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Full Length Research Paper

Effect of hydroclimatic conditions on phytoplankton community at Epe Lagoon tributary, Southwest Nigeria

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The effect of hydroclimatic conditions on phytoplankton was investigated in Ejirin, part of Epe lagoon, south-western Nigeria from December, 2012 to May, 2013. The data obtained for hydroclimatic features responded to rainfall pattern during the study period. The water remained acidic throughout the sampling period as pH value was ≤ 6.6 and salinity value ≤ 0.01%. The micronutrients varied throughout the sampling period and showed a correlation with rainfall. Chlorophyll *a* (Chl. *a*) concentration showed a correlation with conductivity, rainfall and surface water temperature, with a mean value of 0.021 mg L^{-1}. Transparency, salinity, silicate and reactive phosphate showed a dominant effect on the phytoplankton community. The total number of phytoplankton species recorded during dry months differed significantly with that of the wet months ($t^* = 2.723$, $P > 0.05$). A total of 105 species belonging to 5 divisions were recorded throughout the study period: Bacillariophyta (81.3%); Cyanobacteria (10.71%); Chlorophyta (6.5%), Eugleanophyta (1.35%) and Chrysophyta (0.13%). Diatoms were the dominant species in both the dry and wet months with 12 centric and 35 pennate forms. Phytoplankton density correlated significantly with silicate and TDS, indicating the possible effect of silicate on the diatoms and TDS on the whole community.

Key words: Cyanobacteria, phosphate, salinity, transparency.

INTRODUCTION

Good water quality depends largely on a number of hydroclimatic conditions (such as total dissolved solids (TDS), total suspended solids (TSS), pH, DO, conductivity, transparency, micronutrients, etc.) and the magnitude and sources of any pollution load. To effectively monitor the environment, assessment of these parameters is very essential. Water quality assessments of any region are important for the region's development because of the importance of water for domestic, industrial and aquaculture activities.

Lagoons dominate the southwest region of Nigeria and as such are important aquatic ecosystems that have attracted so many scientific researches. Lagoons in this region are interconnected and run parallel to the coastline of the Gulf of Guinea over a distance of 237 km (Hill and Webb, 1958). Ejirin tributary drains into the Epe lagoon, which is one of the nine lagoons in the coastal area of south-western Nigeria. The coastal waters of south-western Nigeria constitute numerous ecological niches that support various biodiversity (Onyema and Nwankwo,

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2006). The ecological characteristics operating in aquatic ecosystems of south-western Nigeria have been reported by many literatures (Hill and Webb, 1958; Olaniyan, 1969; Ezenwa, 1981; Nwankwo, 1984). Rainfall plays an important role in the tropics, diluting the ionic concentration of the coastal waters and breaking down horizontal environmental gradients. Precipitation introduces chelating agents, pollutants as well as increasing nutrients levels of the receiving water body.

The use of chlorophyll *a* to measure algal biomass and pollution status of aquatic environments has gained grounds worldwide (Lee, 1999; Suzuki et al., 2002). Composition and biomass of phytoplankton are very important parameters for understanding the structure and trophic level of aquatic ecosystems. The primary importance of phytoplankton in trophic relationships as autotrophs and their bio-indicator value have been assessed and reported in several literatures (Palmer, 1969; Vanlandingham, 1982; Dakashini and Soni, 1982). Onyema (2007) reported that phytoplankton satisfy conditions to be qualified as suitable indicators in that they are simple, capable of quantifying changes in water quality, applicable over large geographical areas and can also furnish data on background conditions and natural variability of aquatic ecosystems.

This study was conducted within the Ejirin tributary of Epe lagoon at the southwest region of Nigeria and aimed to assess the response of phytoplankton to hydroclimatic changes and to evaluate the dominant hydroclimatic factors.

MATERIALS AND METHODS

Study area

Ejirin is part of Epe lagoon found in south-western Nigeria located in Lat. 6° 89´´ N and Long. 3° 38´´E (Figure 1). Epe is a freshwater non-tidal lagoon. Epe lagoon is sandwiched between Lekki lagoon to the east and Lagos lagoon to the west. It experiences the same hydroclimatic conditions as the rest of south-western Nigeria which has two main seasons (wet and dry season). The littoral vegetation are dominantly Raphia plam and some dotted mangroves while the water surface is dominated by some floating macrophytes like water hyacinth (*Eichhornia crassipes*). The inhabitants of this region are mainly artisanal fishermen, sand miners and petty traders.

Sampling of hydroclimatic conditions

Water samples were collected on each trip from December, 2012 to May, 2013 between 9 am and 1 pm and stored in a 1000 ml well labeled screwed caped plastic bottles and transported to the laboratory in an ice chest. Four replicate samples were made on each trip for the following analysis, micronutrients, biological oxygen demand (BOD), chemical oxygen demand (COD) and chlorophyll *a* content. Surface water temperatures were measured *in situ* using a mercury-in-glass thermometer and recorded to the nearest 0.1°C. Transparency was determined using a 20 cm white painted secchi disc while pH was measured using a Graffin digital pH meter. Dissolved oxygen concentration was determined by unmodified Winkler method (Welch, 1948), conductivity was assessed using the meter, Philip PW9505 and chemical oxygen demand and biochemical oxygen demand values were determined using the method described in American Public Health Association (APHA) (2005). Nitrate-nitrogen, reactive phosphorus, sulphate and silicate were measured as described by APHA (2005).

Phytoplankton studies

The plankton haul was made using a 55 µm mesh size of net tied unto a motorized boat and towed for 5 min at a low speed (4 knots). Plankton sample was preserved immediately by fixing in 4% un-buffered formalin solution. The density of phytoplankton was determined using the sedimentation technique as described by Lund et al. (1958). One millimeter each of shakened sample was observed using a CHA and CHB binocular light microscope with a calibrated eye piece using the ×160 and ×640 fields. Phytoplankton species were identified using relevant texts (Smith, 1950; Vanlandingham, 1982; Whitford and Schmacher, 1973; Cushing, 1975; Biggs and Kilroy, 2002). The phytoplankton count was expressed as units per ml (filaments, colonies or single cells).

Statistical analysis

Statistical package for social sciences (SPSS) (version 18) was used to analyzed Pearson's correlation relationship between phytoplankton density and hydroclimatic variables (temperature, conductivity, salinity, total monthly rainfall, total dissolved solids (TDS), total suspended solids (TSS), transparency, pH and micronutrients) and principal component analysis (PCA) which was used to assessed the phytoplankton respond to the environmental variables. Minitab 23 was used to analyse the dendrogram plot to evaluate the effect of environmental variables on phytoplankton density and PAST (version 3) was used to compute species diversity. T-test analysis was carried out to evaluate the statistical difference ($P > 0.05$) between seasonal (wet and dry) abundance of phytoplankton community. Standard deviation and mean analysis was also evaluated for the hydroclimatic values using Minitab 23.

RESULT

The data obtained for hydroclimatic features at the Ejirin tributary from December, 2012 to May, 2013 is presented in Table 1. Surface water temperature peaked 33.01^{o}C in May and the lowest water surface temperature value of 28°C was recorded in January. The mean surface temperature recorded was 30^{o}C. The surface water temperature showed a strong positive significant correlation with rainfall (0.855*; $P > 0.05$). The surface water pH was acidic throughout the sampling period with pH values ≤ 6.6 and a mean value of 6.39. pH showed a positive correlation with rainfall and phytoplankton abundance (0.650 and 0.689; $P \leq 0.05$). Turbidity remained high during dry months and low during the wet months, with a mean value of 4.63 NTU. The turbidity readings in the dry months coincided with a periodic drop in total suspended solids (TSS) values. Conductivity peaked 0.192 µcm^{-1} in December with a mean value of 0.18 µscm^{-1}. Total suspended solids (TSS) values were higher in the dry months than wet months while total dissolved solids (TDS) values were higher in the wet

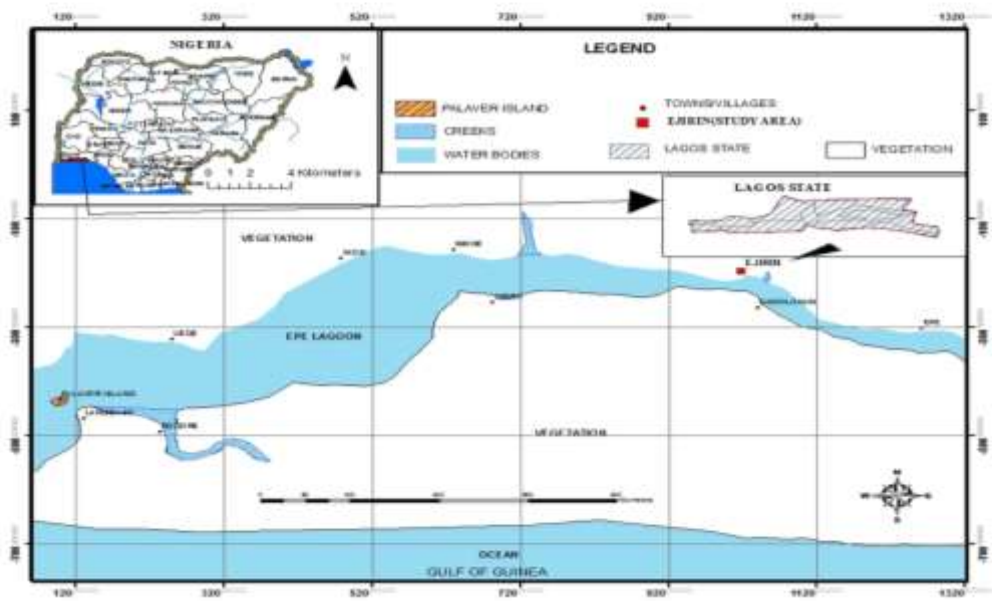

Figure 1. Map of Epe Lagoon showing the study area.

Table 1. Physical and Chemical Parameters of Ejirin from December, 2012 to May, 2013.

Parameter	Dec.	Jan.	Feb.	March	April	May	Mean	Standard deviation
Water Temp. (°C)	29.3	28.3	29	30.6	29.3	33.1	29.93	1.72
Transparency (cm)	43	57	41.5	38.5	34	31	40.83	9.11
Turbidity (NTU)	6	10	8	0.58	2	1.2	4.63	3.93
pH	6.39	6.15	6.22	6.45	6.6	6.5	6.39	0.17
Conductivity (µscm^{-1})	0.192	0.154	0.2	0.006	0.2	0.35	0.18	0.11
TSS (mg L^{-1})	55	66	170	73	1	1.1	61.01	62.09
TDS (mg L^{-1})	0.65	79.00	87.00	141.00	119.00	161.00	97.94	56.95
Rainfall (mm)	55	0	28	50.1	165.3	340.8	99.57	132.25
Salinity (‰)	0.65	0	0	0.01	0	0	0.002	0.004
Reactive Nitrate (mg L^{-1})	0.32	0.11	0.083	0.081	0.118	0.072	0.13	0.095
Reactive Phoshate (mg L^{-1})	0.78	0.65	0.593	1.076	0.712	0.59	0.73	0.18
Sulphate (mg L^{-1})	1.2	0.8	1.255	1.301	1.214	1.258	1.17	0.19
Silicate (mg L^{-1})	0.4	0.8	0.11	0.05	0.05	0.062	0.25	0.30
Chl. A (mg/L)	0.014	0.016	0.013	0.004	0.012	0.07	0.022	0.024
Biological Oxygen Demand (mg L^{-1})	4.8	0.4	2	3.7	2.2	0.8	2.32	1.68
Chemical Oxygen Demand (mg L^{-1})	15	16	20	37	32	32	25.33	9.46
Dissolved Oxygen (mg L^{-1})	6.13	10	4.5	5	5.8	6	6.24	1.95

months than the dry months. The water remained fresh throughout the study period with salinity values ≤ 0.01‰.

Reactive nitrate and reactive phosphate fluctuated throughout the study period but the values however remained NO_3 ≥ 0.32 mg L^{-1} and PO_4 ≥ 1.076 mg L^{-1}, respectively. Reactive nitrate showed a strong significant negative correlation with TDS (-.878*; P ≤ 0.05) while reactive phosphate showed a strong positive correlation with salinity (0.917**; P ≤ 0.01). Silicate values peaked 0.8 mg L^{-1} in the dry months and dropped to 0.05 mg L^{-1} in the wet months. Chlorophyll *a* content peaked 0.07 mg L^{-1} in the wet months and dropped to 0.014 mg L^{-1} in the dry months, with a mean value of 0.0215 mg L^{-1}. It showed a strong significant positive correlation with surface water temperature (0.817*; P ≤ 0.05), conductivity (0.827*, P ≤ 0.05) and rainfall (0.862**, P ≤ 0.01). Biochemical oxygen demand (BOD) and dissolved oxygen (DO) fluctuated greatly throughout the study

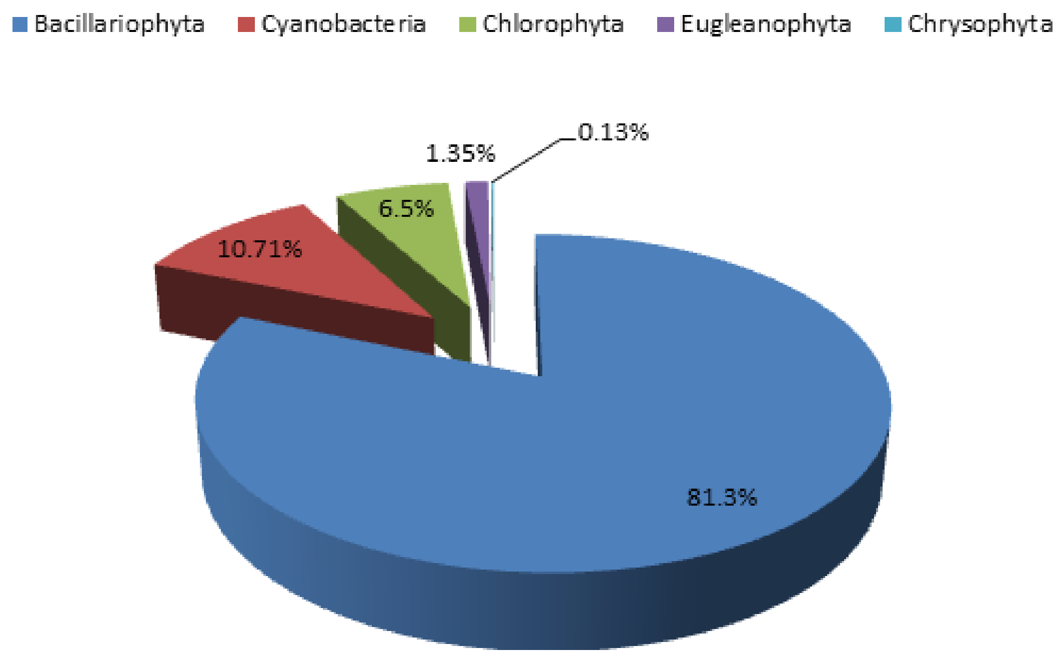

Figure 2. Percentage composition of the different phyla observed during the study from December, 2012 to May, 2013.

Interval but remained BOD ≥ 4.8 mg L^{-1} and DO ≥ 10 mg L^{-1} respectively. BOD correlated positively with reactive nitrate (0.688, P ≤ 0.05), reactive phosphate (0.659, P ≤ 0.05) and sulphate (0.512, P ≤ 0.05). DO showed a positive correlation with turbidity (0.554, P ≤ 0.05) and a weak negative correlation with surface water temperature (-0.343, P ≤ 0.05). It also showed a significant negative correlation with sulphate (-0.967**, P ≤ 0.01) and strong positive correlation with silicate (.906*, P ≤ 0.05). Chemical Oxygen Demand (COD) value ranged between 15 mg L^{-1} (in December) and 37 mg L^{-1} (in March), with a mean value of 25.33 mg L^{-1}. COD showed a positive correlation with surface water temperature (0.632, P ≤ 0.05), pH (0.740, P ≤ 0.05) and rainfall (0.587, P ≤ 0.05).

Phytoplankton community

A checklist of phytoplankton species at the Ejirin tributary between December, 2012 and May, 2013 is presented in Table 2. A total of 105 species were recorded throughout the study period with a total number of taxa varying from 20 in December, 50 in January, 40 in February, 59 in March, 59 in April to 31 in May. Five divisions were recorded during the study including; Bacillariophyta (81.3%), Cyanobacteria (10.71%), Chlorophyta (6.5%), Euglenophyta (1.35%) and Chrysophyta (0.13%) (Figure 2). Diatom populations during both seasons were dominated by 12 centric diatoms and 35 pennate diatoms, with the highest number recorded in the wet months. Phytoplankton density showed a strong negative correlation with turbidity (-0.803, P ≤ 0.05) and reactive nitrate (-0.639, P ≤ 0.05), and a positive correlation with pH (0.689, P ≤ 0.05), rainfall (0.522, P ≤ 0.05) and sulphate (0.632, P ≤ 0.05). Phytoplankton density significantly correlated strongly with TDS (0.821*, P ≤ 0.05), COD (0.937**, P ≤ 0.01) and reactive silicate (-0.847*, P ≤ 0.05), and weakly correlate with chlorophyll *a* (0.084, P ≤ 0.05) as shown in Table 3. Species diversity was relatively high in the wet months than in the dry months. Species diversity showed a positive correlation with TDS (0.536, P ≤ 0.05) and salinity (0.492, P ≤ 0.05).

DISCUSSION

Hydroclimatic features

The surface water temperature reported from the study is notable for tropical waters (Inyang et al., 2015; Nwankwo, 1984). The higher water temperature in January could be as a result of time of collection and heat capacity of water. Throughout the study duration the water remained fresh indicating the absence of salt water. Salinity concentration of any water has an inverse relation with DO saturation. Base on this, the observed DO values were not influenced by salinity level rather by biological activities such as photosynthesis and bacterial respiration. The positive significant correlation between salinity and reactive phosphate showed that salinity level play an important role in the phosphate availability.

Rainfall is ecologically important for coastal waters of

Table 2. Taxonomy and abundance distribution of phytoplankton at Ejirin tributary from Dec. 2012 – May, 2013.

Phytoplankton Taxa	Dec.	Jan.	Feb.	March	April	May
Phylum: Cyanobacta						
Class: Cyanophyceae						
Order I: Chroococales						
Chroococcus major Kom. & Komák.-Legnerová					52	31
Chroococcus occidentalis (N.L.Gardner) Kom.&Komárk.-Legnerová		21			22	26
Chroococcus deltoids Komárek&E.Novelo		27			68	-
Chroococcus mediocris N.L.Gardner		12		47	43	38
Chroococcus mipitanensis (Wolszynska) Geitler		14		54	-	41
Chroococcus minutissimus N.L.Gardner				21	31	28
Merismopedia Meyen		26		51		
Chlorogloea gardneri Kom. & Komák.-Legn.		16	47			
Aphanocapsa conferta (West & West) Komárk-Legn. & Cronberg				36		31
Order II: Nostocales						
Anabaena Bory ex Bornet et Flahault		9	37	27	41	38
Order III: Oscillatoriales						
Arthrospira jenneri Stizenberger ex Gomont		6				
Lyngbya Agard ex Gomont		47	187	140	312	172
Phormidium articulatum (N.L.Gardner) Anagnd&Komk.		21	67	29		42
Phylum: Euglenophyta						
Class: Euglenophyceae						
Order I: Euglenales						
Euglena caudate Hubner		3			8	
Euglena oxyuris var. *charkowiensis* (Swirk.) Chu		7	13		7	
Phacus caudatus Hubner	6		16		14	
Phacus longicuuda (Her.)	7					
Phacus triqueter (Ehrenberg) Dujardin					12	16
Trachelomonas affinis (Lemm.)		3				
Trachelomonas ensifera Daday				38	22	
Trachelomonas gibberosa Playf.			28	28	26	
Phylum: Bacillariophyta						
Class: Bacillariophyceae						
Order I: Centrales						

Table 2. Contd.

Aulacoseira 6ranulate var. *anguastissima* f. *curvata* Simon	181	48	379	454	572	675
Aulacoseira granulate var. *anguastissima*f. *Spiralis* O. Mull.	172	131	367	542	687	703
Aulacoseira islandica subsp. Helvetica O.Mull	107	49	167	201	312	376
Aulacoseria granulate (Her.)	207	178	466	598	748	812
Aulacoseira italic (Her.)	21	52	178	383	307	378
Hemidiscus sp.		43	33	52	52	47
Cyclotella Kützing ex Brébisson		41	105	172	123	
Coscinodiscus excentricus Ehrenberg	7				23	
Coscinodiscus radiates Ehrenberg			21		18	
Rhizosolenia longiseta O. Zacharias			14	11	14	
Rhizosolenia 6ranulat Bail				20	19	
Rhizosolenia eriensis H. L. Smith			17	22	24	
Order II: Pennales						
Fragilaria formisvirescens (Ralfs.) Williams & Round	13	17	27	52	42	17
Eunotia Ehrenberg			51		41	28
Diatoma Bory		17	207	145	185	
Cymbella ventricosa (C.Agardh) C.Agardh		12		18	34	
Cymbella ventricosa Kutz. Compr.				62	57	
Surirella debessi Turpin	16	10	42	41	17	
Surirella tenera var. *nervosa* A. Schmidt	17	11	32	42	37	21
Surirrela robusta var*. Splendida* (Ehrenberg) Van Heurck	14	8	44			22
Surirella robusta var*. armata* Hustedt				71	63	27
Surirella didyma Kützing	12		38	47	51	18
Surirella linearis f. *constricta*				57		
Surirella arctissima A. Schmidt	13			18	38	13
Synedra Ehrenberg				81	21	37
Staurosirella leptostauron (Ehrenberg) Hustedt				23		
Asterionella 6ranula Hassall		32	78	231		72
Gomphonema aequatoriale Hustedt		13				
Gomphonema wulasiense Foged	18			23	31	
Navicula pseudofossalis Krasske		13				
Navicula lancrolata Ehrenberg				98		
Navicula pupula Kutz. Var *rectangularis* GRUN. Compr.					47	
Nitzschia lacustris Hustedt		12	17			
Nitzschia capitellata Wolle			21	57	61	
Nitzschia speculum Hustedt	13		47	68	54	

Table 2. Contd.

Bacillaria paradoxa J.F. Gmelin	42	23	57	62	64	
Nitzschia acicularis (Kützing) W. Smith				101	112	
Nitzschia. Palea (Kützing) W. Smith	17					
Nitzschia intermedia Hantzsch			67			
Nitzschia longissima var. *closterium* (Ehrenberg) Van Heurck			23	22	23	
Nitzschia gracilis Hantzsch				50	78	
Pinnularia acrosphaeria (Breb.) var *minor* Kutz.		11				
Pinnularia microstauron (Ehrenberg) Cleve		14				
Pinnularia mesolepta (Ehrenberg) W. Smith		17				
Amphora ovalis Kutz		13	36			
Epithemia adnata (Kützing) Brébisson		28				
Epithemia sorex Kützing		21				
Phylum: Chlorophyta						
Class: Chlorophyceae						
Order I: Chlorococcales						
Ankistrodesmus falcatus Ralfs var *mirabilis* West f. *longiseta* Nygaard				22	24	
Ankistrodesmus falcatus Ralfs var*setiformis* Nygaard f. *brevis* Nygaard				24	19	
Ankistrodesmus gracilis (Reinsch) Korshikov					27	
Ankistrodesmus braunii (Nägeli) Lemmermann					31	
Actinastrum Hantzschii Lagerheim		7				
Scenedesmus armatus Chodat		13				
Scenedesmus perforates Lemmermann		15	26	31		
Scenedesmus dispar f. *canobe 2-cellulaire*				19		
Scenedesmus quadricauda (Turpin) Brébisson				21		33
Tetrastrum heteracanthum (Nordstedt) Chodat			18			
Tetraedron minimum (A.Braun) Hansgirg					16	
Tetraedron regulare var *incus* Teiling		4				
Schroederia setigera (Schröder) Lemmermann		7		22	18	
Pediastrum Boryanum Meneghine		11				
Pediatrum boryanum var *longicorne* Reinsch					21	23
Pediastrum simplex Meyen		9	18		27	32
Pediastrum simplex var *duodenarium* (J.W.Bailey) Rabenhorst	18		27		33	
Pediastrum sturmii Reinsch			13			
Pediastrum duplex Meyen				38		
Pediastrum tetras var*tetraodon* (Corda.) Rabenhorst		13				
Sphaerocystis schroeteri Chodat			52			

Table 2. Contd.

Order II: Zygnematales						
Spirogyra Link	8	7		19		
Closterium leibleinii Kützing ex Ralfs				57		
Closterium kutzingii Bred.				55		
Staurastrum involutum W.B. Turner		11				
Staurastrum tetracerum Ralfs var *validum* West				14	17	
Staurastrum pingue Teiling				22		
Staurastrum pseudocyclacanthum A.M.Scott & Croasdale					13	18
Saurastrum cyclocanthum var. *subacanthum* Grönblad				18	19	
Staurastrum richianum Thomasson				17	14	
Staurastrum leptocladum var*. cornutum* f. *minor W.B.Turner*			13		9	
Staurastrum branchioprominens var*. archerianum* K.H.Bohlin			33	17	13	
Staurastrum leptostauron		6				
Mougeotia C.Agardh				17		22
Order III: Chaetopherales						
Stigeoclonium tenue (C.Agardh) Kützing				47		
Phylum: Chrysophyta						
Class: Tribophyceae						
Order I: Mischococales						
Ophiocytium capitatum Wolle		6		19		
Phytoplankton density ($cell.ml^{-1}$)	909	1151	3129	4774	4914	3871
Species Diversity	20	50	40	59	59	31

the tropic. Flood caused by precipitation enriches the coastal environmental gradients through horizontal and vertical dimension. Seasonality in the tropics influences hydrological factors. Thus seasonal patterns during the study influenced these parameters: transparency, total dissolved solids and total suspended solids increasing with the onset of rainfall. Conductivity level of an aquatic ecosystem is TDS dependent. Therefore, the positive correlation between rainfall and conductivity could be as a result of dissolution of conductivity increasing substance which affects the TDS. The sudden drop in TSS values during wet months could be due to the short resident time of the suspended particles in the water channel as it drained faster into the lagoon.

Water temperature, rainfall and chlorophyll *a* content controlled the conductivity level in the system (Figures 3 and 4). Phytoplankton activity which was measured by chlorophyll *a* showed a high controlling factor with conductivity more than with rainfall and water temperature. Because increase in CO_2 dissolution encourages phytoplankton productivity and as well increases the conductivity level through formation of carbonate ionic system. Heavy rainfall recorded in May caused dilution of surface water and flood which may lower and increase the conductivity level, respectively. Agricultural runoff or sewage seepage from the catchment area could increase conductivity level due to the addition of chloride, phosphate and nitrate ions. Increased temperature increase the conductivity level

Table 3: Pearson's correlation analysis for the environmental variables and phytoplankton density at Ejirin, from Dec. 2012 – May, 2013.

	W/T	Transp.	Turb.	pH	Cond.	TSS	TDS	R/f	Salin	Nitra.	Phosp.	Sulph.	Silic.	Chl. a	BOD	COD	DO	P.D.	Sp. Div.
W/T	1																		
Transp.	-0.724	1																	
Turb.	-0.73	.856*	1																
pH	0.548	-.854*	-.904*	1															
Cond.	0.449	-0.355	0.006	0.164	1														
TSS	-0.467	0.393	0.575	-0.72	-0.336	1													
TDS	0.648	-0.535	-0.642	0.418	0.088	-0.296	1												
R/f	.861*	-0.766	-0.652	0.674	0.73	-0.681	0.59	1											
Salin	-0.178	0.115	0.164	0.017	0.025	-0.046	-.834*	-0.201	1										
Nitra.	-0.311	0.191	0.228	0.012	0.005	-0.094	-.878*	-0.257	.981**	1									
Phosp.	0.016	-0.07	-0.472	0.283	-.839*	-0.035	0.074	-0.314	0.139	0.103	1								
Sulph.	0.529	-.868*	-0.716	0.638	0.046	0.016	0.289	0.397	0.081	-0.034	0.305	1							
Silic.	-0.561	.927**	0.784	-0.71	-0.098	0.079	-0.56	-0.515	0.246	0.33	-0.204	-.933**	1						
Chl. a	.817*	-0.439	-0.293	0.245	.827*	-0.461	0.441	.871*	-0.158	-0.242	-0.519	0.118	-0.183	1					
BOD	-0.135	-0.174	-0.244	0.282	-0.461	0.106	-0.5	-0.315	0.731	0.688	0.659	0.512	-0.237	-0.503	1				
COD	0.632	-0.731	-.915*	0.74	-0.144	-0.417	.855*	0.536	-0.527	-0.574	0.456	0.581	-0.757	0.202	-0.01	1			
DO	-0.343	0.762	0.554	-0.48	0.03	-0.239	-0.22	-0.217	-0.032	0.071	-0.256	-.967**	.906*	0.039	-0.502	-0.474	1		
P.D.	0.462	-0.755	-0.803	0.689	-0.103	-0.237	.821*	0.457	-0.616	-0.639	0.301	0.632	-.847*	0.084	-0.053	.937**	-0.599	1	
Sp. Div.	-0.232	0.045	-0.225	0.136	-0.579	-0.042	0.536	-0.208	-0.714	-0.624	0.39	-0.123	-0.139	-0.45	-0.234	0.539	0.066	0.604	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

{W/T = Water temperature, Transp. = Transparency, Turb. = Turbidity, Cond. = Conductivity, R/f = Rainfall, Sali. = Salinity, Nitra. = Nitrate, Phos. = Phosphate, Sulph. = Sulphate, Sili. = Silicate, P.D. = Phytoplankton density, SpDiv = Species Diversity}

through evaporation.

The micronutrients concentration increased as precipitation rate increased probably due to input from the wetlands. A strong significant correlation between phosphate and salinity indicates that the phosphate was not obtained from bacteria decomposition of organic matter and plankton excretion rather it was derived from precipitation and disassociation of phosphate-rich particles. On the other hand, reactive nitrate showed no significant correlation with salinity, indicating that part of nitrate were decomposition products of organic matter and plankton excretion. Odum (1959) related pH levels to the amount of carbonate present in the water and often considered it as indicator of the aquatic chemical environment. The observed pH value (pH ≤ 6.6) falls within the range reported by Nwankwo and Ankinsoji (1992), for Epe lagoon. The pH value could be controlled mainly by freshwater swamp exudates that regulate the acidity of the water body. The high value of dissolved oxygen observed in January could be as a result of combined photosynthetic activity of algae and wind mixing, whereas the low value may be attributed to a relatively high water temperature and microbial activity that used up the oxygen in the water column. Dissolved oxygen showed a significant positive correlation with silicate and transparency, indicating that silicate affects DO

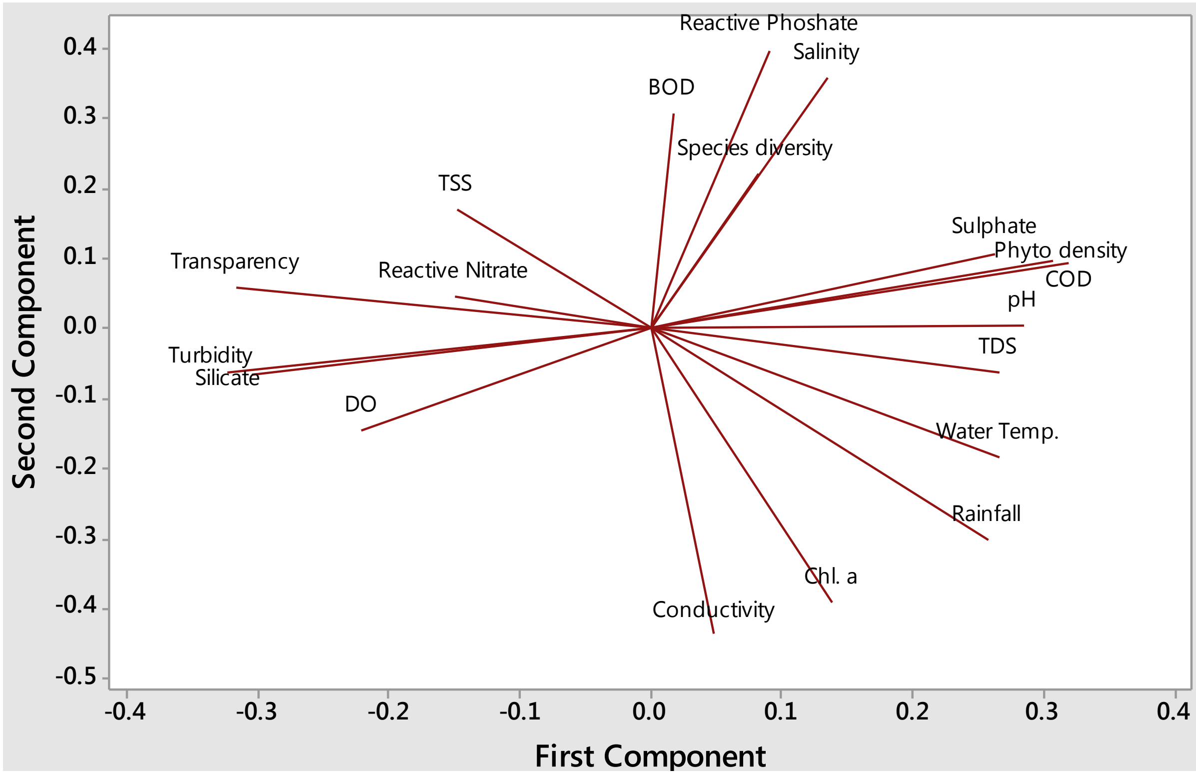

Figure 3. Loading plot for the environmental variables and Phytoplankton density at Ejirin extracted from principal component analysis.

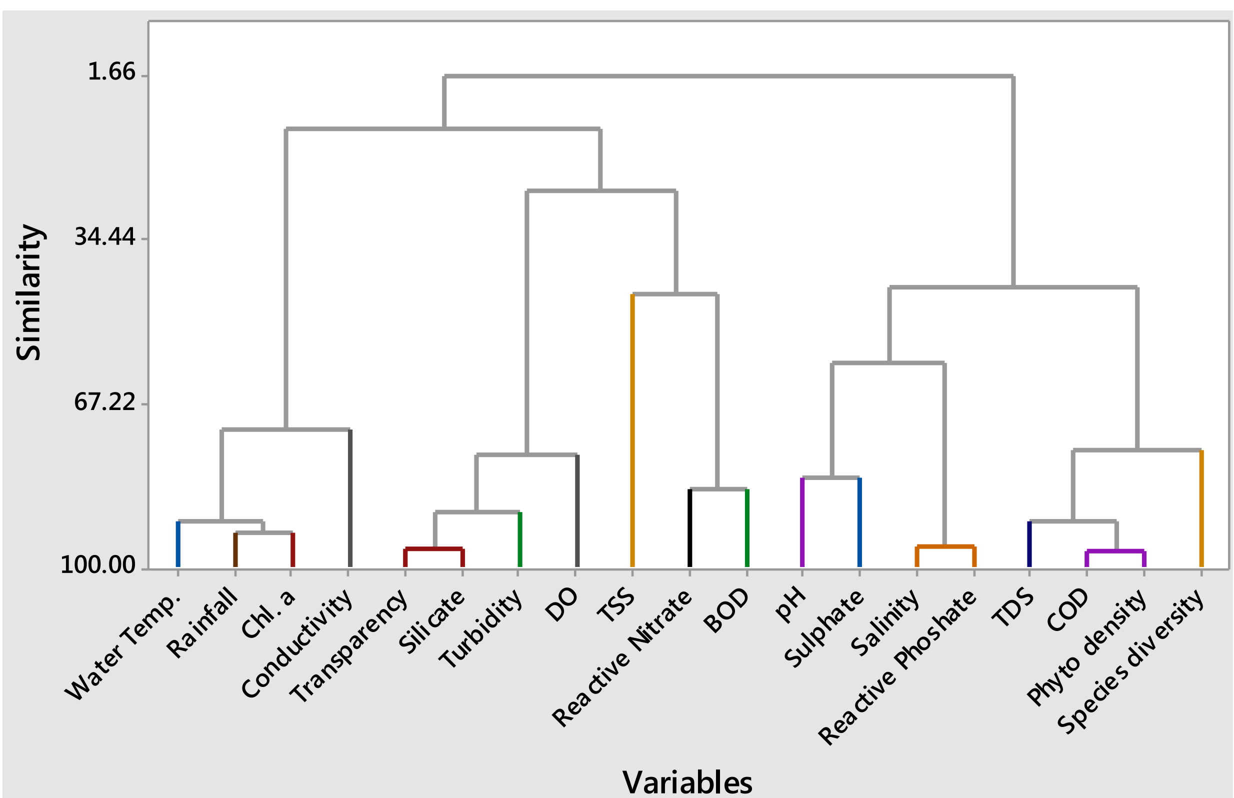

Figure 4. Dendrogram analysis of the environmental variables at Ejirin.

saturation indirectly through its direct effect on diatom productivity. Diatoms use silicate for it frustules growth and by photosynthesis, oxygen is produce.

Transparency is considered as an important parameter of trophic status of coastal waters. It depends on the intensity of sunlight, suspended soil particles, turbid water received from catchment area and density of plankton (Mishra and Saksena, 1991). Its low value during wet months could be as a result of inflow of turbid flood water from the catchment area. Positive correlation of transparency with DO indicated that transparency affects DO saturation directly. The lower the transparency value, the lower the DO saturation and vice versa. Low transparency means high TSS concentration, high water temperature, low light intensity and high bacterial activity. These effect combined may affect the DO saturation of the water.

According to Hynes (1960), BOD levels between 1 to 2 mg L^{-1} or less signifies clean water; 4 to 7 mg L^{-1} denotes slightly or moderately polluted water, and more than 8 mg L^{-1} denotes severe pollution. Therefore base on the above criteria, the site was relatively clean except for December and March where level of contamination were reported. The low content of Chl. *A* recorded in March could be as a result of low nutrient level while the high content recorded in May being the onset of wet season does not reflect the nutrient status but could be as result of input of photosynthetic organisms into the water by flood. Chl. *A* content showed a strong significant correlation with conductivity, water temperature and rainfall (r = 0.827*; r = 0.817* and r = 0.862*, respectively, $P > 0.05$). This could explain a strong relationship of rainfall with water chemistry of tropical aquatic ecosystem.

However the weak correlation of chlorophyll *a* content with the total number of phytoplankton may show that chlorophyll *a* content do not actually represent the number of phytoplankton density. This could be as a result of sampling technique adopted. Since the surface water sample was collected by simple scooping and thus contain a small fraction of phytoplankton. Its strong negative and positive correlation with turbidity and pH, respectively may explain the possible effect of these factors on phytoplankton community. The phytoplankton abundance in the wet months differed significantly with that of dry months ($t^* = 2.723$; $P > 0.05$). This could be as a result of conditions during this period that favored the multiplication of algae and additional inputs of phytoplankton by the flood.

Biological characteristics

The algal spectrum observed showed a higher density in the wet months than in the dry months with diatoms as the dominant dominance species. This could be as a result of favorable conditions and perhaps addition of phytoplankton cells through flood. The abundance of pennate diatoms in the plankton community during the wet months suggests their dislodgement from the substratum probably during high water discharge. The presence of the following organisms could be used as an early signal for organically contaminated aquatic ecosystems: *Chroococcus mediocris* N. L. Gardner, *Chroococcus mipitanesis* (Wolszynska) Geitler, *Chroococcus gardner* Kom. & Komák.-Legn., *Aphanoncapsa confert* (West & West) Komárk-Legn. & Cronberg, *Anabaena* Bory ex Bornetet Flahault, *Eugleana oxyuris* var *charkowiensis* (Swirk.) Chu, *Phacus caudatus* (Hubner); *Phacus longiscuda* (Her.); *Trachelomonas ensiferam* Dady*; Aulacoseria 11ranulate* (Her.); *Aulacoseria granulate* var*. anguastissima* f. *curvata* (Simon), *Melosira granulate var. anguatissima* f*. spiralis* O. Mull, *Fragilariformis visicense* (Ralfs.) Williams & Round, *Surirella debessi* Turpin, *Surirrela didyma* Kützing, *Surirrela arctissima* A. Schmidt; *Gomphonema wulasiense* Foged, *Navicula lancrolata* Ehrenberg, *Nitzschia speculum* Hustedt, *Nitzschiia palea* (Kützing) W. Smith, *Nitzschia gracilis* Hantzsch, *Schroederia setigera* (Schröder) Lemmermann, *Pediastrum simplex* var. *duodenarium* (J.W.Bailey) Rabenhorst, *Pediastrum duplexs* Meyen; *Spirogyra* Link, *Closterium kutzingii* (Bred.), *Closterium leibleinii* Kützing ex Ralfs, *Staurastrum pingue* Teiling and *Ophiocytium capitatum* Wolle.

Therefore, phytoplankton community has shown significant respond to changes in hydroclimatic variables such as TDS, silicate, turbidity, pH, transparency and rainfall. This explains the effect of these variables on the phytoplankton. Transparency and TDS showed dominant role among the hydroclimatic variable measured.

Conflict of Interests

The authors have not declared any conflict of interests.

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