 2014. A total of 27 species from four phyla (Chlorophyta, Euglenophyta, Cyanobacteria, Bacillariophyta) and 33 species belonging to Cyanobacteria, Chlorophyta, Bacillariophyta, Euglenophyta and Dinophyta were identified from Seri Serdang Lake and the Faculty of Engineering Lake, respectively. Chlorophyta were most dominant in both lakes. Highest number of species recorded was *Monoraphidium* sp. in Seri Serdang Lake and *Pediastrum tetras* in Faculty of Engineering Lake. Seri Serdang Lake had lower phytoplankton density (20 cells ml^{-1} to 396 cells ml^{-1}) as compared to the Faculty of Engineering Lake (250 cells ml^{-1} to 300 cells ml^{-1}). Although the distance between the two lakes is short, they do not share the same tributary probably leading to the observed differences in water quality, species diversity and succession pattern.

Keywords: Chlorophyta, Diversity, Man-made lake, *Monoraphidium*, Phytoplankton, *Pediastrum tetras,* Tropical climate.

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Introduction

Urbanization period has been escalating rapidly in developing countries such as Malaysia. Continuous development and construction of residential areas have critically led to the loss of natural resources (Chan & Parker 1996). Natural water catchment areas, lakes and their appropriate environmental process were disturbed causing inharmonious balance and have left most established organisms to lose their diversity and habitats. Some man-made lakes were reconstructed close to the residential areas by reckless properties authorities upsetting long-established natural lakes. However, the physical properties of most man-made lakes are dissimilar from natural lakes in terms of size and volume. Hence, the biological properties of the lakes were believed could be affected because the development and succession of certain organisms require suitable periods (Omar *et al.* 2016).

Weather conditions, few physical factors, nutrient availability and also geographical location might also play important roles determining new phytoplankton successions in the urban lakes humidity in Malaysia, the phytoplankton succession might have specific patterns under weather conditions. Less study was high (Pilkaityte

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Table 1. Water quality parameters (mean ± SE) of lakes under study.

Parameters as (mg l^{-1})	Engineering Lake	Seri Serdang Lake	T -value
DO	5.73 ± 0.02	5.18 ± 0.01	28.08 (P<0.05)
TDS	0.06 ± 0.00	0.23 ± 0.01	–19.97 (P<0.05)
Ammonia	0.07 ± 0.02	3.19 ± 0.13	–23.27 (P<0.05)
Phosphate	0.06 ± 0.02	3.48 ± 0.15	–21.99 (P<0.05)
Nitrate	0.18 ± 0.02	0.04 ± 0.00	5.80 (P<0.05)
Silica	1.45 ± 0.03	4.01 ± 0.09	–27.23 (P<0.05)

& Razinkovas 2007). Due to different conducted to collect more information on the succession patterns of phytoplankton in small man-made lakes (Bruun 2012).

Among pioneer community in primary succession, phytoplankton is responsible for preserving water environment sustained with higher plants and animals (Butz 2004; Moulten 2013). Water quality properties of certain lakes are susceptible to the changes due to excessive loading of nutrients into the water bodies from numerous sources (Xu *et al.* 2010). Few phytoplankton species are able to adapt physiologically or morphologically and may have better potential to dominate or co-dominate the hierarchy (Celekli *et al.* 2014).

Studies of freshwater phytoplankton in Malaysia are encouraged due to the needs of data collections and distributions in lakes, rivers and dams; though numbers of phytoplankton studies conducted are very few especially in Sabah and Sarawak (Chan 2008). The diversity and density of phytoplankton species are varied on several factors such as the level of nutrient composition, physico-chemical properties, climate patterns and hydrodynamics of lake water (Naqqiuddin *et al.* 2013; Normawaty *et al.* 2013).

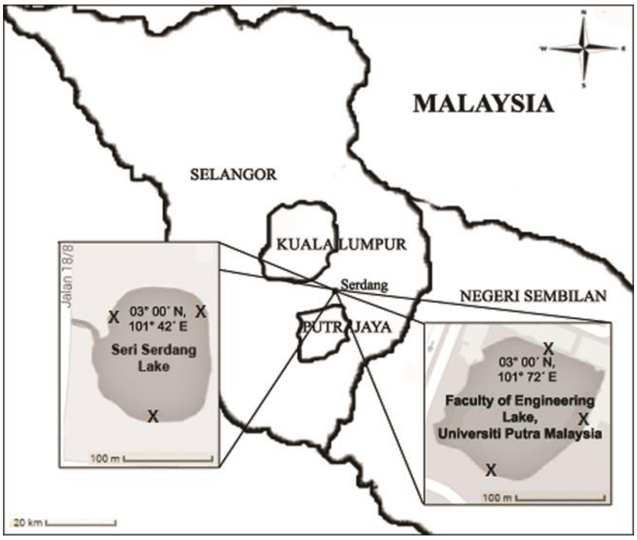

Fig. 1. A map of Serdang, Selangor showing the location of Seri Serdang Lake and the Engineering Faculty Lake. **X:** Sampling sites.

Ahmad *et al.* (2001) reported a total of 135 phytoplankton species from 81 genera and six phyla based on a study conducted in Lake Chini, Pahang. Lam (2007) recorded as many as 129 species of phytoplankton from 58 genera and five phyla in Lake Raban, Perak and a total of 107 phytoplankton species from 50 genera and five phyla in Lake Kenyir, Terengganu. Both Lake Raban and Kenyir documented Chlorophyta as the most dominant phylum while *Staurastrum* sp. was the dominant genus. Another phytoplankton study conducted in Lake Bera, Pahang identified a total of 149 species from 55 genera and six phyla with *Closterium* sp. under Chlorophyta phylum as a

Table 2. List of phytoplankton in the Seri Serdang Lake.

Division	Genus	No of species
Chlorophyta	*Desmodesmus* sp.	3
	Golenkinia sp.	1
	Micractinium sp.	3
	Monoraphidium sp.	5
	Pandorina sp.	1
	Platydorina sp.	1
	Scenedesmus sp.	3
	Chlorella sp.	1
Euglenophyta	*Euglena* sp.	1
	Phacus sp.	2
	Trachelomonas sp.	1
Cyanobacteria	*Arthrospira* sp.	2
	Oscillatoria sp.	1
Bacillariophyta	*Coscinodiscos* sp.	1
	Opephora sp.	1

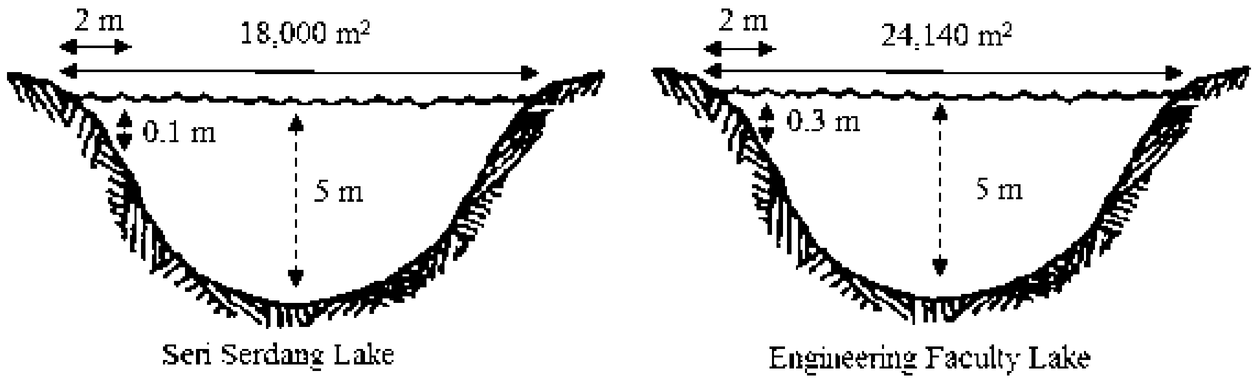

Fig. 2. Illustrative representations of Seri Serdang Lake and the Engineering Faculty Lake.

dominant genus (Chan 2008). Sample collected from Lake Putrajaya and Wetland from October 2006 until December 2012 identified 194 species from 87 genera and seven phyla (Yusoff & Nursuhayati 2013). Though, these big lakes are less vulnerable due to its size, huge water volume and watershed in the surroundings that are incomparable to the smaller lakes. The fact that there are no reports concerning the vulnerability of smaller water bodies especially in residential areas are majorly caused by disturbed watershed areas.

It is necessary to update the status of phytoplankton diversity in freshwater bodies due to environmental degradation. Under tropical climate: dry condition, freshwater lakes having higher concentrated nutrients would greatly enhance the growth of limited species, hence promoting eutrophication process and low diversity. Hypothetically, undisturbed lakes would have a tendency to have more diversity. The objective of this study were to determine the changes of water quality parameter weekly from different locations of the small freshwater lake, Seri Serdang Municipal Lake and Engineering Faculty Lake and to relate the algal species composition, succession pattern with respect to the water quality.

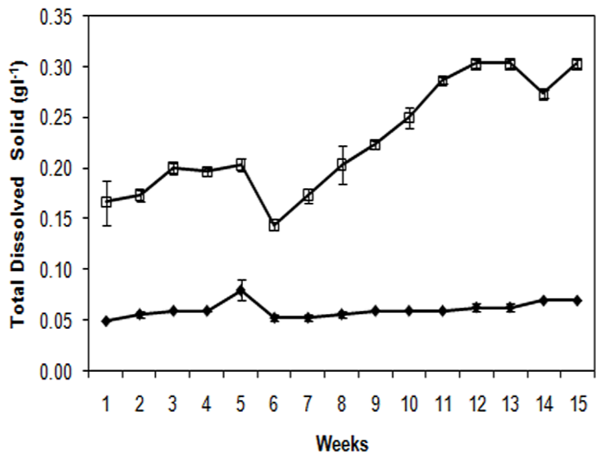

Fig. 3. Total dissolved solids (g l^{-1}) during 15 weeks of sampling in the Engineering Faculty Lake; (◆) and in Seri Serdang Lake; (□). Values are presented as Mean ± SE (n = 3).

Materials and methods

Weekly water sampling was performed in surface water of Seri Serdang Municipal Lake (latitudes 03°00´N, longitudes 101°42´E) and Engineering Faculty Lake (latitudes 03° 00´N, longitudes 101°72´E). Sampling commenced for 15 weeks starting 20th November 2013 to 26th February 2014 on Wednesday of each week (Fig. 1). The physical properties of both lakes were illustrated as in Fig. 2.

Sample preservation and identification

A 25 micron mesh sizes was equipped to the modified water collector for filtration of the surface water samples. Then, samples were measured with measuring cylinder. Surface water samples were collected from three sampling sites from each lakes (refer Fig. 1). Water samples were preserved in Lugol's iodine solution for enumeration of phytoplankton (Pomeroy 1984). Cell count and identification of phytoplankton were carried out after sedimentation using Olympus CX21 compound microscope (Kaeswari & Traichaiyaporn 2012; Prescott 1978; Vuuren *et al.* 2006). Daily weather determinations (Light intensity, µmol m^{-2} s^{-1} using Licor Li-250, weather condition and temperature (°C) range: Hot (Sunny), 31–32 °C; Moderate (Mix weather), 29–30 °C; Cloudy/Rainy, 27–28 °C were observed and recorded daily. Water

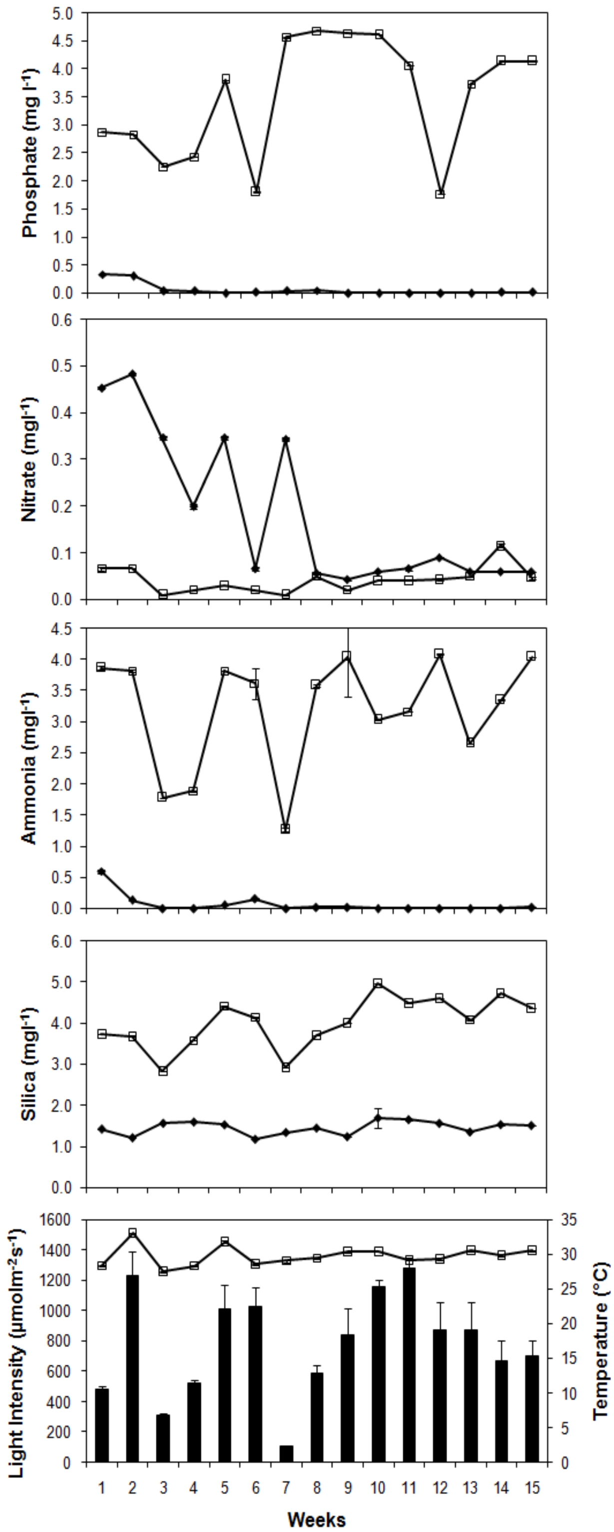

Fig. 4. Phosphate, nitrate, ammonia and silica (mg l^{-1}), average light intensity (μmol m^{-2} s^{-1}); (■) and temperature (°C); (□) were monitored over 15 weeks in the Engineering Faculty Lake; (◆) and in Seri Serdang Lake; (□). Values are presented as Mean ± SE (n = 3).

Table 3. List of phytoplankton in the Engineering Faculty Lake.

Division	Species
Cyanophyta	*Chroococcus* sp.
	Merismopedia sp.
Chlorophyta	*Ankistrodesmus* sp.
	Arthrodesmus fuellebornei
	Coaelastrum reticulatum
	Coaelastrum astroideum
	Coaelastrum micropium
	Dimorphococcus lunatus
	Eudorina elegans
	Gonium pectoral
	Kirchneriella sp.
	Pachycladonum brinus
	Pediastrum tetras
	Pediastrum simplex
	Pediastrum duplex
	Scenedesmus quadricauda
	Scenedesmus incrassatulus
	Scenedesmus obliquus
	Staurastrum natator
	Tetraedron gracile
	Tetraedron trigonum
	Tetraedron regulare
	Tetrapedia sp.
Bacillariophyta	*Asterionella* sp.
	Cymbella sp.
	Gyrosigma sp.
	Navicula sp.
Euglenophyta	*Euglena acus*
	Euglena gracilis
	Phacus longicauda
	Phacus orbicularis
Dinophyta	*Glenodinium* sp.
	Peridinium sp.

quality parameters (pH; dissolved oxygen, DO, in mg l^{-1}; total dissolved solid, TSS, in g l^{-1}) were determined using a YSI-556 MPS multiparameter probe. Water samples (500 ml) were collected and preserved with 0.5 ml Hydrochloric acid (HCl) for nutrient determinations: nitrate, phosphate, ammonia and silica following APHA standard methods (1976). Freshwater algae were identified following the keys of Vuuren *et al.* (2006) and Bellinger & Sigee (2010). Shannon-Weaver index (1949), Margalef Species Richness and Evenness (Margalef 1958) were used for diversity index calculation. Principal Component Analysis (PCA) using SPSS 22.0 and Canonical Correspondence

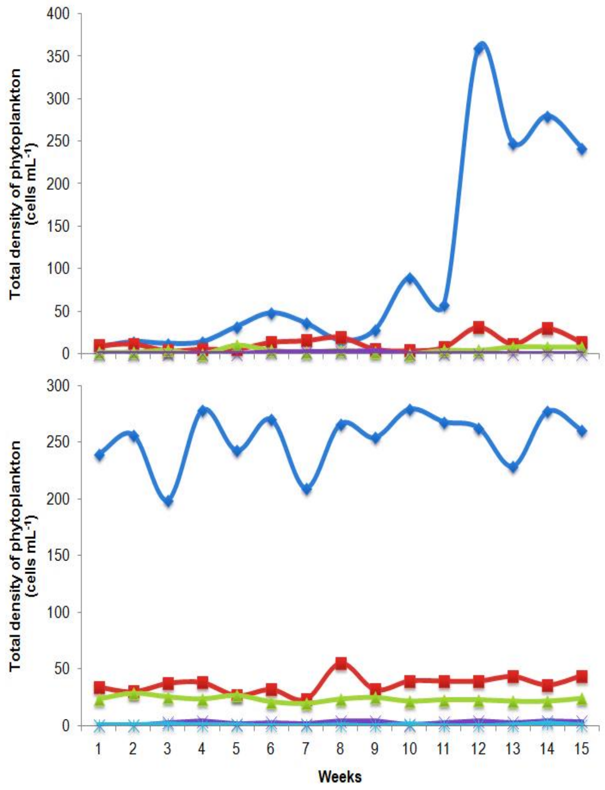

Fig. 5. Succession of phytoplankton in Seri Serdang Lake and Engineering Faculty Lake over the 15 week sampling period. Top: Phyla of Chlorophyta, (◆); Cyanobacteria, (□); Euglenophyta, (△); Bacillariophyta, (×). Bottom: Phyla of Chlorophyta, (◆); Cyanophyta, (□); Bacillariophyta, (△); Euglenophyta, (×); Dinophyta, (✱).

Analysis (CCA) using XLSTAT 5.02 (TerBraak 1995) was performed to exemplify the connections between phytoplankton and environmental variables for both Seri Serdang Lake and Engineering Faculty Lake. Monte Carlo permutation test (999) was conducted to test the significance level of the relationships between predictor variables (environmental factors) and response variables (phytoplankton species) in the lakes.

Values are reported as mean±SE and mean differences between lakes were assessed using t-test.

Results

Water Quality Parameters

For 15 sampling weeks, the water quality parameters recorded for Engineering Faculty Lake and Seri Serdang Lake were as shown in Table 1. The amount of dissolved oxygen and pH values in both lakes were not affected by weather conditions. Average amount of total dissolved solid (TDS) (g l^{-1}) observed in Engineering Faculty Lake was significantly lower as compared to Seri Serdang Lake (P < 0.05; Fig. 3). The pH value for Engineering Lake was significantly different than pH of Seri Serdang Municipal Lake.

As shown in Fig. 4, ammonia, phosphate and silica (mg l^{-1}) were significantly higher ($P < 0.05$) in Seri Serdang Lake than Engineering Faculty Lake, whereas the nitrate concentration (mg l^{-1}) was significantly lower ($P < 0.05$) in Seri Serdang Lake as compared to Engineering Faculty Lake. Average amount of ammonia, nitrate, phosphate and silica (mg l^{-1}) were determined for both Engineering Faculty Lake (EF) and Seri Serdang Lake (SS). T-test was conducted to differentiate data collected between both lakes in average of the sampling weeks. It is as follows (mean±SE, N= 45): Ammonia (t = 23.27, df = 88), 0.07 ± 0.02 and 3.212 ± 0.13; Phosphate (t = 22.00, df = 88), 0.058 ± 0.02 and 3.389 ± 0.15; Nitrate (t = 5.80, df = 88), 0.18 ± 0.02 and 0.042 ± 0.00; Silica (t = 27.23, df = 88), 1.45 ± 0.03 and 4.012 ± 0.09, respectively.

Diversity of microalgae

A total of 27 microalgae species from 15 genera and four phyla were identified in the surface water of Seri Serdang Lake (Table 2). A total of 23 genera and 33 species belonging to five phyla were observed from the Engineering Faculty Lake (Table 3). The Chlorophyta was observed as most diverse phylum contributing 66.7% to total algal density (%) in Seri Serdang Lake and 63.6% in Engineering Faculty Lake. The Chlorophyta: *Desmodesmus* sp., *Golenkinia* sp., *Micractinium* sp., *Monoraphidium* sp., *Pandorina* sp., *Platydorina* sp., *Scenedesmus* sp., and *Chlorella* sp. were found in Seri Serdang Lake as compared to 13 genera (*Ankistrodesmus* sp., *Arthrodesmus* sp., *Coaelastrum* sp., *Dimorphococcus* sp., *Eudorina* sp., *Gonium* sp., *Kirchneriella* sp., *Pachycladon* sp., *Pediastrum* sp., *Scenedesmus* sp., *Staurastrum* sp., *Tetraedron* sp., and *Tetrapedia* sp.) were identified from the Engineering Faculty Lake. *Monoraphidium* sp. was most abundant in Engineering Faculty Lake. Other phyla found in Seri Serdang Lake were Euglenophyta, Cyanobacteria and Bacillariophyta. Meanwhile, other phyla noticed in Engineering Faculty Lake were Cyanophyta, Bacillariophyta, Euglenophyta and Dinophyta.

Chlorophyta dominated phytoplankton density in Seri Serdang Lake and have achieved highest density at 86.67% compared to other phytoplankton division followed by Cyanobacteria, Euglenophyta and Bacillariophyta, respectively (Fig. 5). Phylum Chlorophyta has also attained highest density with *Pediastrum tetras* as the most dominant species followed by *Scenedesmus quadricauda* in Engineering Faculty Lake. After experiencing frequent rainfall during week 7 and 8, the weather conditions were subsequently dry. The diversity in Seri Serdang Lake was higher at the beginning and ended up lower than Engineering Faculty Lake (Fig. 6).

Canonical Correspondence Analysis

Principal Component Analysis (PCA) was executed based on collected physicochemical data before performing Canonical Correspondence Analysis (CCA) to extract out precise influence of the variables on the species communities in both Seri Serdang Municipal Lake (Fig. 7) and Engineering Faculty Lake (Fig. 8). For CCA on Seri Serdang Municipal Lake, both axis 1 and 2 were not linearly related ($P > 0.05$) based on Monte Carlo significance level test of first constrained axis (999 permutations; $P < 0.05$), however significance level test of Engineering Faculty Lake showed that the phytoplankton density during the 15 weeks were linearly related to the physicochemical parameters ($P < 0.05$). CCA ordination for Seri Serdang Municipal Lake had eigenvalues for axis 1 and 2 at 0.256 and 0.096, respectively, which explained 88.47% of the data variance while, for Engineering Faculty Lake had eigenvalues for both axis 1 and 2 at 0.011 and 0.003, respectively, which explained 77.98% of the data variance. Based on the canonical correspondence results shown on Seri Serdang Lake, the variable of highest weight in the ordination of axis 1 was phosphate and total phosphate, respectively. Positive side of axis 1 was correlated to high value of phosphate ($r = 0.48$), while lowest value of axis 1 being correlated to the value of light intensity ($r = 0.09$). Canonical correspondence on Engineering Faculty Lake shown the variable of greatest weight in the ordination of axis 1 was the nitrate concentration whereas axis 2 had ammonia as the variable of highest weight. Value of ammonia was highly correlated and located on the positive side of axis 1 ($r = 0.37$) and value of nitrate was highly correlated to the negative side of axis 1 ($r = -0.87$).

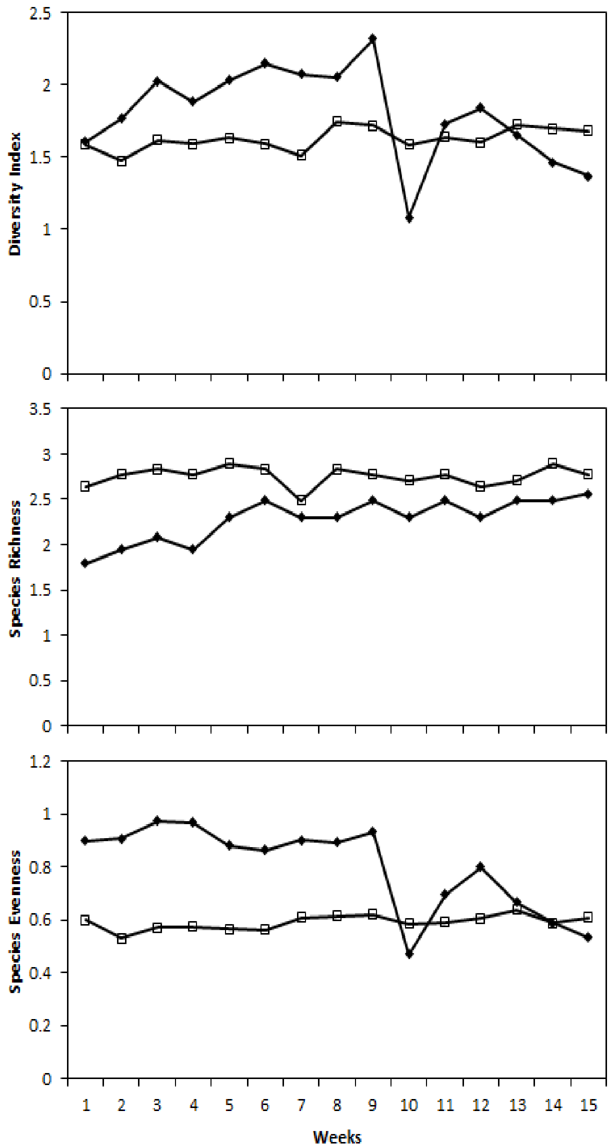

Fig. 6. Weekly changes of phytoplankton species diversity, richness and evenness index. Seri Serdang Lake, (◆); Engineering Faculty Lake, (□).

Discussion

Fluctuations in (Nitrogen Phosphorus) ratios play significant parts as limiting growth factors to most algal species. In different sampling weeks, contrast dominance of algal species in Seri Serdang Lake and Engineering Faculty Lake are shown in Table 4. Lakes are typically P-limited especially in this case Engineering Faculty Lake, an isolated man-made freshwater environment from any discharges link that may contribute to the deficiencies of phosphorus supplies. Constant and

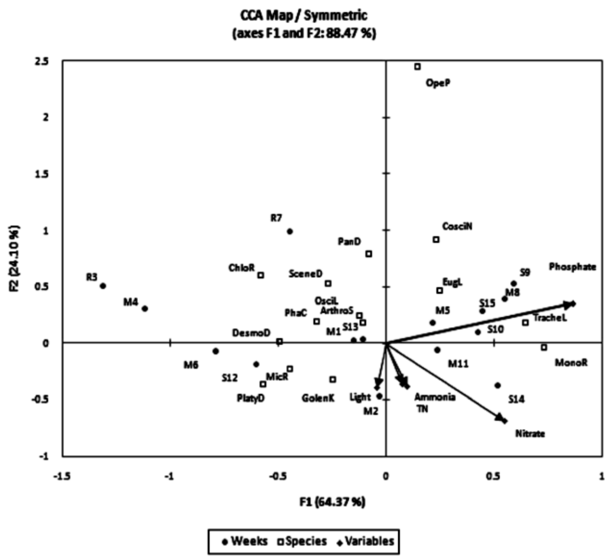

Fig. 7. CCA ordination of phytoplankton in Seri Serdang Municipal Lake with respect to physical and chemical variables during the 15 week sampling period. MonR- *Monoraphidium* sp.; ChlR- *Chlorella* sp.; DesD- *Desmodesmus* sp.; MicR- *Micractinium* sp.; GolK- *Golenkinia* sp.; PanD- *Pandorina* sp.; PlaD- *Platydorina* sp.; SceD- *Scenedesmus* sp.; ArtS- *Arthrospira* sp.; OscL- *Oscillatoria* sp.; EugL- *Euglena* sp.; PhaC- *Phacus* sp.; TraL- *Trachelomonas* sp.; CosN- *Coscinodiscos* sp.; OpeP- *Opephora* sp. Abbreviations: TN: total nitrogen; TP: total phosphorus; Weather: (S= sunny, M= mix, R= rainy). Numbers after S/M/R represents sampling week.

abrupt tropical weather changes has affected nutrient cycling, and NP limitations and thus phytoplankton communities.

Overly drained lake water most likely has dropped the water level during final sampling weeks due to dry climate condition and high evaporation rate. The condition might favor selected dominant species to continue dominating while other species fail to thrive and collapsed. Hence, species richness index increased while decreasing evenness and diversity index.

The location of Engineering Faculty Lake is a bit detached from urban, agricultural and industrial areas, sewage and other runoffs, unlike Seri Serdang Lake which is surrounded by residential areas. Despite short distance between both lakes, drainage linkages from residential areas that are connected to the municipal lake, Seri Serdang Lake signified differences of phytoplankton diversity, density and successions in comparison to non-municipal of Engineering Faculty Lake. Engineering Faculty Lake lacks outflows drainage, unlike Seri Serdang Lake which has several inflows and a wide overflow drain connected to nearby rivers as illustrated in Fig. 1. Run-off flushing from residential areas, especially on week 7 experiencing heavy rains has dramatically increased the total dissolved solid (TDS) (g l^{-1}) in Seri Serdang Municipal Lake, while in Engineering Faculty Lake pattern of TDS remained flat until the end of 15 weeks.

Nutrients fluctuation occurred throughout the sampling weeks for Seri Serdang Lake as this lake was majorly affected by water discharges. Despite facing similar weather condition, the amount of nitrate, phosphate, ammonia and silica in EF Lake showed contrast outcome and has remained low below 0.2, 0.5, 1.0 and 2.0 (mg l^{-1}) respectively. In this study, nutrient concentrations were found to be main factors influencing the phytoplankton succession and density. Though, growth rate of phytoplankton could be inhibited with limited nitrogen and phosphorus concentrations especially for the green algae, Chlorophyta (Sommer 1989). In Lake Ogelube, Nigeria, Chlorophyceae has been seen most abundant followed by Cyanophyceae, Bacillariophyceae, Euglenophyceae, Dinophyceae and Chrysophyceae in decreasing order during rainy season of high humid. Yet, this order changed slightly during dry season as all lakes under seasonal climate are often fluctuated generating seasonality patterns of phytoplankton abundance and diversity (Chale 2004). In Malaysia, frequent rainfall mixed with dry hot condition causes huge changes to the phytoplankton growth. Rainfall over residential areas washed down contaminants, pollutants, chemicals, oily, liquid or solid leftovers through drainage linkages into the municipal lakes. Most dissolved and suspended solids settled down deteriorate inside the lake basin. Discharged rainwater run-off from residential areas has high mixing force once flushed into the lake. Ordinarily lakes with huge water capacity and deep may not be disturbed significantly in terms of turbidity; however, Seri Serdang Lake may possibly exposed to high turbidity during rainy days where these have caused higher total dissolved solid particles and lower total dissolved oxygen concentration to the lake's water quality (Lee & Jones 1981).

Under lower rates of dissolved oxygen, the amount of ammonia oxidized into nitrate is declined, as ammonia are produced through the decomposing process by some types of bacteria thus,

Table 4. List of dominant microalgae species and Nitrogen Phosphorus Ratio (N/P) per week in Seri Serdang Lake and Engineering Faculty Lake.

	Seri Serdang Lake		Engineering Faculty Lake	
Week	N/P	Dominant species	N/P	Dominant species
1	4.98	*Arthrospira* sp.	7.40	*Pediastrum* sp.
2	4.98	*Arthrospira* sp.	1.73	*Pediastrum* sp.
3	1.94	*Scenedesmus* sp.	5.42	*Pediastrum* sp.
4	ND	*Oscillatoria* sp.	3.35	*Pediastrum* sp.
5	2.47	*Euglena* sp.	ND	*Pediastrum* sp.
6	7.39	*Pandorina* sp.	50.38	*Pediastrum* sp.
7	1.02	*Oscillatoria* sp.	4.47	*Pediastrum* sp.
8	2.83	*Oscillatoria* sp. *Arthrospira* sp.	2.23	*Pediastrum* sp. *Scenedesmus* sp.
9	3.22	*Scenedesmus* sp.	ND	*Pediastrum* sp.
10	2.43	*Monoraphidium* sp.	1.00	*Pediastrum* sp.
11	2.87	*Monoraphidium* sp.	ND	*Pediastrum* sp.
12	8.51	*Micractinium* sp.	ND	*Pediastrum* sp.
13	2.63	*Golenkinia* sp.	1.33	*Pediastrum* sp.
14	3.00	*Monoraphidium* sp.	2.01	*Pediastrum* sp.
15	3.60	*Monoraphidium* sp.	5.47	*Pediastrum* sp.

*ND = Non-Detectable

toxicity ascends. High pH and temperature in Seri Serdang Lake have intensified the toxicity level of ammonia left which have caused some fish kills (Banadda 2011). As presented, significant lower nitrate concentration produced in Seri Serdang Municipal Lake could be due to depletion on the growth of nitrifying bacteria compared to Engineering Faculty Lake. During rainy weeks with low light intensity, the amount of ammonia dropped below 3.0 mg l^{-1} after being diluted in Seri Serdang Lake; however ammonia concentration in Engineering Faculty Lake remained constant below 0.5 mg l^{-1} throughout the sampling period. Other factors contributing diversity variations in relation to the fluctuations of phytoplankton biomass would be water transparency and few other limiting factors (light intensity and nutrients) depending on the weather condition (Eloranta 1993). Rapid disturbance to the lake water environment could instantaneously cause low diversity (Connell 1978).

According to Dos Santos & Calijuri (1998), species from genus *Monoraphidium* (Chlorophyta) are generally characterized as opportunistic in luminosity condition and are tolerant of turbulence environments (Queiroz *et al.* 2012). On the other hand, *Arthrospira* sp. has unique characteristics surviving high pH condition range of 9–10 (Dejsungkranont *et al.* 2012). At optimal ratio for growth on the basis of experiments with monocultures, *Scenedesmus* sp. was concluded to need the supply of N:P, ratio equal to 30:1, while limited growth resulted with higher or lower ratio values of N:P respectively (Rhee 1978). Maximum biomass with Chlorophyta, N:P > 20 followed by Bacillariophyta and Cyanophyta, N:P= 2–5, whereas Euglenophyta increased at higher N:P = 50–100 (Bulgakov & Levich 1999). In this experiment (Fig. 5), the succession of the Chlorophyta has been observed continuously growing until the end of the experiment for both lakes (natural community). The dominance orders were frequently changed following the proportion of nutrient composition in the water bodies and weekly circumstances. Other species, *Chlorella* sp. favors optimal pH condition that was in range of 7.5–8.0 (Ranchin & Grosso 1991) and light intensities range of 75–1000 µE m^{-2} s^{-1} (Imaizumi *et al.* 2014). A noticeable change in the N:P ratio was observed for Engineering Lake Faculty during mixed weather in week 6, with 50:1. After the occurrence of heavy rainfalls, stored and settled nutrients inside the lake might be flushed or stirred as there were no outlets to let the collected nutrients flow out from the lake.

Some non-heterocystous algal species (e.g., *Oscillatoria*) has the advantage over represent-tatives of other taxa, as it can also fix N (Carpenter & Price 1976). At limited nutrient supplied

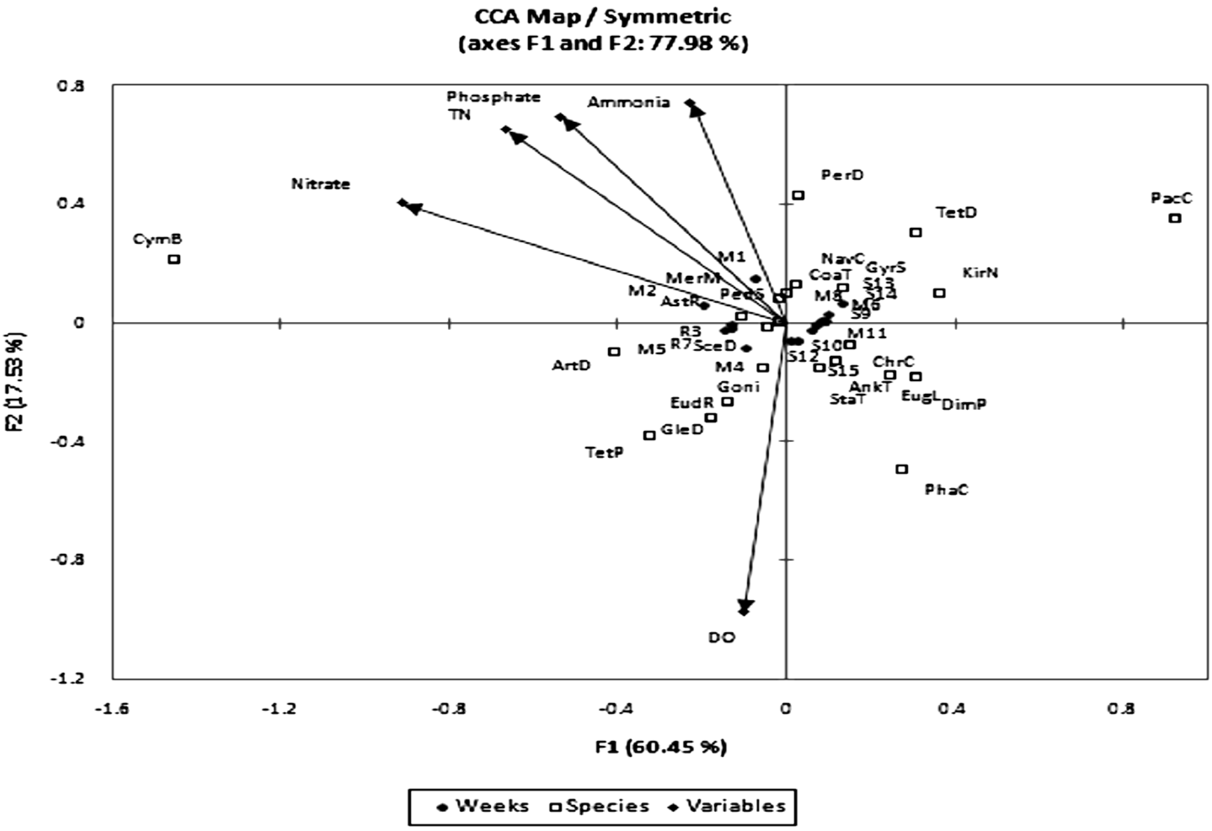

Fig. 8. CCA ordination of phytoplankton in the Engineering Faculty Lake with respect to physical and chemical variables during the 15 week sampling period. AnkT- *Ankistrodesmus* sp.; ArtD- *Arthrodesmus* sp.; CoaT- *Coaelastrum* sp.; DimP- *Dimorphococcus* sp.; EudR- *Eudorina* sp.; Goni- *Gonium* sp.; KirN- *Kirchneriella* sp.; PacC- *Pachycladon* sp.; PedS- *Pediastrum* sp.; SceD- *Scenedesmus* sp.; StaT- *Staurastrum* sp.; TetD- *Tetraedron* sp.; TetP- *Tetrapedia* sp.; ChrC- *Chroocossus* sp.; MerM- *Merismopedia* sp.; AstR- *Asterionella* sp.; CymB- *Cymbella* sp.; GyrS- *Gyrosigma* sp.; NavC- *Navicula* sp.; EugL- *Euglena* sp.; PhaC- *Phacus* sp.; GleD- *Glenodinium* sp.; PerD- *Peridinium* sp. Abbreviations: TN: total nitrogen; TP: total phosphorus; Weather: (S= sunny, M= mix, R= rainy). Numbers after S/M/R represents sampling week.

condition, different responses from the microalgal community will either promote or disregard some of the phytoplankton species depending on their adaptive physiological mechanisms (Levich 1989). *Pediastrum tetras* was found common forming large colonies in shallow waters specifically meso- to eutrophic lakes (Komarek & Jankovska 2001). Phytoplanktons that are considered to be a good quality lake indicators present were *Euglena* sp., *Oscillatoria* sp., *Scenedesmus* sp, *Navicula* sp., *Ankistrodesmus* sp. and *Phacus* sp., From an observation of active water lakes eutrophication that has caused rise to cyanobacteria, intense blooms of cyanobacteria have restricted green algae community to small Chlorococcales green algae including *Coelastrum*, *Golenkinia*, *Monoraphidium*, *Tetraedron*, *Scenedesmus/ Desmodesmus* and *Pediastrum* genera (Messyasz 2006). This explained the succession patterns and phytoplankton diversity from Seri Serdang Municipal Lake.

Canonical Correspondence Analysis has shown the influence of some factors such as nutrient concentrations between both lakes of Seri Serdang and Engineering Faculty that indicated different distribution of phytoplankton species throughout the sampling period. The ordination of the species was less correlated with nutrient concentrations during higher light intensity under different weeks with varying weather conditions. Solorzano *et al.* (2011) recorded that most *Trachelomonas* species were found during dry season where nutrients consisted of organic matter, nitrogen and phosphorus were highly concentrated along with warm temperature. From the observation in this study, *Trachelomonas* sp. and *Euglena* sp. are both member of Euglenoaphyta and were grouped under similar growing condition as in Fig. 7. In Seri Serdang Lake, high values of ammonia, total nitrogen and nitrate were encountered during week 11 and 14 (dry conditions), though only *Monoraphidium* sp. dominated at this condition. For Engineering Faculty Lake, the values of ammonia, total nitrogen, and total phosphorus were found at high rates during week 1 and 2. During weeks with average light intensity and moderate temperature, *Glenodinium* sp., *Coaelastrum* sp., *Merismopedia* sp., *Asterionella* sp. and *Pediastrum* sp. were identified more abundant as compared to others. Mixed weather conditions were labeled as (M) indicated in abrupt change in weather conditions, light illuminations and heavy rains for few days. This explained high light intensity observed during week M2 and lower average amount of light on week S13. Nutrients availability are strongly connected to water movements flushed during rainfalls that has circuitously influenced the morphology and hydrology of the water bodies, the food web structure and also the diversity and density of phytoplankton (Naqqiuddin *et al.* 2014; Reynolds 1999).

Conclusion

Results signified big differences in the succession and phytoplankton diversity of both Seri Serdang Municipal Lake and Engineering Faculty Lake. From this study, some information was gathered to determine the pollution levels based on the water properties and species diversities. There is a need to study the potential of robust microalgae in the future as the phytoplankton species diversity has a strong connection to the size of man-made freshwater lakes. Eco-restoration practices shall be the better solution to preserve nature of water organism biodiversity.

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