

Full Length Research Paper

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

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Received 21 March, 2016; Accepted 24 May, 2016

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 $\leq 0.01\%$. 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* plum 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 capped 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% unbuffered 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 x160 and x640 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°C in May and the lowest water surface temperature value of 28°C was recorded in January. The mean surface temperature recorded was 30°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

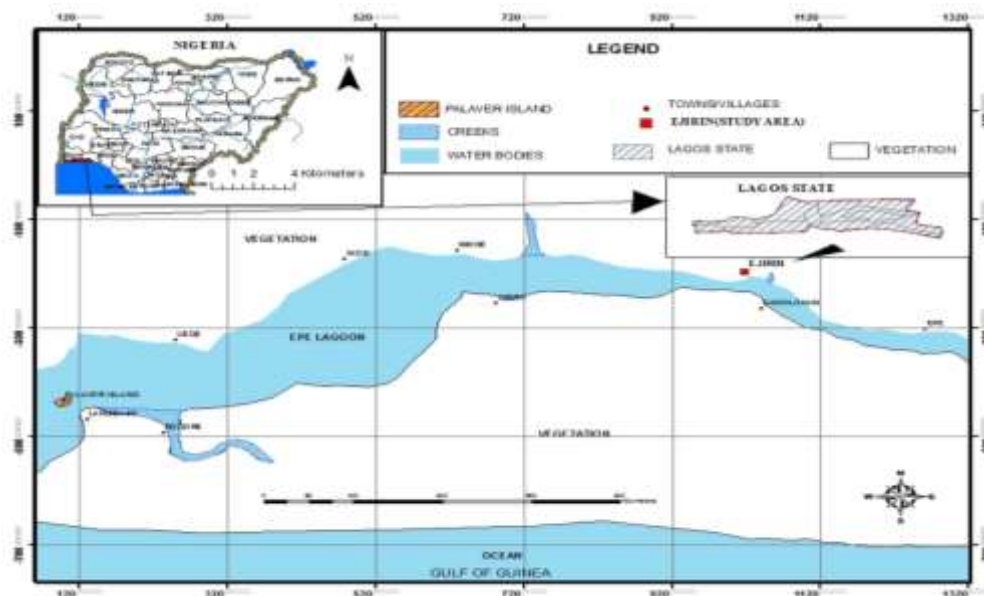


Figure 1. Map of Epe Lagoon showing the study area.

Table 1. Physical and Chemical Parameters of Ejerin 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 Phosphate (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 $\leq 0.01\%$.

Reactive nitrate and reactive phosphate fluctuated throughout the study period but the values however remained $\text{NO}_3 \geq 0.32 \text{ mg L}^{-1}$ and $\text{PO}_4 \geq 1.076 \text{ mg L}^{-1}$, respectively. Reactive nitrate showed a strong significant negative correlation with TDS (-0.878^* ; $P \leq 0.05$) while reactive phosphate showed a strong positive correlation with salinity (0.917^{**} ; $P \leq 0.01$). 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^* ; $P \leq 0.05$), conductivity (0.827^* , $P \leq 0.05$) and rainfall (0.862^{**} , $P \leq 0.01$). Biochemical oxygen demand (BOD) and dissolved oxygen (DO) fluctuated greatly throughout the study

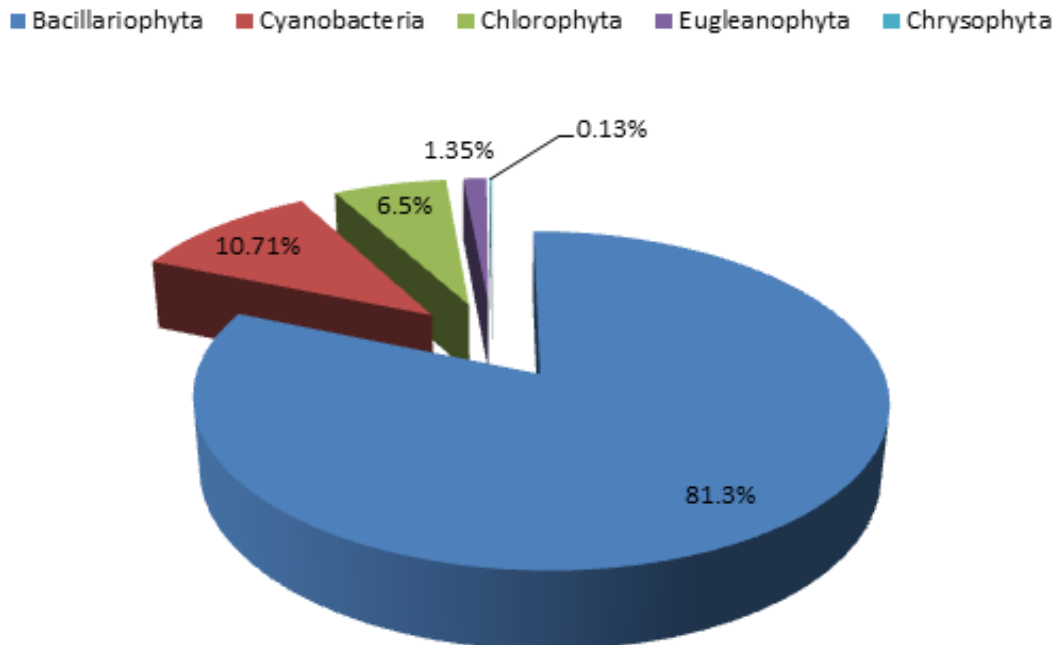


Figure 2. Percentage composition of the different phyla observed during the study from December, 2012 to May, 2013.

Interval but remained $\text{BOD} \geq 4.8 \text{ mg L}^{-1}$ and $\text{DO} \geq 10 \text{ mg L}^{-1}$ respectively. BOD correlated positively with reactive nitrate ($0.688, P \leq 0.05$), reactive phosphate ($0.659, P \leq 0.05$) and sulphate ($0.512, P \leq 0.05$). DO showed a positive correlation with turbidity ($0.554, P \leq 0.05$) and a weak negative correlation with surface water temperature ($-0.343, P \leq 0.05$). It also showed a significant negative correlation with sulphate ($-0.967^{**}, P \leq 0.01$) and strong positive correlation with silicate ($.906^*, P \leq 0.05$). 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 ($0.632, P \leq 0.05$), pH ($0.740, P \leq 0.05$) and rainfall ($0.587, P \leq 0.05$).

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 ($-0.803, P \leq 0.05$) and reactive nitrate ($-0.639, P \leq 0.05$), and a positive correlation with pH ($0.689, P \leq 0.05$), rainfall ($0.522, P \leq 0.05$) and sulphate ($0.632, P \leq 0.05$). Phytoplankton density significantly correlated strongly with TDS ($0.821^*, P \leq 0.05$), COD ($0.937^{**}, P \leq 0.01$) and reactive silicate ($-0.847^*, P \leq 0.05$), and weakly correlate with chlorophyll a ($0.084, P \leq 0.05$) 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 ($0.536, P \leq 0.05$) and salinity ($0.492, P \leq 0.05$).

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

Table 2. Contd.

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

Table 2. Contd.

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

Table 2. Contd.

Order II: Zygnematales						
<i>Spirogyra</i> Link	8	7		19		
<i>Closterium leibleinii</i> Kützing ex Ralfs				57		
<i>Closterium kützingii</i> Bred.				55		
<i>Staurastrum involutum</i> W.B. Turner		11				
<i>Staurastrum tetracerum</i> Ralfs var <i>validum</i> West				14	17	
<i>Staurastrum pingue</i> Teiling				22		
<i>Staurastrum pseudocyclacanthum</i> A.M.Scott & Croasdale					13	18
<i>Saurastrum cyclocanthum</i> var. <i>subacanthum</i> Grönblad				18	19	
<i>Staurastrum richianum</i> Thomasson				17	14	
<i>Staurastrum leptocladum</i> var. <i>cornutum</i> f. <i>minor</i> W.B.Turner			13		9	
<i>Staurastrum branchioprominens</i> var. <i>archerianum</i> K.H.Bohlin			33	17	13	
<i>Staurastrum leptostauron</i>		6				
<i>Mougeotia</i> C.Agardh				17		22
Order III: Chaetopherales						
<i>Stigeoclonium tenue</i> (C.Agardh) Kützing				47		
Phylum: Chrysophyta						
Class: Tribophyceae						
Order I: Mischococcales						
<i>Ophiocytium capitatum</i> 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 CO₂ 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 \leq 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

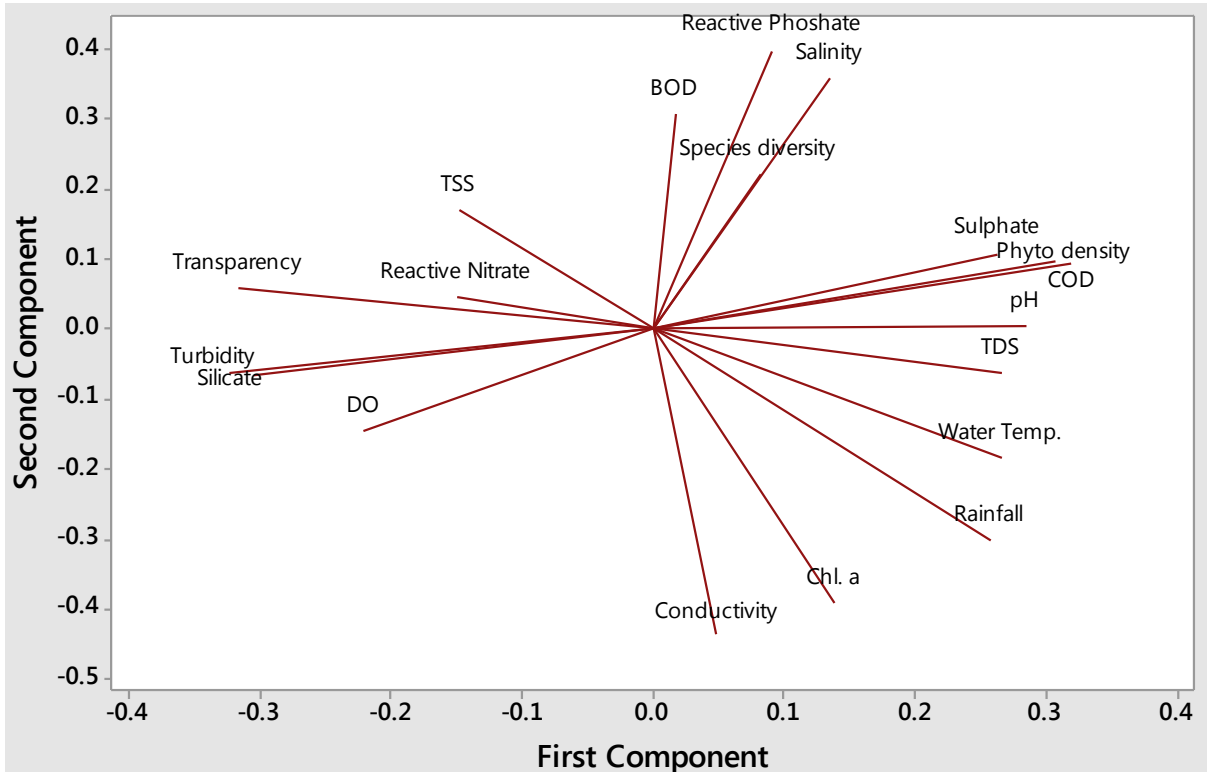


Figure 3. Loading plot for the environmental variables and Phytoplankton density at Ejirin extracted from principal component analysis.

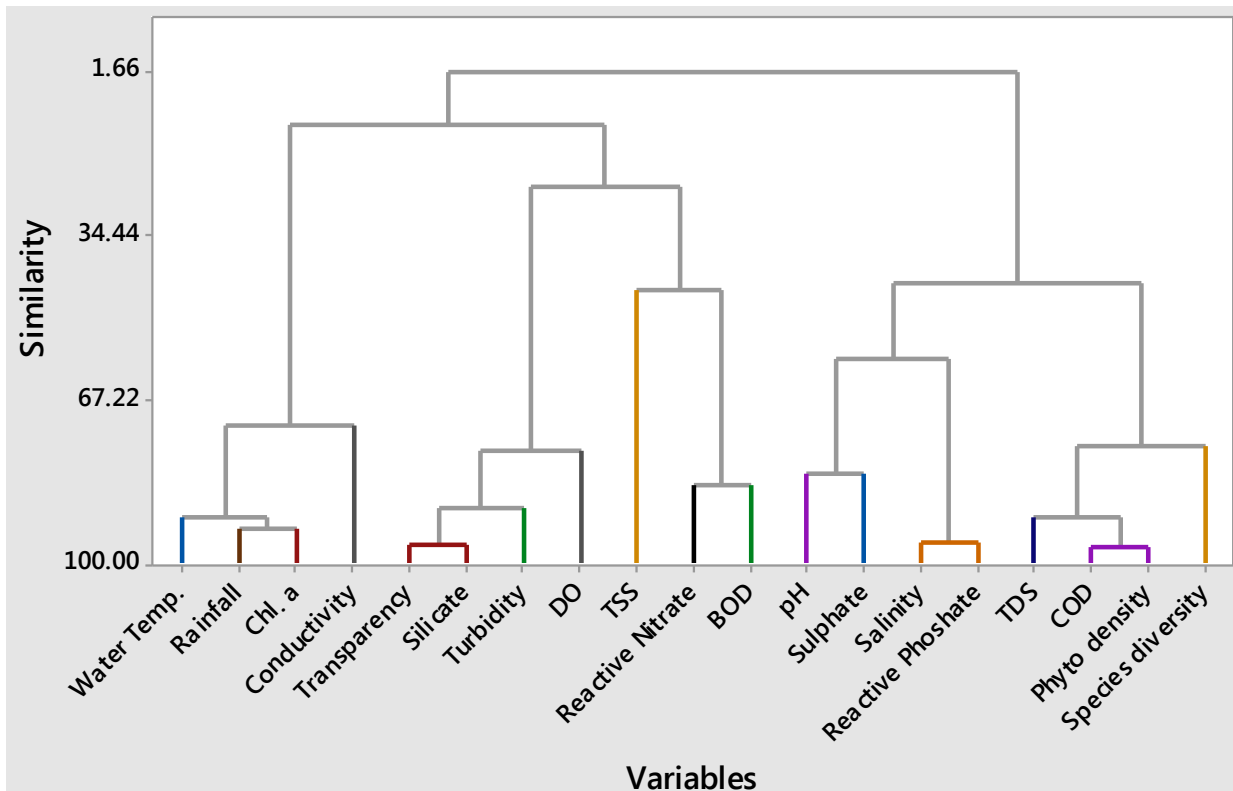


Figure 4. Dendrogram analysis of the environmental variables at Ejirin.

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

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 effects 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 based 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 gardneri* Kom. & Komák-Legn., *Aphanoncapsa confert* (West & West) Komárk-Legn. & Cronberg, *Anabaena Bory de Saint-Vincent* Flahault, *Eugleana oxyuris* var. *charkowiensis* (Swirk.) Chu, *Phacus caudatus* (Hubner); *Phacus longiscuda* (Her.); *Trachelomonas ensiferam* Dady; *Aulacoseria 11ranulate* (Her.); *Aulacoseria granulate* var. *anguatissima* f. *curvata* (Simon), *Melosira granulate* var. *anguatissima* f. *spiralis* O. Mull, *Fragilariformis visicense* (Ralfs.) Williams & Round, *Surirella debessi* Turpin, *Surirella didyma* Kützing, *Surirella arctissima* A. Schmidt; *Gomphonema wulsiense* Foged, *Navicula lancrolata* Ehrenberg, *Nitzschia speculum* Hustedt, *Nitzschia palea* (Kützing) W. Smith, *Nitzschia gracilis* Hantzsch, *Schroederia setigera* (Schröder) Lemmermann, *Pediastrum simplex* var. *duodenarium* (J.W.Bailey) Rabenhorst, *Pediastrum duplex* Meyen; *Spirogyra* Link, *Closterium kützingii* (Bred.), *Closterium leibleinii* Kützing ex Ralfs, *Staurastrum pingue* Teiling and *Ophiocytium capitatum* Wolle.

Therefore, phytoplankton community has shown significant response 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.

ACKNOWLEDGEMENT

My special thanks goes to the staff of phytoplanktology laboratory for their assistance and to Prof. Dike Nwankwo for his support academically throughout the research period.

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