Borneo Journal of Resource Science and Technology (2022), 12(1): 23-31
DOI: https:doi.org/10.33736/bjrst.4215.2022

The Inter-Seasonal Phytoplankton Compositions and Density in Response to Abiotic Factors in Puah Reservoir Hulu Terengganu Hydroelectric Dam, Peninsular Malaysia

MUHAMAD KABIRU ABUBAKAR*[1,2], AMIR SHAH RUDDIN MD SAH*[1], ALYAA FILZA EFFENDI[3], AHMAD NAZRI SAIDIN[3] & SHAHRIL MOD HUSIN[3]

[1]Pusat Pengajian Sains Kajihayat, Universiti Sains Malaysia, 11800 Penang, Malaysia; [2]Hussaini Adamu Federal Polytechnic P.M.B. 5004, Kazaure, Jigawa State, Nigeria; [3]TNB Research Sdn Bhd, No 1 Lorong Air Itam, Kawasan Institusi Penyelidikan, 43000 Kajang Selangor, Malaysia
*Corresponding authors: auchikb@gmail.com; amirshsh@usm.my
Received: 18 November 2021 Accepted: 7 June 2022 Published: 30 June 2022

ABSTRACT

The distribution of the phytoplankton community in different locations of Puah Reservoir, Malaysia was investigated from May to December 2019 to examine the phytoplankton compositions and density. Seven sampling locations were selected namely Terengganu Mati (P1), Limbing Besar (P2), Temba Outlet (P3), Pela-gong (P4), Sireh (P5), Centre Dam (P6) and Power Intake (P7). A total of 543 cell/mL were recorded from 35 genera in the reservoir. These identified species belonged to six major plankton groups: 12 green algae (35.29%), nine blue-green algae (26.47%), nine diatom (23.53%), two golden algae (5.88%), two filamentous (5.88%) and one flagellate (2.94%). During this period, Chlorophyta was the most abundant group (40% of the total phytoplankton), followed by Bacillariophyceae (29%), Pyrrhophyta (19%), Cyanophyta (12%) and Chrysophyceae (1%). The highest composition of phytoplankton was recorded at P7 (32%), followed by P3 (16%), P1 (14%) and P4 and P2 with the lowest (8% and 7%), respectively. The lowest density was observed during dry season (162 cell/mL) and high density during wet season (412 cell/mL). Species richness was discreetly greater in the wet season however, evenness index was $\geq$0.8, thereby indicating a similarity in species abundance. The water temperature, pH and dissolved oxygen correlate positively with phytoplankton at $P = 0.01$. The overall mean values of temperature for wet and dry season were 29.3 ± 1.79 °C and 27.5 ± 1.55 °C while dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS) were 16.2 mg/L and 4.7 mg/L, 3.4 mg/L and 2.9 mg/L, 15.2 mg/L and 12.7 mg/L, and 0.5 mg/L and 2.3 mg/L, respectively. Water transparency, pH and DO were found to be important factors characterising each sampling location.

Keywords: Density, inter-seasonal, phytoplankton, Puah Dam, Terengganu

INTRODUCTION

The detailed consideration of the biology of the reservoir and other water body types begins with the phytoplankton as they form the baseline of the aquatic food web. Thus, the dynamics of the rest of the biological community is dependent to a very large extent on these photosynthetic microorganisms (Asma *et al.*, 2014). Nevertheless, phytoplankton possesses the capacity to tolerate and co-occur even though each species may have a specific niche based on its physiological requirements and the constraints of the environment. Knowledge of the changes in phytoplankton biomass and species composition across time and space can provide useful early warning signals of degrading conditions and the possible causes (Yusoff *et al.*, 1998). Meanwhile, the effects of different local regions in a reservoir towards the dynamics of phytoplankton population are rarely studied and understood. Phytoplankton are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. They are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. As primary producers, phytoplankton are most directly affected by physical and chemical factors. There assemblages are sensitive to some pollutants, and they readily accumulate pollutants, and algal metabolism is also sensitive to the variation of environmental and natural disturbances (Omar, 2010). Alterations and shifts in the species composition and productivity of algal assemblages in response to anthropogenic stresses should be considered in order to predict the effects on food web interactions and other ecosystem components (Omar, 2010). Due to the fact that no research has been done in Puah Reservoir on phytoplankton after dam completion, the information obtained from this research should serve as basis to improving water quality management of the system and the connected dams.

MATERIALS AND METHODS

Study Area

The task area is located within Hulu Terengganu catchment (Figure 1), at the north of existing Kenyir Reservoir in Kuala Berang, Daerah Hulu Terengganu, Negeri Terengganu Darul Iman or also known as Hulu Terengganu Hydroelectric Project. It is about 50 km from Bandar Gua Musang – Hulu Terengganu roadway, and about 65 km west of Kuala Terengganu in a geographical location of 5 05°N 102 45°E / 5 08°N 102.750°E with a total area of 134,690.54 ha. The project is for hydroelectric generation with capacity of 250 MW.

Phytoplankton Sampling, Identification and Counting

Phytoplankton sampling was performed from May to December 2019 cutting across wet and dry season (May – August and September – December), respectively. An amount of 30 L from the composite sample (three replicates) per sampling station was filtered using a plankton net (30-micron mesh size) to obtain a 100 ml subsample. The collected subsamples were then transferred to individual clean bottles, preserved and fixed using Lugol's solution. The filtered

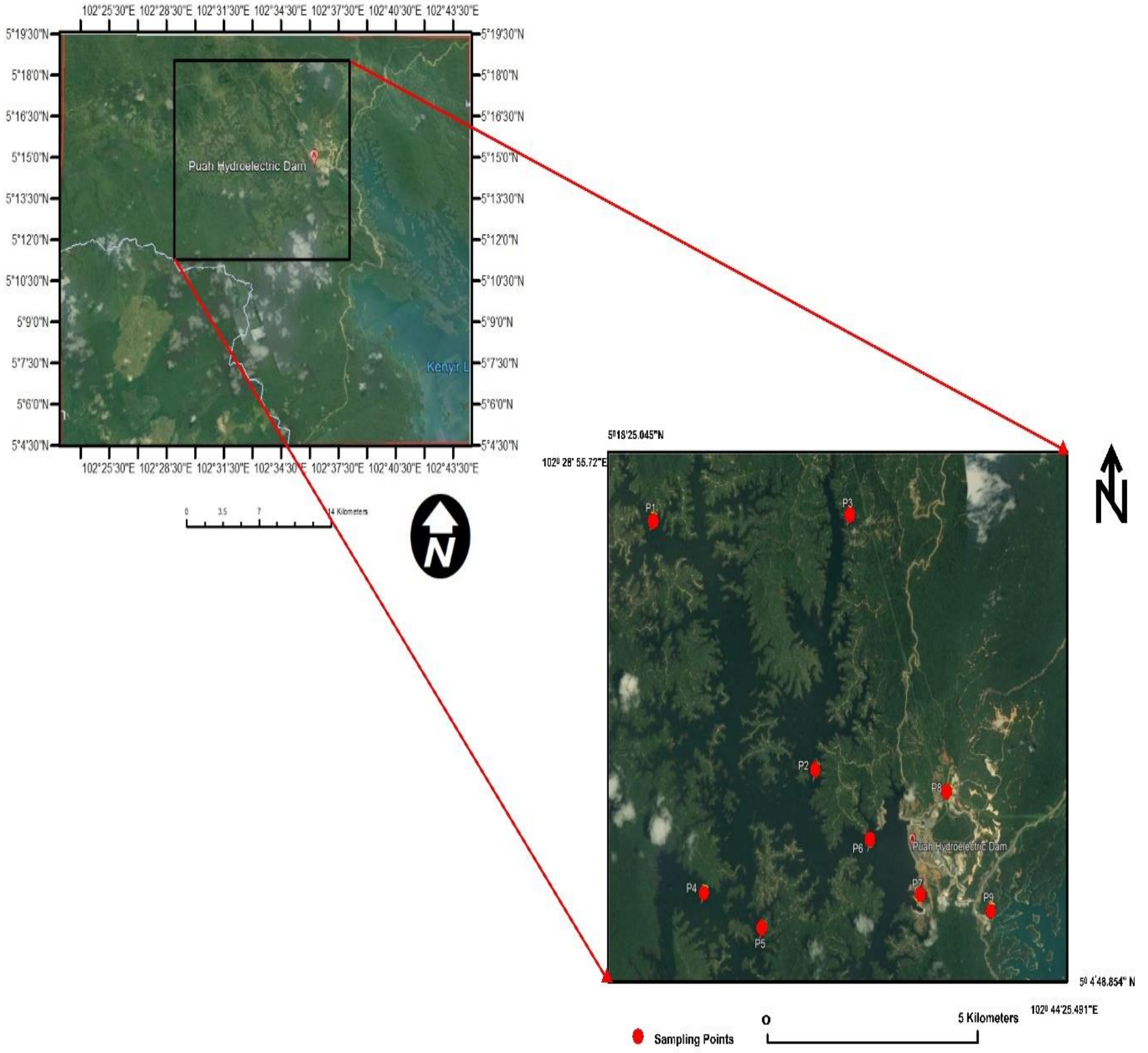

Figure 1. Hulu Terengganu catchment area and sampling stations of Puah Reservoir (Google maps)

phytoplankton sample (100 ml) was then transferred to a graduated cylinder and was allowed to stand for 24 hours. The upper 90 ml was gently siphoned off after the settling, leaving the concentrated phytoplankton in the bottom. The concentrated 10 mL sample was transferred to a vial, where one mL was obtained for cell counting using an improved Neubauer haemocytometer (Tiefe-Depth Profondeur 0.100 mm; BLAU, Germany) for each of the three replicates and the average obtained. Identification of phytoplankton groups and species were done by placing the counting slide under a compound microscope (Motic BA410 Compound Binocular Microscope, China) equipped with Moticam 10.0 camera. The identification was guided by available literature and identification keys (Palmer, 1980; Anand, 1998; APHA, 2005; Huynh & Serediak, 2006; Sanet *et al.*, 2006; Edward & David, 2010; Miriam & Nicole, 2012; Rosen & Amand, 2015).

Water Quality Analysis

The geographical position of each location was established by a Garmin Global Positioning System (GPS). The latitudes and longitudes are given in decimal degrees in Table 1 above. Water temperature, pH, and DO were determined *in situ* using calibrated multi meters YSI Professional Plus handheld multi-probe from the photic zone. Nitrate and Nitrite-nitrogen (NO_2-N), phosphate, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and total suspended solid (TSS) all in mg/L were analysed using Hach DR/2000 5 portable water analysis kit in the laboratory according to APHA, 2005 and HACH, 2003 procedures.

Table 1. Shows the description of the sampling stations

Sampling Station Code		Coordinates
P1	Terengganu Mati	5°12'30.75"N 102°32'17.01"E
P2	Limbing Besar	5°10'10.50"N 102°34'29.11"E
P3	Tembat Outlet	5°12'33.09"N 102°34'56.17"E
P4	Pela-gong	5° 9'3.67"N 102°33'1.19"E
P5	Sireh	5° 8'44.54"N 102°33'47.21"E
P6	Centre Dam	5° 9'31.93"N 102°35'12.24"E
P7	Power Intake	5° 9'1.97"N 102°35'50.62"E

Statistical Analysis

One-way Analysis of Variance (ANOVA) was applied for testing differences in relative abundance of phytoplankton among stations and within station between seasons. Multiple comparisons table with Tukey's test showed which among the sites are significantly different from one another. Pearson correlation matrix was employed to determine which physico-chemical parameters were correlated with relative abundance of phytoplankton. Species diversity for each season was determined using Shannon-Wiener Index (*H'*) in Multi Variate Statistical Package.

RESULTS AND DISCUSSION

Phytoplankton Community

The present research study shows that the phytoplankton density of the Puah Dam was lower during dry season (162 cell/mL) compared to during wet season (412 cell/mL). Identified organisms belonged to six major plankton groups: 12 green algae (35.29%), nine blue-green algae (26.47%), nine diatom (23.53%), two golden algae (5.88%), two filamentous (5.88%) and one flagellate (2.94%) as shown in Fig 2. A total of 574 cell/mL were recorded from 34 genera in Puah Reservoir comprises of green algae (209), blue-green algae (67), diatom (168), golden algae (5), filamentous (20) and flagellate (20) as shown in Table 2. Among sampling stations in terms of green algae, Station P7 was the richest with 67 cell/mL; followed by Station P5 (32 cell/mL); Station P3 (31 cell/mL); Stations P1 and P6 (28 and 30 cell/mL); P2 (12 cell/mL); while Station P4 has the least number of species (6 cell/mL). For diatoms, Station P7 was the richest with 67 cell/mL; followed by Station P1 (29 cell/mL); Station P5 (17 cell/mL); Stations P3 and P4 (15 and 16 cell/mL); P2 (13 cell/mL); while Station P6 has the least number of species (11 cell/mL). Blue green algae on the other hand had Station P4 has the richest with 14 cell/mL; followed by Station P7 (15 cell/mL); Station P3 (13 cell/mL); Stations P6 (7 cell/mL); P1 (6 cell/mL); P2 (5 cell/mL) and Station P5 has the least number of species (4 cell/mL). Flagellate had Station P3 has the richest with 30 cell/mL ; followed by Stations P7, P6, P1 (26, 25 and 13 cell/mL respectively); P2 (9 cell/mL); while Station P4 has the least number of species (6 cell/mL), and none was recovered at station P5. Filamentous recorded highest in station P7 with 8 cell/mL; followed by Stations P5, P1 and

P3 (5, 4 and 3 cell/mL, respectively) and none was recovered at station P2, P4 and P6. More so, golden algae was only recorded at stations P1 and P6 with three species and two species respectively as presented in Figure 3. Green algae and diatoms had the greatest contribution to taxon richness in both seasons, with a greater number of species in the wet season, whereas there was a decrease in species of filamentous in the dry season (Figure 4). The remaining groups exhibited little variation between seasons. Species richness was discreetly greater in the wet season. However, Evenness Index was ≥0.8, thereby indicating a similarity in species abundance as shown in Figure 5. One-way ANOVA showed that there were significant differences of relative abundance between sampling sites ($P \geq 0.05$). Phytoplankton density was found higher during wet season, between the month of May to August, which corresponded to increase in DO and pH levels in lakes (Golder and Chattopadhyay, 2016). The result of this work correspond with that of Asma (2014), that phytoplankton in Putrajaya Lake exhibited high densities in the wet season. Seasonal patterns of green algae and diatoms in this reservoir were consistent with the earlier findings in Bera Lake, where higher densities were reported during April to June, whilst a reduction in filamentous algae could be related to changes in water level as reported by Sharip and Yosoff (2017).

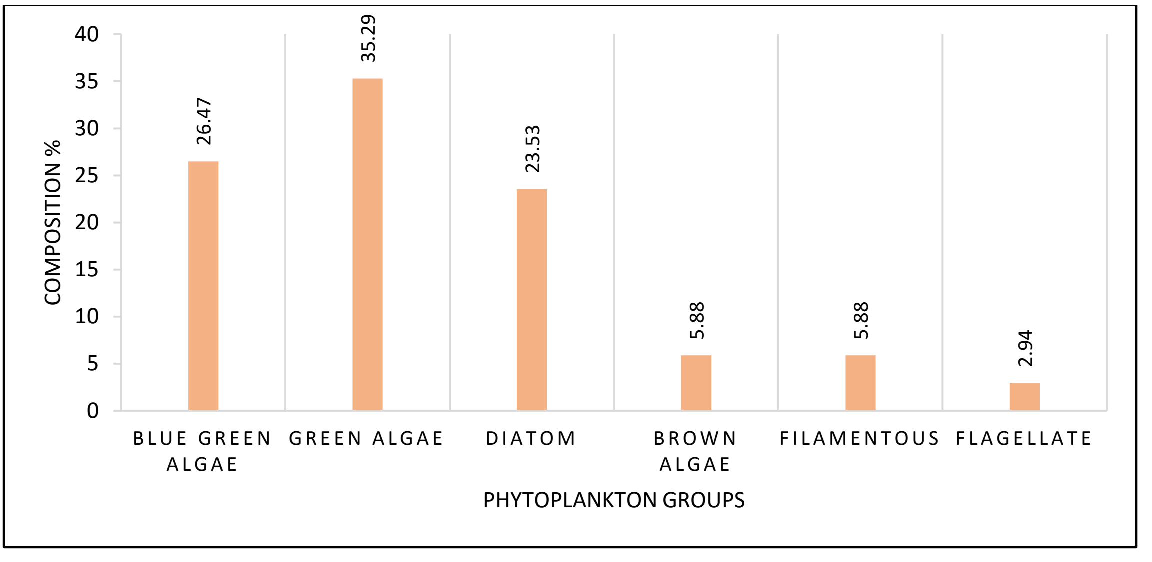

Figure 2. Composition (%) of phytoplankton density obtained from Puah Reservoir (May – December 2019)

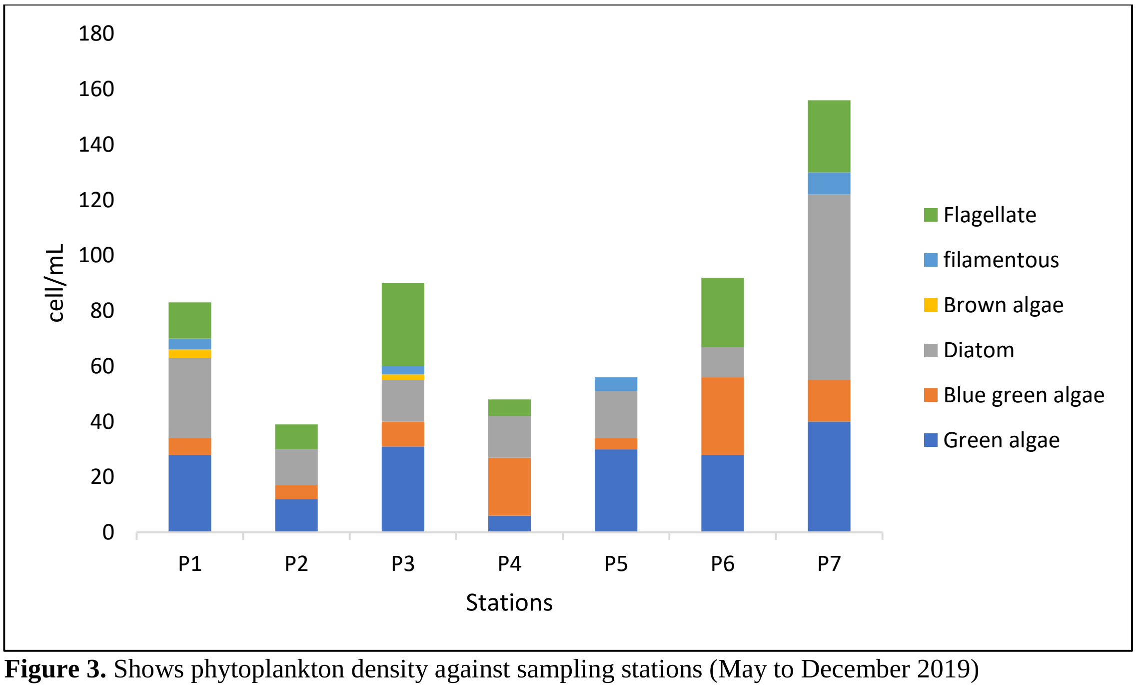

Figure 3. Shows phytoplankton density against sampling stations (May to December 2019)

Table 3. Algal taxa identified during the study and their abundances per sampling station in 2019

Genera	Phyla	Sampling station							
		P1	P2	P3	P4	P5	P6	P7	Total cell/mL
Green algae									
Mougeotia sp.	Chlorophyta			17		18	8	26	69
Uluthrix sp.	Chlorophyta		4			2	3		9
Ankistrodesmus sp.	Chlorophyta	3		4	2	2		1	12
Desmidium sp.	Chlorophyta			3					3
Botruococcus sp.	Chlorophyta							2	2
Chlorella sp.	Chlorophyta	7			2				9
Sorastrum sp.	Chlorophyta			4					4
Scenedesmus sp.	Chlorophyta		2	1		8			11
Chodatella sp.	Chlorophyta	16	6	2			19	11	54
Microspora sp.	Chlorophyta					2			2
Dactylococcopsis sp.	Chlorophyta	2			2				4
Staurastrum sp.	Chlorophyta							27	27
Total cell/mL		**28**	**12**	**31**	**6**	**32**	**30**	**67**	**206**
Diatom									
Asterionella sp.	Bacillariophyta	27	5	7	3	15	4	25	86
Melosira sp.	Bacillariophyta				1				1
Actinastrum sp.	Bacillariophyta				3			1	4
Tabellaria sp.	Bacillariophyta				3			26	29
Aulacoseira sp.	Bacillariophyta				1				1
Chaetoceros sp.	Bacillariophyta		8	8	5	2	7		30
Cyclotella sp.	Bacillariophyta							14	14
Diatoma sp.	Bacillariophyta	2							2
Total cell/mL		**29**	**13**	**15**	**16**	**17**	**11**	**67**	**168**
Flagellate									
Peridinium sp.	Pyrrhophyta	13	9	30	6		25	26	**109**
Filamentous									
Pithophara sp.	Charophyta					5			5
Pediastrum sp.	Charophyta	4		3				8	15
Total cell/mL		**4**		**3**		**5**		**8**	**20**
Blue-green algae									
Oscillatoria sp.	Cyanophyta	3	2	6	17	2	2	15	47
Anabaena sp.	Cyanophyta			3					3
Calothrix sp.	Cyanophyta	3	3						6
Gloeotrichia sp.	Cyanophyta						1		1
Schizothrix sp.	Cyanophyta					2			2
Nodularia sp.	Cyanophyta			2					2
Gomphosphaeria sp.	Cyanophyta			2					2
Golenkinia sp.	Cyanophyta						2		2
Sacconema sp.	Cyanophyta						2		2
Total cell/mL		**6**	**5**	**13**	**17**	**4**	**7**	**15**	**67**
Golden algae									
Dinobryon sp.	Chrysophyta						2		2
Synura sp.	Chrysophyta	3							3
Total cell/mL		**3**					**2**		**5**

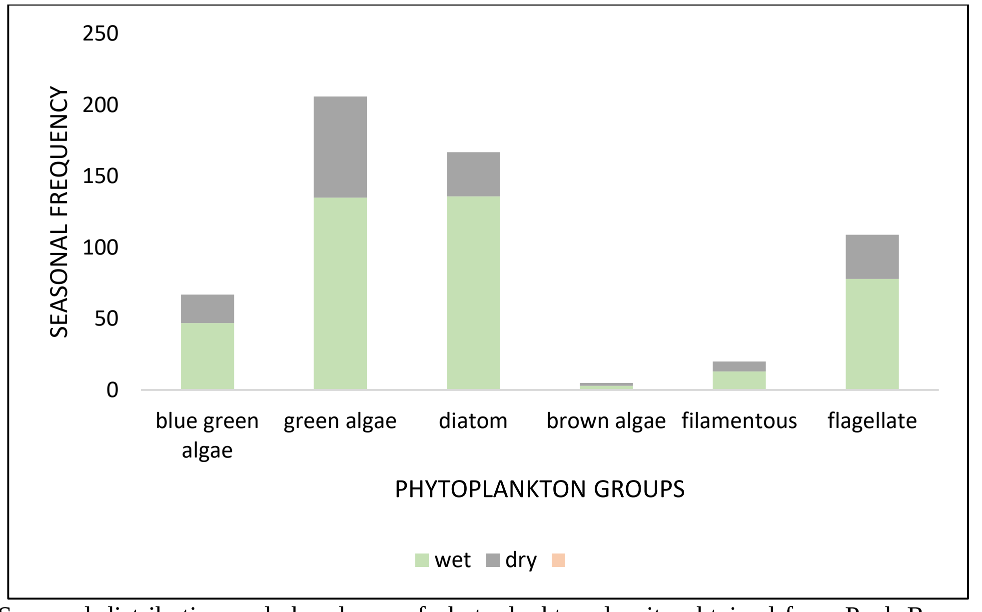

Figure 4. Seasonal distribution and abundance of phytoplankton density obtained from Puah Reservoir (May – December 2019)

Diatoms are considered as one of the most common and dominant taxa in freshwater environment (Bellinger & Sigee, 2010). In polluted water, it can exhibit tolerance towards high concentration of nutrients (Akbulut, 2003; Çelekli & Külköylüoğlu, 2006) thus supporting its survival. Generally, a water body is considered clean if the diversity of diatoms is high, but the population of each species is low which is found to correlate with our result. Stressed environments are known to have lower number of species, with only one or two species having significantly greater individuals than the other species (Palleyi *et al.*, 2011). In Lake Buhi, there was only one very abundant diatom species, namely *A. granulata*, which made up 28.5% of the total cell count, indicating that the water only favoured the proliferation of species that can tolerate high level of nutrients and pollutants.

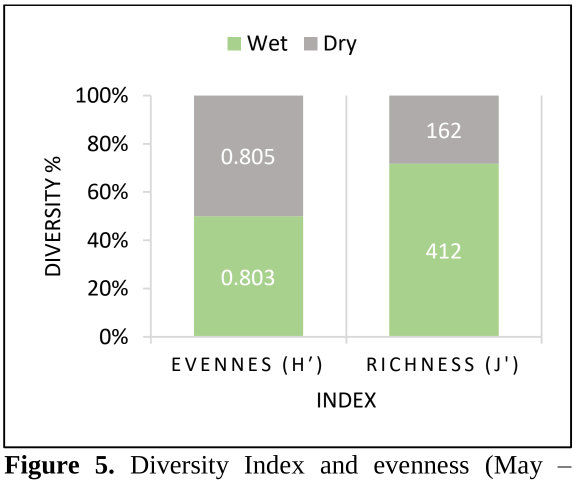

Figure 5. Diversity Index and evenness (May – December 2019)

The phytoplankton community abundance can be a useful indicator of the trophic conditions of lake zones based on their relative abundance (Yusoff & Fatimah, 1994). The desmid genus dinoflagellates *Peridinium* which was found dominant in the present study is generally found in oligotrophic waters (Ngearnpat & Peerapornpisal, 2007). Phytoplankton group composition in Puah Reservoir is comparatively like Lake Chini, Pahang, Malaysia (Kutty *et al.*, 2001) and Banglang Reservoir, Pattani in Southern Thailand (Ariyadej *et al.*, 2004). Both studies documented 135 phytoplankton species and had *Peridinium* amongst the most dominant and diverse genus recorded. Other reports on density in lakes across Malaysia showed a high variation depending on the type, size, and history of the water bodies, e.g., 19 and 33 genera were recorded from a study in small urban water bodies, Lake Aman and Lake Titiwangsa, respectively. Forty three genera were identified in a highly stained (dystrophic) swamp, Paya Bungor, Pahang, and 56 species were documented from a study in Kenyir Reservoir, Terengganu (Asma *et al.*, 2014). From other tropical reservoirs such as the Barra Bonita Reservoir, Brazil, 131 taxa were recognised (Calijuri *et al.*, 2002).

Phytoplankton are very useful for biological monitoring of water quality as they respond quickly to changes in environmental conditions (Sharma & Bhardwaj, 2011). These environmental conditions can show direct or inverse proportional influence or limited effect on phytoplankton. From the study, temperature and DO correlate positively with phytoplankton at P = 0.01. DO correlated positively with pH and temperature at P = 0.01 as shown in Table 3.

Table 3. Pearson correlation matrix of physico-chemical and biological parameters in the study area in 2019

	pH	temp	DO	TSS	BOD	COD	Nitrite	Phosphate	Phyt
pH	1	.485*	.776**	-.159	.063	.285	.046	-.009	.423**
temp		1	.728**	.051	-.259	.171	-.095	-.180*	.628**
DO			1	-.034	-.137	.307*	.200	-.057	.705**
TSS				1	-.080	.017	.523**	-.021	.032
BOD					1	-.117	-.133	-.060	-.075
COD						1	.315*	.051	.228
Nitrite							1	-.010	.118
Phosphate								1	-.170
Phyt									1

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level; temp = water temperature; TSS = total suspended solids; BOD = biochemical oxygen demand; DO = dissolved oxygen; COD = chemical oxygen demand; Phyt = phytoplankton.

Seasonal mean values of all variables investigated in relation to the sampling sites in the reservoir and a few notable features are observed. Water temperature is of enormous importance as it regulates various abiotic characteristics and biotic activities of a reservoir. The temperature difference for both season was small (less than 4 °C) for all stations, being similar to other local lentic systems (Kok Yeng, 2002). Minimum and maximum temperature recorded were 29.67 °C and 31.65 °C (P7 and P4) for wet season while 27.86 °C and 29.64 °C for P6 and P4, respectively during dry season. The overall mean values for wet and dry seasons were 29.3 ± 1.79 °C and 27.5 ± 1.55 °C as shown in Figure 6. Significant difference occurred only between P5 and P7 at (ANOVA, P ≤ 0.05). The observed variation in water temperature might be related to the seasonal weather conditions. There was significant difference in the pH, temperature and DO between wet and dry season (P ≤ 0.01). The pH was very high (8.94 - 10.31) at P7 and P5 during wet season, coinciding with periods of algal blooms and high dissolved oxygen levels while 7.75 (P3) and 8.31 (P5) as minimum and maximum during dry season. Although all pH values were slightly above neutral for both seasons (Figure 6). The pH is one of the most important factors that influence the aquatic production. The pH for both season was found to be basic. There were no significant differences between pH values with regards to stations and season (ANOVA, P ≥ 0.05).

The seasonal (wet and dry) mean values for DO, BOD and COD were 16.2 mg/L and 4.7 mg/L, 3.4 mg/L and 2.9 mg/L, and 15.2 mg/L

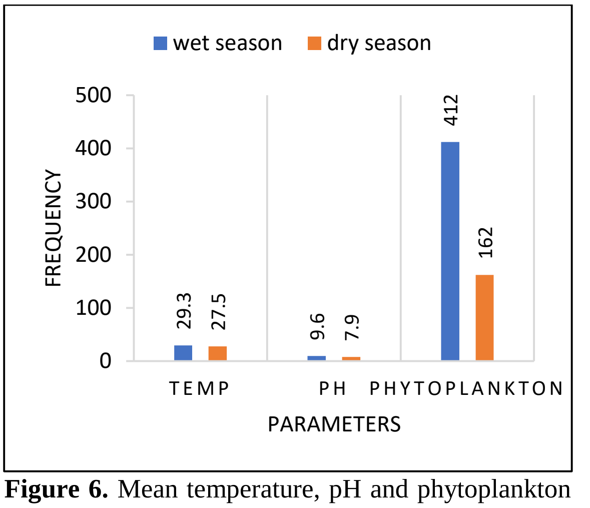

Figure 6. Mean temperature, pH and phytoplankton values of wet and dry seasons (mg/L) (May – December 2019)

and 12.7 mg/L as shown in Figure 7. There were no significant differences recorded among the sampling stations for DO but existed in BOD (P6 & P3) and COD (P1, P2 & P3, P6) at ANOVA, P ≥ 0.05. DO and BOD are important parameters which increase the favourable condition of algal growth during the study period. DO is important parameter of biological life in the water. Throughout the investigation period, high DO contents were noticed during wet season 16.2 mg/L and low during dry 4.7 mg/L similar to the observation found on seasonal variations in physico-chemical characteristics of Rudrasagar Wetland - A Ramsar Site, Tripura, Northeast, India (Abir, 2014). The amount of DO range between the seasons was high in comparison to minimum DO recommend by World Health Organization (WHO). The BOD is found to be more sensitive test for organic pollution. From this investigation, the highest BOD values 4.1

mg/L and 4.2 mg/L were observed in wet (P2) and dry (P6) seasons, respectively. There was no significant differences between DO values with regards to sampling stations but existed with season. There was significant differences between BOD and COD values with regards to stations and season (ANOVA, P ≤ 0.05). DO and BOD are important parameters which increase the favourable condition of algal growth during the study period. DO is important parameter of biological life in the water. Throughout the investigation period, high DO contents were observed during wet season with 16.2 mg/L and lowest during dry season with 4.7 mg/L. Same finding also been recorded by Abir (2014) at Rudrasagar Wetland - A Ramsar Site, Tripura, Northeast, India. BOD is found to be more sensitive test for organic pollution. BOD value of dam water ranged between 2.1 – 4.2 mg/L. Highest BOD value was observed in wet season at P2.

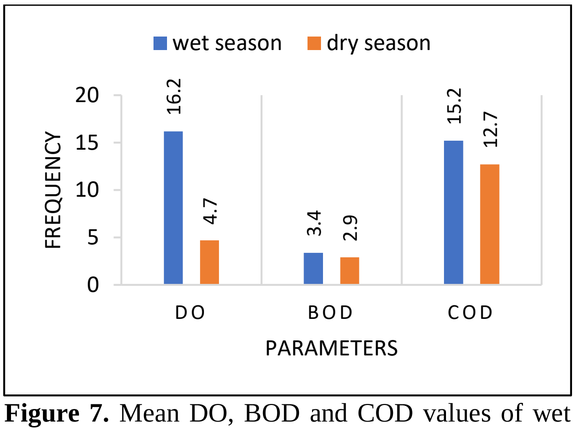

Figure 7. Mean DO, BOD and COD values of wet and dry seasons (mg/L) (May – December 2019)

Total suspended solid mean values of 0.5 mg/L and 2.3 mg/L were obtained for wet and dry seasons (Figure 8). There were no significant differences between TSS values with regards to season and stations (ANOVA, P ≥ 0.05). More so, the level of nitrite in the water ranged between 0.003 – 0.030 mg/L (P5 and P1) during wet season and 0.004 – 0.028 mg/L (P3/P6 and P1) in dry season (Figure 8). Phosphate concentration was 0.52 mg/L and 0.34 mg/L for dry and wet season (Figure 8). The concentrations of phosphate at both seasons indicate important limiting factor of primary production in the lake. There were significant differences between phosphate values with regards to season (ANOVA, P ≤ 0.05).

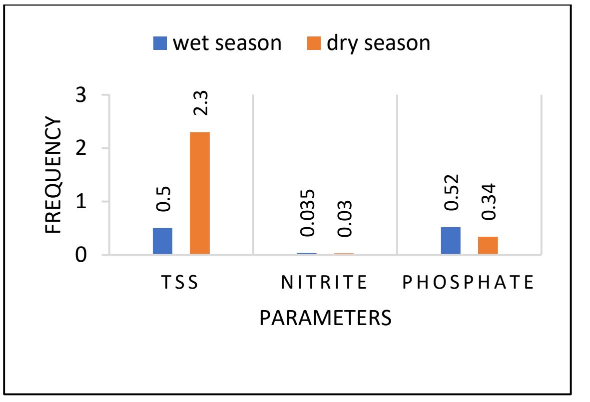

Figure 8. Mean TSS, nitrite and phosphate values of wet and dry seasons (mg/L) (May – December 2019)

CONCLUSION

Findings from this study indicated that the dynamics and community structure of the phytoplankton community in Puah Reservoir were influenced by temperature, pH and DO at different times of the year. Phytoplankton richness was higher in Power Intake (P7) and Centre Dam (P6) as a result of lower pH, temperature and higher DO compared to P2 (Limbing Besar) and P4 (Pela-gong).

ACKNOWLEDGEMENTS

The authors would like to acknowledge Universiti Sains Malaysia and Hussani Adamu Federal Polytechnic Kazaure for the opportunity to conduct this study.

REFFERENCES

Abir, S. (2014). Seasonal variations in physico-chemical characteristics of Rudrasagar Wetland: A Ramsar Site, Tripura, North East, India. *Research Journal of Chemical Sciences*, 4(1): 31-40.

Akbulut, A. (2003). Planktonic diatom (Bacillariophyceae) flora of Sultan *Sultan Sazlığı* Marshes (Kayseri). *Turkish Journal of Botany*, 27: 285–301.

Anand, N. (1998*). Handbook of blue-green algae of rice fields of South India*. Bishen Singh Mahendra Pal Singh. New Delhi, India.

APHA. (2005). *Standard Methods for the Examination of Water and Wastewater*. American water works, association and water pollution control Federation (sd), 21st Edn. American Public Health Association Washington DC, USA.

Ariyadej, C., Tansakul, R., Tansakul, P. & Angsupanich, S. (2004). Phytoplankton diversity and its relationships to the physico-chemical environment in the Banglang Reservoir, Yala Province. *Songklanakarin Journal Science and Technology*, 26: 595-607.

Asma, J., Yusoff, F.M., Banerjee, S. & Shariff, M. (2014). Littoral and limnetic phytoplankton distribution and biodiversity in a tropical man-made lake, Malaysia. *Advanced Studies in Biology,* 6: 149-168.

Bellinger, E.G. and David C. Sigee, D.C. (2010). *Freshwater Algae: Identification and use as Bioindicators*. John Wiley & Sons, Ltd.

Calijuri, M.C., Dos Santos, A.C.A. & Jati, S. (2002). Temporal changes in the phytoplankton community structure in a tropical and eutrophic reservoir (Barra Bonita, S.P.-Brazil), *Journal of Plankton Research*, 24: 617-634.

Çelekli, A. & Külköylüoğlu, O. (2006): On the relationship between ecology and phytoplankton composition in a karstic spring (Çepni, Bolu). *Ecological Indicators*, 7: 497–503.

Golder, D. & Chattopadhyay, S. (2016). Interrelationship between physicochemical characteristics of a tropical lake and their impact on biodiversity of planktons. *Journal of Environmental Biology,* 37: 1281.

Huynh, M. & Serediak. N. (2006). *Algae identification field guide, an illustrative field guide on identifying common algae found in the Canadian Prairies*. Agriculture and Agri-Food, Canada.

Khuantrairong, T. & Traichaiyaporn, S. (2008). Diversity and seasonal succession of the phytoplankton community in Doi Tao Lake, Chiang Mai Province, Northern Thailand. *The Natural History Journal of Chulalongkorn University*, 8: 143-156.

Kok Yeng, C. (2002). *A Study on Limnology and Phytoplankton Biodiversity of Ahning Reservoir, Kedah.* M.Sc. Thesis. Universiti Sains Malaysia.

Kutty, A.A. Ismail, A. & Fong, C.S. (2001). A preliminary study of phytoplankton at Lake Chini, Pahang, *Pakistan Journal of Biological Sciences*, 4: 309-313.

Miriam, S.K. & Nicole, L. (2012). *A field guide to algae and other "scums" in ponds, lakes, streams, and rivers.* Northern Kentucky University, USA.

Ngearnpat, N. & Peerapornpisal, P. (2007). Application of desmid diversity in assessing the water quality of 12 freshwater resources in Thailand. *Journal of Applied Phycology*, 19: 667-674.

Omar, W.M.W. (2010). Perspectives on the use of algae as biological indicators for monitoring and protecting aquatic environments, with special reference to Malaysian freshwater ecosystems. *Tropical Life Sciences Research*, 21(2): 51.

Palleyi, S., Kar, R.N. & Panda, C.R. (2011). Influence of water quality on the biodiversity of phytoplankton in Dhamra River Estuary of Odisha Coast, Bay of Bengal. *Journal of Applied Sciences and Environmental Management,* 15(1): 69–74.

Palmer, G.M. (1980). *Algae and Water Pollution*. Castle House Publications Limited, England. Pp. 72-75.

Rosen, B.H. & St. Amand, A. (2015). *Field and laboratory guide to freshwater cyanobacteria harmful algal blooms for Native American and Alaska Native Communities*: *U.S. Geological Survey Open-File Report,* Virginia.

Sanet, J.V., Jonathan, T., Carin, G. & Annelise, G. (2006). *Easy identification of the most common algae*. North-West University, Potchefstroom.

Sharip, Z. & Yusoff, F.M. (2017). Plankton community characteristics of natural and man-made tropical lakes. *Journal of Environmental Biology*, 38(6): 1365-1374.

Sharma, N.K. & Bhardwaj, S. (2011). An assessment of seasonal variation in phytoplankton community of Mahi River (India). *Geneconserve,* 10: 154-164.

Yusoff, F.M. & Fatimah, I. (1994). A comparative study of phytoplankton populations in two Malaysian lakes. *International Association of Theoretical and Applied Limnology*, 24: 251-257.

Yusoff, F.M., Happey-Wood, C.M. & Anton, A. (1998). Vertical and seasonal distribution of phytoplankton in a tropical reservoir, Malaysia. *International Review of Hydrobiology*, 83: 121-134.