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Seasonal variation in algal diversity and productivity in Dachi lake, Meghalaya

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Abstract: Seasonal variation in algal diversity and productivity in Dachi lake was carried out from September 2015 to August 2016. Dachi lake is well known tourist spot in West Garo Hills. It is maintained by Soil and Water Conservation Department of Meghalaya. A total of 176 algal species belonging to 8 classes were recorded. A distinct seasonal variation in diversity was observed, which varied from 1.45 in summer to 3.1 in spring. Primary productivity was also maximum in spring (3.07 gC/m^3/h) and was minimum in summer (0.97gC/m^3/h). Seasonal variation in physico-chemical parameters was observed and the nutrients concentration was recorded within the permissible limit of World Health Organization standard. Pearson's correlation analysis revealed that primary productivity positively correlated with pH, transparency and dissolved oxygen and negatively correlated with turbidity and nutrients. It can be concluded that productivity in Dachi lake is driven by transparency of the water which allowed light to penetrate and promote productivity. Diversity indicated the clean status of the lake. The lake is maintained well by the Soil and Water Conservation Department hence pollution caused by the tourist was negligible. The changes in physico-chemical parameters, algal community and primary productivity are mainly due to seasonal changes.

Keywords: Diversity, Primary productivity, Chlorophyll a and Pearson's correlation.

Introduction:

The seasonal fluctuations in algal diversity and productivity in any water body is due to differential response of different algal species to changing levels of light, temperature, nutrients and grazing pressure with change in season during a course of year (Agrawal, 1999). The seasonal fluctuations of algae are more pronounce in temperate or polar lakes and reservoirs than those in tropical regions (Reynolds, 1988). Phytoplankton follows a fairly recognizable annual cycle of growth, but sometimes the synchrony in their normal annual cycle is disrupted by explosive growth of some species (Vaulot, 2001). Primary production is the most important phenomenon in nature on which the entire diverse array of life depends, either directly or indirectly. It is the driving force for all metabolic activities in the biosphere. It also shows the ability of an area to support the growth of biological population (Prasad, 1990). The algal flora constitutes a vital link in the food chain and its productivity depends on water quality at a given time (Meshram and Dhande, 2000). The occurrence and abundance of these algae varies seasonally and their study provides a relevant focus for research on eutrophication of water bodies and its adverse impact on aquatic life. Study of diversity of algae serves as a useful tool for the assessment of water quality and in understanding the basic nature of the water body (Palmer, 1969; Cascallar *et al*., 2003; Siangbood and Ramanujam, 2014; Gopinath and Kumar, 2015). A high diversity count suggest a healthy ecosystem, the reverse indicates a degraded environment (Ghosh *et al.,* 2012).

Meghalaya, a state in North East India is known for its rich floral resources. It is rich in aquatic resource also with many rivers, lakes, streams and springs. West Garo Hills is one of the districts of Meghalaya. The region is mostly hilly with plains fringing the northern, western and the southwestern borders. South-West monsoon and seasonal winds, largely controls the climate of the district. The district being relatively lower in altitude, experiences a fairly high temperature for most part of the year. Dachi lake is one of the protected tourist spots of the region. The lake is maintained and governed by the Soil and Water Conservation Department of Meghalaya. Literature regarding the algal potential of the region is very scanty. Therefore, to assess the diversity of algae in the region, the lake was selected for the present work.

MATERIALS AND METHODS

Study site

Dachi lake is situated at an altitude of 318m asl, with the geographical coordinates at latitude 25° 44' 10.337" N and longitude 90° 23' 6.259" E, is a well known tourist spot with an area of 3236 square meters, at Anogre in West Garo

Hills, Meghalaya (Figure 1). It is about 60 km from Tura, the main town in West Garo Hills. The lake is under the Soil and Water Conservation Department, Government of Meghalaya. The depth of the lake is about 7.62 m.

Fig 1 Map of study site

Sample collection and analysis

Water and algal samples were collected monthly from September 2015 to August 2016. Water temperature, pH, turbidity, conductivity, transparency were measured at the spot. Dissolved oxygen, phosphate, nitrate and nitrite were estimated following APHA (2012). Primary productivity was analyzed by dark and light bottles method and by estimating Chlorophyll ‘a’ by spectrophotometer method (Strickland and Parson, 1972).

Phytoplankton was collected from surface water by using plankton net (45 μm). Periphytic algae were collected from different substrata like stones, rocks, pebbles, dead leaves and sediments with help of scalpel and tooth brush. The algal samples were preserved in 4% formaldehyde and brought to the laboratory for further study. For extraction of diatoms, sediments samples were homogenized with acid (Hendey, 1974). Algal samples were observed under a trinocular microscope and photographed (using Olympus B41 microscope). Taxonomic identification up to species level were carried out with the help of standard books and Monographs like Fritsch (1935), Prescott (1982), Desikachary (1985), Gandhi (1998), ADIAC (1999), John *et al*., (2002) and taxonomy was updated using the online database Algae Base [World-wide electronic publication (www.algaebase.org)].

Data Analysis

Shannon-wiener diversity index was calculated. Pearson’s correlation was applied to establish relation between physico-chemical parameters and productivity.

Result

Physico-chemical parameters

The physico-chemical parameters differed seasonally (Figure 2).Water temperature was 28^{0}C in summer and winter was 17 ^{0}C. pH ranged from slightly acidic to alkaline, it was recorded maximum during spring (7.8) and minimum during summer (6.7). Electric conductivity was maximum in summer (0.04 mS/cm) and minimum in winter (0.01 mS/cm). Water transparency varied significantly with seasons, maximum transparency was recorded during winter

(28.75 cm) and minimum during summer (14.75 cm). Turbidity was high during summer (7.62 NTU) and was lowest during winter (4.1NTU). Dissolved oxygen was found maximum during spring (7.65 mg/l) and minimum during summer (6.4mg/l). Nitrite was high during autumn (0.11 mg/l) and low during winter (0.07 mg/l) but in the case of nitrate, it was recorded maximum in summer (0.15 mg/l) and minimum in winter (0.04mg/l). Phosphate was recorded maximum during summer (0.16 mg/l) and minimum during spring (0.12 mg/l) and autumn (0.12 mg/l).

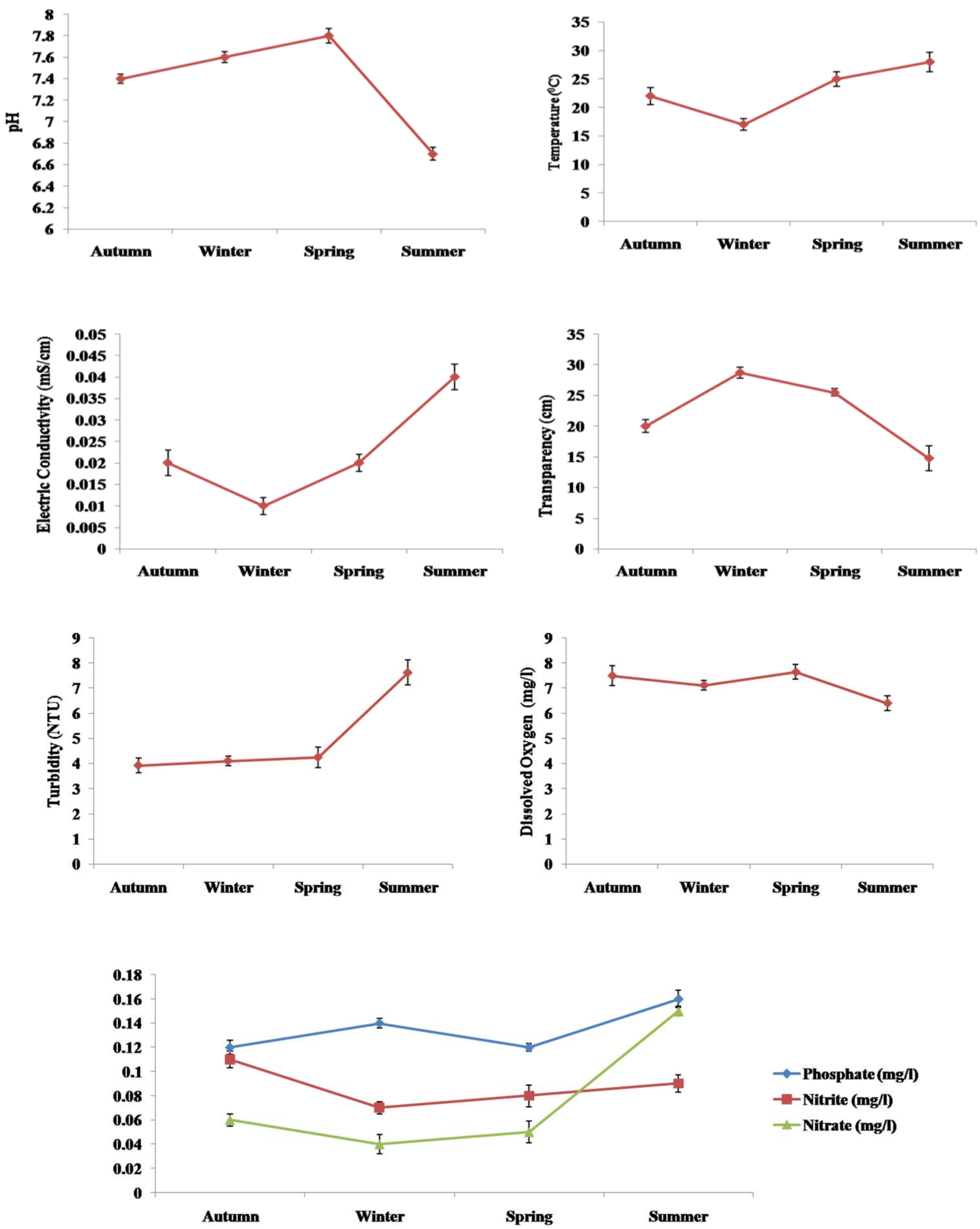

Figure 2: Seasonal variation of physico-chemical parameters in Dachi lake

Algal Community Structure

A total of 176 algal species belonging to 8 classes were recorded from Dachi lake across four seasons (Table 1). Class Zygnematophyceae were represented by maximum number of species (58 species) followed by Chlorophyceae (51 species), Bacillariophyceae (42 species), Cyanobacteria (7 species), Trebouxiophyceae (6 species), Xanthophyceae (5 species), Euglenophyceae (4 species) and Dinophyceae (3 species). Abundance of algal species also varied significantly with seasons. Abundance was maximum in spring and was dominated by members of Zygnematophyceae (36724 cells/ml), followed by members of Trebouxiophyceae (2830 cells/ml) and Xanthophyceae (345 cells/ml). Members of Chlorophyceae (22886 cells/ml) along with very few members of Dinophyceae (61cells/ml) were dominant in winter, members of Bacillariophyceae (11083 cells/ml) along with members of Euglenophyceae (921 cells/ml) and members of Cyanobacteria (851 cells/ml) were dominant and abundant in summer (Figure 3). Some dominant genera recorded were *Cosmarium, Closterium* and *Staurastrum* from Zygnematophyceae, *Scenedesmus* and *Pediastrum* from Chlorophyceae, *Navicula* and *Cymbella* from Bacillariophyceae. Trebouxiophyceae, Xanthophyceae and Dinophyceae were represented by 6, 5 and 3 species respectively. Cyanobacteria and Euglenophyceae were represented by 7 and 4 species respectively. Shannon diversity index varied seasonally and it varied from 1.45 in summer to 3.1 in spring (Figure 4).

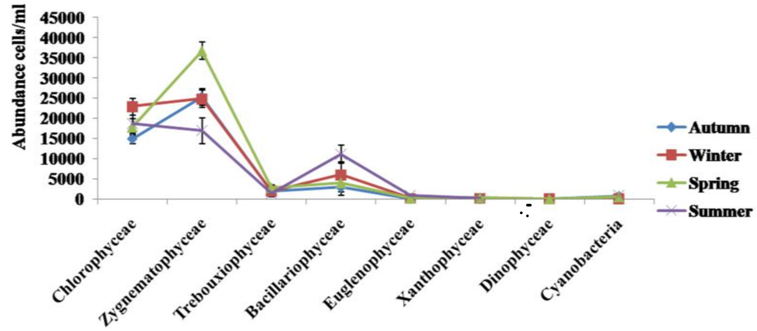

Figure 3: Seasonal variation of different algal groups in Dachi lake

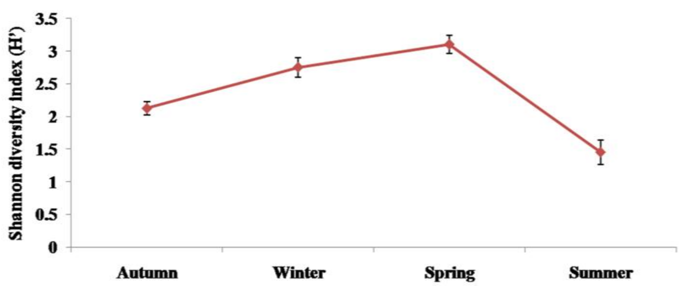

Figure 4: Seasonal variation of Shannon diversity index (H') in Dachi lake

Table 1: Seasonal variation in the distribution of algae in Dachi lake

Algal taxa	Autumn	Winter	Spring	Summer
CHLOROPHYCEAE				
Ankistrodesmus falcatus (Corda) Ralfs	+	+		+
Ankistrodesmus spiralis (W.B.Turner)	+		+	
Chlamydomonas peterfii Gerloff		+	+	
Chlorella pyrenoidosa H.Chick	+			+

Chlorella vulgaris Beyerinck (Beijerinck)		+	+	+
Chlorococcum echinozygotum Starr		+	+	+
Chlorococcum infusionum (Schrank) Meneghini	+	+		
Coelastrum astroideum De Notaris		+	+	
Coelastrum cambricum W. Archer	+	+		+
Coelastrum microporum Nageli			+	
Coelastrum reticulatum (P.A.Dangeard) Senn		+	+	+
Eudorina elegans Ehrenberg	+	+	+	
Gloeocystis sp	+			+
Gloeocystis vesiculosa Nageli		+		
Golenkinia paucispina West &G.S.West			+	+
Golenkinia radiate Chodat	+	+	+	
Kirchneriella obese West &G.S.West	+	+	+	+
Kirchneriella sp	+	+	+	
Microspora floccose (Vaucher) Thuret				+
Monoraphidium sp	+	+		
Oedogonium capillare Kutzing ex Hirn		+		+
Oedogonium hispidum Nordstedt ex Hirn		+	+	+
Oedogonium porrectum Nordstedt ex Hirn	+	+		
Palmodictyon viride Kutzing			+	
Pandorina morum (O.F.Muller) Bory	+	+	+	+
Pediastrum boryanum (Turpin) Meneghini	+	+		
Pediastrum duplex Meyen		+	+	+
Pediastrum integrum Nageli		+	+	
Pediastrum simplex Meyen	+		+	+
Pediastrum subgranulatum (Raciborski) J.Komarek&V.Jankovsk	+	+		+
Pediastrum tetras Ehrenberg Ralfs		+	+	+
Pithophora varia Wille		+		
Planktosphaeria gelatinosa G.M. Smith			+	+
Quadrigula quaternata (West &G.West) Printz		+		

Scenedesmus abundan s(Kirchner) Chodat	+	+	+	+
Scenedesmus acutiformis Schroder	+			+
Scenedesmus acutus Meyen		+	+	+
Scenedesmus bijugatus Kutzing	+	+		
Scenedesmus brasiliensis Bohlin			+	
Scenedesmus denticulatus Lagerheim		+		+
Scenedesmus dimorphus (Turpin) Kutzing	+	+	+	+
Scenedesmus obliquus (Turpin) Kutzing	+	+	+	+
Scenedesmus opoliensis P.G. Richter		+		
Scenedsemus sp				+
Selenastrum gracile Reinsch	+	+		+
Sphaerocystis planctonica (Korshikov) Bourrelly		+		
Sphaerocystis sp			+	
Sphaerocystis sp				+
Tetraedron gracile (Reinsch) Hansgirg	+	+		
Tetrallantos lagerheimii (Teiling)	+	+		
Tetrastrum heterocanthum (Nordstedt) Chodat			+	
ZYGNEMATOPHYCEAE				
Arthrodesmus convergens Ehrenberg ex Ralfs		+	+	
Arthrodesmus octocornis Ehrenberg ex Ralfs	+		+	
Bambusina brebissonii Kutzing ex Kutzing	+			
*Closteriumleibleinii*Kutzing ex Ralfs		+	+	+
Closterium lineatum Ehrenberg ex Ralfs	+	+	+	+
Closterium acutum Brebisson	+	+	+	+
Closterium littorale F. Gay	+	+	+	+
Closterium cornu Ehrenberg ex Ralfs	+		+	
Closterium Cynthia De Notaris	+			
Closterium dianae Ehrenberg ex Ralfs	+	+	+	+
Closterium intermedium Ralfs			+	
Closterium kuetzingii Brebisson	+			

Closterium navicula (Brebisson) Lutkemuller			+	
Closterium rostratum Ehrenberg ex Ralfs	+		+	+
Closterium strigosum Brebisson		+	+	
Cosmarium bioculatum Brebisson ex Ralfs			+	
Cosmarium granatum Brebisson in Ralfs	+		+	+
Cosmarium amaenum Brebisson ex Ralfs			+	
Cosmarium anceps P.Lundell	+	+		
Cosmarium angulosum Brebisson	+	+	+	+
Cosmarium bicrenatum W.B. Turner	+			
Cosmarium bioculatum Brebisson ex Ralfs		+	+	+
Cosmarium biretum Brebisson ex Ralfs	+		+	
Cosmarium botrytis Meneghini ex Ralfs	+	+		
Cosmarium circulare Reinsch	+			
Cosmarium constrictum f. minus F.E.Fritsch&M.F.Rich	+	+	+	+
Cosmarium depressum (Nageli) P.Lundell		+	+	+
Cosmarium difficile var. Constrictum Messikommer	+			
Cosmarium pachydermum P. Lundell			+	+
Cosmarium quadrum P. Lundell	+	+	+	
Cosmarium quinarium P. Lundell	+		+	+
Cosmarium regnellii Wille			+	
Cosmarium reniforme (Ralfs) W.Archer	+	+	+	+
Cosmarium retusiforme (Wille) Gutwinski	+		+	
*Desmidium grevillii (*Kutzing ex Ralfs) De Bary		+		
Euastrum ansatum Ehrenberg ex Ralfs	+		+	
Euastrum binale Ehrenberg ex Ralfs		+	+	+
Euastrum denticulatum F.Gay	+		+	
Euastrum pulchellum Brebisson			+	
Euastrum sp	+		+	
Euastrum sublobatum Brebissonex Ralfs		+	+	
Gonatozygon monotaenium De bary		+		

Hyalotheca dissiliens Brebisson ex Ralfs	+		+	
Mougeotia sp		+		
Onychonema sp	+			
Penium cylindrus Brebisson ex Ralfs		+	+	
Spirogyra punctiformis Transeau		+		
Staurastrum anatinum Cooke & Wills		+	+	+
Staurastrum armigerum Brebisson		+	+	
Staurastrum connatum (P.Lundell) J.Roy&Bisset	+	+		+
Staurastrum egregium M.Noda&Skvortzov	+			
Staurastrum gracile Ralfs ex Ralfs		+	+	
Staurastrum longipes (Nordstedt) Teiling	+		+	
Staurastrum margaritaceum Meneghini ex Ralfs		+	+	
Staurastrum muticum Brebisson ex Ralfs	+			
Staurastrum arctison (Ehrenberg) Lundell			+	+
Staurastrum sunderbundense W.B. Turner	+	+	+	
Staurastrum trifidum Nordstedt			+	
BACILARIOPHYCEAE				
Achnanthes minutissima Kutzing	+	+	+	+
Cyclotella glomerata H. Bachmann	+			
Cyclotella meneghiniana Kutzing				+
Cylindrocystis gracilis I.Hirn			+	+
Cymbella affinis Kutzing	+	+	+	+
Cymbella cistula (Ehrenberg) Kirchner	+	+	+	+
Cymbella prostrate (Berkeley) Cleve			+	
Cymbella amphicephala Naegeli			+	
Cymbella gracilis (Rabenhorst) Cleve	+	+	+	
Cymbella turgidula Grunow	+			
Cymbella ventricosa C.Agardh	+	+	+	+
Eunotia bilunaris (Ehrenberg) Schaarschmidt			+	
Eunotia lunaris (Ehrenberg) Grunow			+	
Eunotia pectinalis (Kutzing) Rabenhorst			+	

Fragilaria capucina Desmazieres	+	+		
Fragilaria virescens Ralfs	+	+	+	+
Gomphonema abbreviatum C.Agardh		+	+	
Gomphonema angustatum (Kutzing) Rabenhorst	+	+	+	+
Gomphonema lanceolatum Kutzing		+	+	
Gomphonema olivaceum (Hornemann)	+	+	+	+
Gomphonema parvulum (Kutzing) Kutzing	+		+	
Melosira granulate (Ehrenberg) Ralfs			+	
Melosira varians C.Agardh			+	
Navicula cryptocephala Kuetzing			+	
Navicula cuspidate (Kutzing) Kutzing		+	+	+
Navicula lanceolata Ehrenberg	+	+	+	+
Navicula capitatoradiata H.Germain		+		
Navicula gracilis Ehrenberg			+	
Navicula protracta (Grunow) Cleve			+	
Navicula radiosa Kutzing		+	+	+
Navicula viridis (Nitzsch) Ehrenberg	+	+		
Navicula viridula (Kutzing) Ehrenberg			+	
Neidium dubium (Ehenberg) Cleve			+	
Nitzchia intermedia Hantzsch	+	+		+
Nitzschia linearis W. Smith		+	+	
Pinnularia viridis (Nitzsch) Ehrenberg		+	+	
Pinnularia biceps W.Gregory	+			+
Pinnularia graciloides var.jogensis H.P.Gandhi		+	+	
Pinnularia interrupta W.Smith			+	
Pinnularia mesolepta (Ehrenberg) W.Smith	+	+	+	+
Sellaphora bacillum (Ehrenberg) D.G.Mann			+	
Synedra ulna (Nitzsch) Ehrenberg		+	+	
Trebouxiophyceae				
Closteriopsis longissima (Lemmermann) Lemmermann	+		+	+

Crucigenia crucifera (Wolle) O.Kuntze	+	+	+	
Crucigenia rectangularis (Nageli) Gay			+	
Crucigenia tetrapedia (Kirchner) Kuntze	+	+	+	+
Micractinium sp	+	+	+	
Oocystis solitaria Wittrock			+	
Xanthophyceae				
Centritractus belenophorus (Schmidle) Lemmermann			+	+
Goniochloris fallax Fott		+	+	
Tribonema minus (Wille) Hazen			+	+
Tribonema viride Pascher	+	+		
Tribonema vulgare Pascher			+	+
Dinophyceae				
Peridinium cinctum (O.F.Muller) Ehrenberg		+		
Peridinium gatunense Nygaard	+	+		
Peridinium sp			+	
Cyanobacteria				
Aphanocapsa sp	+			
Chroococcus tenax (Kirchner) Hieronymus	+		+	+
Coelosphaerium kuetzingianum Nageli		+		
Gloeocapsa punctata Nageli	+		+	
Microcystis aeruginosa (Kutzing) Kutzing	+		+	
Oscillatoria curviceps C.Agardh ex Gomont	+		+	+
Oscillatoria Formosa Bory ex Gomont	+		+	
Euglenophyceae				
Phacus caudatus Hubner		+		+
Phacus elegans Pochmann	+		+	+
Trachelomonas volvocina (Ehrenberg)		+	+	+
Trachelomonas hispida (Perty) F.Stein	+		+	+

Productivity of Dachi lake

Primary productivity was measured by light and dark bottle method and by estimation of chlorophyll a showed significant seasonal variations (Figure 5). Primary productivity and Chlorophyll a were maximum in spring season (3.07 gC/m^3/h and 0.64 mg/l respectively) and minimum in summer season (0.97 gC/m^3/h and 0.32 mg/l respectively). Primary productivity was positively correlated with pH, transparency and dissolved oxygen and negatively correlated with turbidity and nutrients (Table 2).

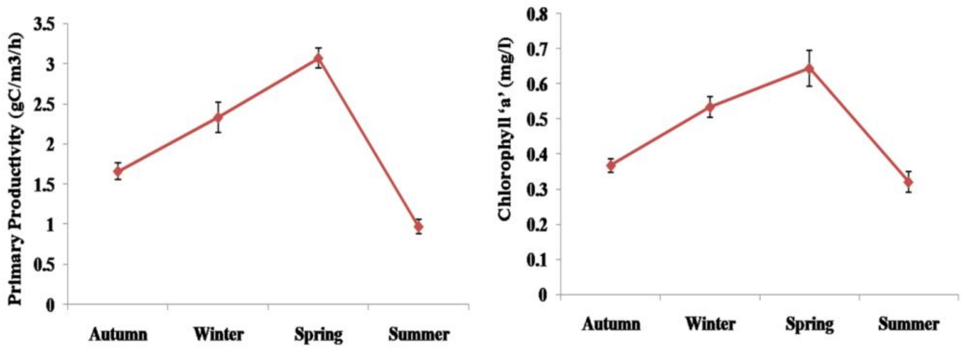

Figure 5: Seasonal variation of primary productivity and chlorophyll a in Dachi lake

Table2: Pearson's Correlation Coefficients between the Physico-chemical parameters and productivity (Temp= Temperature, EC= Electric Conductivity, Trans=Transparency, Tur=Turbidity, DO=Dissolved Oxygen, PP= Primary productivity, Chl 'a'=Chlorophyll a).

	pH	Temp	EC	Trans	Tur	DO	NO_3	NO_2	PO_4	PP	Chl 'a'
pH	1										
Tempt	-0.83	1.00									
EC	-0.87	0.94	1.00								
Trans	0.89	-0.99	-0.92	1.00							
Tur	-0.91	0.77	0.92	-0.78	1.00						
DO	0.90	-0.54	-0.71	0.61	-0.91	1.00					
NO_3	-0.95	0.87	0.96	-0.89	0.98	-0.87	1.00				
$N0_2$	-0.26	0.55	0.25	-0.58	-0.06	0.17	0.14	1.00			
PO_4	-0.82	0.41	0.62	-0.48	0.87	-0.99	0.80	-0.32	1.00		
PP	0.94	-0.36	-0.71	0.85	-0.72	0.78	-0.80	-0.47	-0.68	1.00	
Chl 'a'	0.87	-0.32	-0.64	0.84	-0.59	0.64	-0.71	-0.63	-0.52	0.98	1

Discussion

The pH of the lake water was alkaline during spring, winter and autumn but in summer it was slightly acidic. Low pH in summer might be due to entry of rain water, sediment and organic matter from surrounding areas which might have resulted in increase in respiration and decomposition rate and lowered the pH level. Similar result was reported by Kulmatov *et al*., (2013) in Aydar and Arnasay lake. Water temperature was low during winter season and gradually became warmer reaching its maximum temperature in summer. Increase in water temperature during summer and decrease during winter seasons were reported by many authors (Garg *et al.,* 2009; Islam *et al*., 2012; Siangbood and Ramanujam, 2014; Shylla and Ramanujam, 2014 and Sharma *et al*., 2016). Electrical conductivity and turbidity were maximum in summer season which could be due to decomposition of organic matter, entry of nutrient and soil particles from adjoining areas of the lake. Boateng and Aboagye (2013) in Amponsah lake, reported high conductivity values in summer and low in winter and explained that the fluctuation in conductivity values were due to variations in the decomposition rate of organic matter. Transparency was maximum in winter and minimum in summer. Low transparency value in summer could be due to deposition and accumulation of suspended matter into the water body and high transparency value during winter might be due to absence of entry of rain water, flood water. Similar results were reported by Oso and Fagbuaro (2008) and Ewebiyi *et al*., (2015). High dissolved oxygen in spring could be due to high photosynthesis rate of phytoplankton communities in clear water that resulted in higher dissolved oxygen (Ravindra *et al*., 2003). Low dissolved oxygen during the peak summer months was reported by Tian *et al*., (2012). According to them rise in temperature led to increase bacterial population and their consumption of oxygen. Therefore, water temperature directly influenced the amount of dissolved oxygen. Low dissolved oxygen in water in summer compared to other seasons was also reported by Mangaiyarkarsai *et al*., (2017). Phosphate and nitrate concentration were maximum in summer which could be due to entry of runoff water from its periphery and release of sediment in the form of sand in the lake during summer season. Similar findings were recorded by Ufodike *et al.,* 2001; Dublin-Green *et al*., 2003 and Seitzinger *et al*., 2010. Nitrate, nitrite and phosphate contents recorded in Dachi lake has been found within the permissible limit 50 mg/l for nitrate and nitrite and 0.3 mg/l for phosphate as per WHO (2011).

The seasonal changes observed in algal diversity could be due to seasonal changes in the water quality. Dominance of Zynematophyceae in spring could be related to low phosphate concentration and alkaline pH during that season. Kiran (2016) reported that phosphate at low concentration trigged the growth of desmids. Hajong and Ramanujam, (2017) reported that low turbidity and low concentration of phosphate and nitrate favour the growth of Zynematophyceae members. Desmids were generally more in oligotrophic lakes and ponds (Gerrath, 1993). Gonzalves and Joshi (1946) also reported that desmid community grow well in alkaline pH. Many authors considered desmids as a group of phytoplankton that are very sensitive to environmental changes and their growth was restricted in eutrophic condition of water (Charles, 1995; Edmondson, 1959, Gayathri *et al.*, 2011). Chlorophyceae members were recorded in maximum number in winter season which could be related to low turbidity, low conductivity, low water temperature and low nutrient status. Chlorophyceae is an important group of fresh water algae whose growth are controlled by parameters like transparency, water temperature, dissolved oxygen, pH and nutrients (Rajagopal *et al*., 2010, Rao and Pragada, 2010 and Verma *et al*., 2014). Dominance of Bacillariophyceae members in summer season could be related to slightly acidic pH and high temperature which lead to increase in the density of diatom. Patil *et al*., (2013) reported maximum density of diatom in summer and minimum in post-monsoon in Lotus lake. Occurrence of Cyanobacteria members and members of Euglenopyceae during summer might be due to increase in nutrient content which in turn resulted from influx of rainwater. Murulidhar and Murthy (2015) reported increase in density of eugleniods in summer season. Similarly, Panigrahi and Patra (2013) reported peak growth of Cyanobacteria during summer and minimum in winter in polluted area where Chlorophyceae could not grow. According to literature the normal value of diversity ranges from 0-4. The value greater than 3 indicate clean water; 1-3 indicate moderate pollution and value less than 1 are characterized as heavily polluted (Wilham and Dorris, 1968). Higher diversity value in spring and comparatively low in summer could be due to change in pH, transparency and dissolved oxygen due to entry of runoff from the surroundings. Entry of runoff with organic matter and nutrients prevented the rapid growth of algae (Ghosh *et al*., 2012; Shylla and Ramanujam, 2014). In general, the high Shannon's diversity Index (H') value obtained in the present study clearly indicated the clean status of the lake.

Transparency is one of the most important physical factors which strongly influence the productivity (Jayaweera and Asaeda 1996; Wei *et al*., 2004). Balogun *et al*., (2014) reported increased productivity with increase in dissolved oxygen. Kuehl and Troelstrup (2013) and Sukla *et al*., (2013) reported increase in primary productivity in alkaline transparent water. Higher primary productivity recorded in spring in the present study could be explained with the positive correlation of productivity values to high transparency, dissolved oxygen and alkaline pH during spring season. Nutrients were high in summer season, but primary productivity was low which could be due to high turbidity of lake water caused by entry of runoff water from periphery. Similar results were also reported by Knight *et al*., (2015) from Moon Lake where transparency was positively related to chlorophyll a and negatively to total phosphorus

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and nitrogen. Since the lake is maintained well by soil and water conservation department, pollution that caused by tourist is negligible. The changes in physico-chemical parameters, algal community and primary productivity are mainly due to seasonal changes.

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References

Agrawal, S.C. 1999 Limnology. APH Publishing Corporation.

Algae Base [World-wide electronic publication (www.algaebase.org)].

American Public Health Association (APHA) 2012 Standard methods for the examination of water and wastewater, 22nd Ed. Washington DC. p.1496.

Automatic Diatom Identification and Classification (ADIAC). Funded by the European MAST (Marine Science and Technology). Programme (1999),Contract MAS3-CT97-0122.

Balogun, K.J., Adedeji, A.K. and Ladigbolu, I.A. 2014 Primary production estimation in the euphotic zone of a tropical harbor ecosystem Nigeria. *International Journal of Scientific and Research Publication*. 4(8):1-8.

Boateng, O.G. and Aboagye, K.E. 2013 An assessment of the status of pollution of the lake Amponsah in the Bibiani-Anhwiaso-Bekwai District, Ghana. *Am. J. Sci. Ind. Res*. 4(5):499-511.

Cascallar, L., Mastranduono, P., Mosto, P., Rheinfeld, M., Santiago, J., Tsoukalis, C. and Wallace, S. 2003 Periphytic algae as bioindicators of nitrogen inputs in lakes. *J. Phycol*. 39:7-8.

Charles, C.D. 1955 The marine and freshwater plankton. Mishigan State University Press. Mishigan

Desikachary, T.V. 1985 Cyanophyta. Indian Council of Agriculture Research: New Delhi.

Dublin-Green,C.O., Ayinla, A.O., Ogori, T.K. 2003 Management of fish ponds built on acid sulfate soils in Buguma Creek, Niger Delta, Nigeria. *J. Appl. Sci. Environ. Mgt*. 7: 39-43.

Edmondson, W.T. 1959 Freshwater biology. University of Washington Seattle. London.

Ewebiyi, F.O., Appah, J. and Ajibade, G. A. 2015 Contribution of Physico-Chemical Parameters Of Water Bodies To Taxonomy, Distribution and Diversity of Phytoplankton within Kaduna Metropolis, Nigeria. *Journal of Environment and Earth Science*.5 (15):132-140.

Fritsch, F.E. 1935 The structure and reproduction of Algae: Vol. I and II Cambridge University Press. London.

Gandhi, H.P. 1998 Freshwater diatoms of central Gujarat-With a review and some others: Shiva offset Press: Dehradun: India

Garge, R.K., Rao, R.J. and Saksen, D. N. 2009 Water quality and conservation management of ramsagar reservoir Datia, Madhya Pradesh. *J. Environ. Biol*. 30:909-916.

Gayathri, N., Rajashekhar, M., Fatima, K., Vijaykumar, K., Ratandeep and Baburrao, M. 2011 Hydrochemistry and plankton diversity of Tungabhadra reservoir Bellary district, Karnataka. *Int J Zool Res*. 1(1):01-07.

Gerrath, J.F. 1993 The biology of desmids: A decade of progress. In: Progress in Phycology Research. Round, F.E. and D. J. Chapman (Ed.). Biopress Ltd. Bristol: 79-192.

Ghosh, S. Barinova, S. and Keshri, J.P. 2012 Diversity and seasonal variation of phytoplankton community in the Santragachi lake, West Bengal, India .*QScience Connect*.3http://dx.doi.org/10.5339/connect.2012.

Gonzalves, E.A. and Joshi, D.B. 1946 Freshwater algae near Bombay. The seasonal succession of the algae in a tank at Bandra. *J.Bomb.Nat.Hist.Soc*. 46:154-176.

Gopinath, P. and Kumar, A. K. G. 2015 Micro algal diversity of the fresh water lake in Thiruvananthapuram district, Kerala. *International journal of plants, animals and environment science*. 5 (1): 288-291.

Hajong, P. and Ramanujam, P. 2017 Effect of anthropogenic activities on algal community in Ganol river, West Garo Hills, Meghalaya. *Bull. Env. Pharmacol. Life Sci*. 6 (9):109-120.

Hendey, N.I. 1974 The Permanganate Method for cleaning freshly gathered diatom. *Microscopy*. 32: 423-426.

Islam, M. S., Ismail, B .S., Barzani, G. M., Sahibin, A. R. and Ekhwan, T.M. 2012 Hydrological assessment and water quality characteristics of Chini lake, Pahang, Malayasia. *Journal of agriculture and environmental Science*.12:737-749.

Jayaweera, M. and Asaeda, T. 1996 Modeling of biomanipulation in shallow, eutrophic lakes: an application to Lake Bleiswijkse Zoom, the Netherlands. *Ecological Modelling*. 85:113-127.

John, D.M., Whitton, B.A. and Brook, A.J. 2002 The freshwater Algae Flora of the British Isles: An Identification Guide to freshwater and Terrestrial Algae: Cambridge University Press, Cambridge.

Kiran, B.R. 2016 Distribution and occurrence of desmids in Bhadra Reservoir Karnataka. *International Journal of Research in Environmental Science*. 2(3):16-23.

Knight, S., King, M. and Cooper, C. 2015 Suspended sediment impact on chlorophyll a, nitrogen and phosphorus relationships in Moon lake, MS, USA. *International journal of earth & environmental science*. 1(1): 1-9.

Kuehl, L.C. and Troelstrup, N.H. 2013 Relationship between net primary production, water transparency, chlorophyll a and total phosphorus in Oak lake, Brookings County, South Dakota. *Proc S Dak Acad Sci*. 92:67-78.

Kulmatova, R., Mullabaev, N., Nigmatov, A., Kulmatova, D. and Sobirov, J. 2013 Qualitative and Quantitative Assessment of Water Resources of Aydar Arnasay Lakes System (AALS). *J Water Resource Prot*.5: 941-952.

Mangaiyarkarasi, A., Geetha, R.D., Helen, L.G. and Naveena, M. 2017 A study on seasonal variation and algal biodiversity in Sulur pond, Coimbatore, Tamil Nadu. *Int J Pharma Bio Sci*
8(3):580-591.

Meshram, C.B. and Dhande, R.R. 2000 Algal diversity with respect to pollution status of Wadali lake, Amaravati, Maharashtra, India. *J. Aqua. Biol*. 15:1-5.

Murulidhar, V.N. and Murthy, V.N.Y. 2015 Ecology, Distribution and Diversity of Phytoplankton in Teetha Wetland, Tumakuru District, Karnataka, India. *International Journal of Environment and Pollution Research*. 3(2):1-12.

Oso, J. A. and Fagbuaro, O. 2008 An assessment of the physic-chemical properties of a tropical reservoir, South-western, Nigeria. *Journal of Fisheries International*. 3:42-45.

Palmer, C.M.1969 A composite rating of algae tolerating organic pollution.*J.Phycol*.5:78-82.

Panigrahi, S. and Patra, A.K. 2013 Studies on seasonal variations in phytoplankton diversity of river Mahanadi, Cuttack city, Odisha, India. *Indian J.Sci.Res*. 4(2):211-217.

Patil, J.L., Ekhande, A.P. and Padate, G.S. 2013 Water quality monitoring-Study of seasonal variation of diatoms and their correlation with physicochemical parameters of Lotus Lake, Toranmal(M.S.) India. *Arch Appl Sci Res*.5(1):172-176.

Prasad, D.Y. 1990 Primary Productivity and Energy Flow in Upper Lake, Bhopal. Indian *J. Environ Health*. 32(2):132-139.

Prescott, G.W. 1982 Algae of the Western great lakes area.Otto Koelts Science Publishers, Koenigstein. West Germany. p.977.

Rajagopal, T., Thangamani, A., Archunan, G. 2010 Comparison of physic-chemical parameters and phytoplankton species diversity of two perennial ponds in Sattur area, Tamil Nadu. *J. Environ. Biol*. 31:787-794.

Rao, G.M.N. and Pragada, P.M. 2010 Seasonal abundance of micro algae in Pandi Back waters of Godavari Estuary, Andra Pradesh, India. *Not Sci Biol*. 2:26-29.

Ravindra, K., Ameena., M eenakshi., Monika., Rani., and Kaushik, A. 2003 Seasonal variations in physico-chemical characteristics of River Yamuna in Haryana and its ecological best- designated use. *J. Environ Monit*. 5(3):419-426.

Reynolds, C.S. 1988 The concept of ecological succession applied to seasonal periodicity of freshwater phytoplankton. *Verh. Int. Verein. Limnol*. 23:683-691.

Seitzinger, S. P., Mayorga, E., Bouwman, A.F., Kroeze, C., Beusen, A.H.W., Billen, G., Van Drecht, G., Dumont, E., Fekete, B. M., Garnier, J. and Harrison, J. A. 2010 Global river nutrient export: A scenario analysis of past and future trends. *Global biogeochem cycle*. 24:13-19.

Sharma, R.C., Singh, N., Chauhan, A. 2016 The influence of physico-chemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: A case study. *Egyptian Journal of Aquatic Research*.42:11-21.

Shylla, O. and Ramanujam, P. 2014 Algal diversity in selected lentic bodies of Meghalaya with emphasis on productivity and nutrient value. Ph.D. Thesis. North-Eastern Hill University, Shillong, India.

Siangbood, H. and Ramanujam, P. 2014 Effect of anthropogenic activities on algal assemblages in Umiew river, Meghalaya. *Phykos*. 44(1):415-51.

Strickland, J.D.H. and Parsons, T.R. 1972 A Practical Handbook of Seawater Analysis: The Alger Press Ltd: Ottowa, 1-310 pp

Sukla, B., Patra, A.K. and Panda, R.P. 2013 Primary Productivity in River Birupa, India. *Proc. Natl. Acad. Sci., India, Sec.B Biol. Sci*. 83(4):593-602.

Tian, C., Lu, X., Pei, H., Hu, W., Xie, J. 2012 Seasonal dynamics of phytoplankton and its relationship with the environmental factors in Dongping Lake, China. *Environ Monit Assess*. 185(3):2627-2645.

Ufodike, E.B.C., Kwanasie, A.S. and Chude, L.A. 2001 On-set of rain and its destabiling effect on aquatic physicochemical parameters. *J. aquat. Sci*. 16(12): 91-94.

Vaulot,D. 2001 Phytiplankton. Encyclopedia of Life Science. Nature Publishing Group. London.

Verma, P., Gupta, U.C., Adiyecha, P.R. and Solanki, H.A. 2014 Seasonal variation in the phytoplankton biodiversity of Chandlodia lake. *International Journal of Innovative Research in Science, Engineering and Technology*. 3(1):1-6.

Wei, H., Sun, J., Moll, A. and Zhao, L. 2004 Phytoplankton dynamics in the Bohai Sea observation and modeling. *Journal of Marine System*. 44:233-251.

WHO 2011 Guidelines for drinking water quality (6^{th} Ed.). World Health Organization. Geneva, Switzerland.

Wilham, J.L. and Dorris, T.C. 1968 Biological parameters of water quality criteria, *Bioscience*. 18:447-481.