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A Comparative Study of the Periphyton on *Eichhornia crassipes* and Phytoplankton Communities: An Overview of Environmental Conditions at Ejirin Part of Epe Lagoon, South Western Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Periphyton and phytoplankton communities were compared and investigated in view of the environmental conditions at Ejirin part of Epe lagoon, from Dec. 2012 – May, 2013. This was to evaluate the effect of the environmental characteristics on the biotic communities. Surface water temperature correlated significantly with rainfall (r 0.855*; P < 0.05), surface water Chl. *a* (r = 0.817*; P < 0.05) and with periphyton individual (r = 0.745). The water pH remained acidic throughout the study period (pH < 6.6) with a mean value of 6.39. Transparency values were high in the dry months and low in the wet months, with the strong significant correlation with the periphyton and phytoplankton individual (r =0.844*; P < 0.05) and (r = -0.887*; P < 0.05) respectively. Total suspended solids has a mean value of 61.02mg/L, and correlated significantly with periphyton individual (r=0.836*; P < 0.05), and strongly correlated with phytoplankton individual and rainfall (r =0.791 and 0.678) respectively. The micronutrients varied throughout the study periods with reactive nitrate (NO_3-N ≤ 0.32mg/L), reactive phosphate (PO_4-P ≤ 0.78mg/L), silicate (SiO_3 ≤ 0.80mg/L), and

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sulphate (≤1.30mg/L). Sulphate correlated strongly with phytoplankton and periphyton individual (r=0.616 and 0.707) respectively. Five divisions were recorded in phytoplankton community with their percentage of occurrence: Bacillariophyta (82.45%), Cyanobacteria (9.99%), Chlorophyta (6.08%), Euglenophyta (1.32%), and Chrysophyta (0.12%), whereas four divisions were recorded in periphyton community with their percentage occurrence: Bacillariophyta (82.67%), Cyanobacteria (10.54%), Chlorophyta (5.64%), and Euglenophyta (1.15%). The PCA factor analysis revealed the importance of the followings: water temperature, pH, TDS, rainfall, sulphate, COD, BOD, nitrate, phosphate, salinity and, phytoplankton and periphyton individual to the future environmental analysis. Therefore, the periphyton community has shown a more promising tool in the event of environmental studies by responding significantly to most of the environmental parameters studied.

Keywords: Blue-green algae; diatoms; heavy metals; PCA.

1. INTRODUCTION

Algae found in water bodies depend on cells, which may either float on the surface or grow on submerged objects, and are divided into two main categories namely, phytoplankton and periphyton respectively [1,2]. However, *Eichhornia crassipes* commonly known as water hyacinth habours a variety of organisms which include algae, rotifers, nematodes, annelids, molluscs, hydracerids, cladocerans, copepod, conchostracans, isopod, amphipods, crabs, and fishes [3]. Periphyton species assemblage, biomass and productivity may be affected by organism such as snails and mayflies [4,5].

Phytoplankton and periphyton are mostly unicellular, filamentous or aggregate autotrophic cells from a variety of eukaryotic and prokaryotic phyla. As applied to this work, [6] defined periphyton as the ‘‘micro-floral’’ community living attached to the substrate inside water. These unique creatures serve as food for herbivores thereby transferring energy from the incident photon to the next trophic level. The amount of phytoplankton in the water column reflects the influence of hydro-climatic factors and processes [7,8]. Phytoplankton and periphyton serve as an indicator of water quality with ability to detect even a minute changes taking place in their ambient environment [9-16].

However, periphyton was reported to show a significant relation with substrate type [17-20], and also affect the nutrient turnover between the benthic and pelagic zone [21]. Algae can deplete aquatic systems of nutrients and algal communities can vary compositionally by the nutrient availability [22] and with environmental conditions. Periphyton assemblages can play several roles that lead to increased retention of nutrinets. Firstly, they can remove nutrients from the water column and cause a net flux of nutrients toward the sediments. Secondly, they can slow water exchange across the sediment/water column boundary thus decreasing advective transport of phosphate away from sediments. Third, they can intercept nutrients diffusing from the benthic sediments or senescent macrophytes. Fourth, they can cause biochemical conditions that favour phosphate deposition. Finally, they can trap particulate material from water column [23].

Moreover, the coastal waters of southwestern Nigeria are blessed with numerous ecological niches that support various biodiversity [24]. The ecological characteristics operating in aquatic realm of southwestern Nigeria have been documented by many literatures [25-28]. Tropics have been blessed with two seasons – wet and dry. Rainfall plays an important role in this region. It dilutes the ionic concentration of the coastal waters and breaks down horizontal environmental gradients. It also introduces chelating agents, pollutants as well as increasing nutrients levels of the receiving water body. During hamattan period, the hamattan dust contain a high percentage of quartz (SiO_2) and other minerals [29] where they are transported by wind from the Sahara desert and deposited into any aquatic ecosystem, where it promote the development of diatom frustule.

There exist literatures on the composition and distribution of phytoplankton community on the Lagos lagoon, Epe lagoon, Rivers and other coastal waters of Nigeria [30,14,31,32,33,34, 35,16]. There is presently a paucity of information on the periphyton and phytoplankton communities, and nutrient status of the Ejirin part of Epe lagoon. This work is set to answer the following questions: Will changes in environmental conditions leads to the compositional and abundance change in phytoplankton and periphyton communities? Will the periphyton community response high or low to the environmental conditions analysis? Will the phytoplankton community response high or low to the environmental conditions analysis?

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Ejirin (Fig. 1), located (06°60´89´´N, 03°90´38´´E) is part of Epe Lagoon, freshwater and with no maritime influence. It is sandwiched between Lekki Lagoon to the east and Lagos Lagoon to the west. It experiences the same hydroclimatic conditions as the rest of southwestern Nigeria such that there are two main seasons (wet and dry). The mainly fringing vegetation is Raffia palm and some dotted mangrove, while water hyacinth (*Eichhornia crasippes*) float on the water surface as a dominant macrophyte [16]. Ejirin people are mainly artisanal fishermen, petty traders and some few sand miners.

2.2 Sample Collection

Water samples for hydroclimatic analysis were collected on each trip between 09:00 and 13:00 and stored in 250 mL well labelled plastic bottles and transported to the laboratory in an ice chest. 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 20 cm white painted Secchi disc while pH values were measured using a Graffin digital pH meter. Dissolved oxygen concentration was determined by unmodified Winkler method [36], conductivity was assessed using the meter (Philips PW9505), and chemical oxygen demand and biochemical oxygen demand values were determined using the method described in [37]. Reactive nitrogen, reactive phosphorus, sulphate, and silicate were measured as described by [37]. Rainfall data was obtained from the Federal Meteorological Department, Oshodi, Lagos.

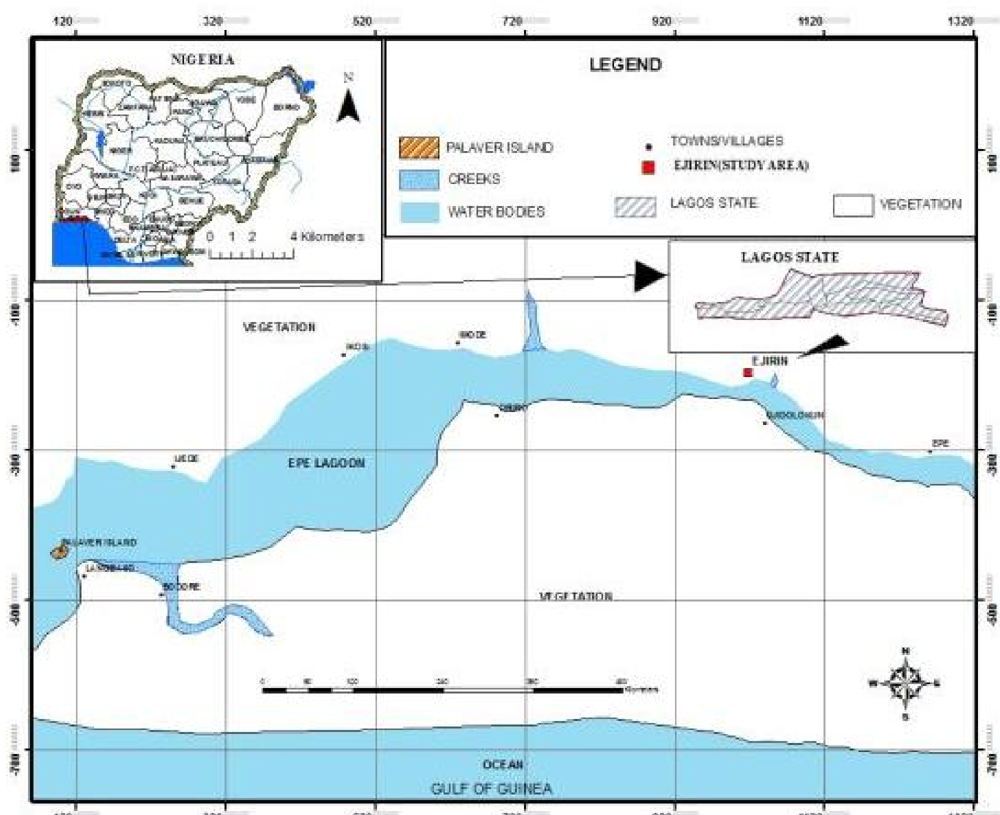

Fig. 1. Map of Epe Lagoon showing the study area at Ejirin

2.3 Biological Analysis

The plankton haul was made using a 55 µm mesh size of net tied unto a motorized boat and towed for 5minutes at a low speed (4knots). Plankton sample was preserved immediately by fixing in 4% unbuffered formalin solution. However, concerning periphyton sample, a healthy plants were carefully selected to ensure uniformity in size before putting each into plastic containers with 500 mL of tap water. The attached algae were removed mechanically by shaking vigorously in water as suggested by [38] and preserved in a well labelled plastic container with 4% unbuffered formalin added to fix the periphyton sample.

Furthermore, the density of phytoplankton and periphyton were enumerated as described by [39]. 1ml each of shaken sample was investigated using a CHA and CHB binocular light microscope with a calibrated eye piece, noting all fields. Phytoplankton and periphyton species were identified using the relevant texts [40-43]. The plankton counts were expressed as units per ml (filaments, colonies or single cells).

2.4 Statistical Analysis

Statistical analysis was carried out with the aid of Microsoft Excel 2010 version, SPSS (version 17) and PAST (version 3) statistical tools. Correction coefficient and PCA were used to evaluate relationship between the biotic communities and the environmental variables. Three community structure indexes were used to determined possible response of the phytoplankton and periphyton flora to environmental stress. These were as follows: Shannon-Wiener diversity index (Hs), Species Richness index (d) and Species evenness or equitability (j). Correlation coefficient is given as:

$$r = 1 - \frac{6\sum D^2}{n(n^2 - 1)}$$

Where r is the correlation coefficient, $\sum D^2$ is the sum of squares of difference of the ranks, and n is the number of months.

3. RESULTS

The data for environmental conditions at Ejirin from December, 2012 – May, 2013 showed significant variation as presented in Table 1. Surface water temperature showed strong significant correlation with rainfall ($r = 0.855^*$; $P < 0.05$) and surface water Chl. *a* ($r = 0.817^*$; $P < 0.05$), and a strong negative correlation with transparency ($r = -0.724$), turbidity ($r = -0.730$), phyto evenness index ($r = -0.748$) and peri evenness index ($r = -0.804$). It also showed strong positive correlation with periphyton individual ($r = 0.745$). Surface water temperature peaked 33.01°C in May and lower value of 28°C in January with a mean value of 30°C. The surface water pH was acidic throughout the study period (pH ≤ 6.6) with a mean value of 6.39. It correlate significantly with phyto evenness index ($r = -0.844^*$; $P < 0.05$) and peri evenness index ($r = -0.881^*$; $P < 0.05$). It also showed a strong correlation with COD, peri. Individual and phyto individual (r = 0.740, 0.733 and 0.679) respectively. The depths of light penetration or water transparency values were high in the dry months and low in the wet months. This corresponds to the rainfall pattern encountered during the study period. Water transparency correlate significantly with phyto evenness ($r = 0.844^*$; $P < 0.05$), peri individual ($r = -0.887^*$; $P < 0.05$) and peri evenness ($r = 0.950^{**}$; $P < 0.01$), and also significantly correlate with turbidity ($r = 0.856^*$ $P < 0.05$), pH ($r = -0.56^*$; $P < 0.05$) and SO_4 ($r = -0.865^*$; $P < 0.05$). It also showed a correlation with rainfall, COD, DO and phyto individual (r = -0.755, -0.731, 0.762 and -0.713) respectively. Turbidity peaked 10NTU in January and lower value as 0.58NTU in March with a mean value of 4.63NTU. It significantly correlate with pH ($r = -0.904^*$; $P < 0.05$), COD ($r = -0.915^*$; $P < 0.05$), peri margalef index ($r = -0.837^*$; $P < 0.05$), peri individual ($r = 0.924^{**}$; $P < 0.01$) and peri evenness ($r = -0.946^{**}$; $P < 0.01$) respectively. It also strongly correlates with phyto individual ($r = -0.796$), phyto evenness ($r = 0.7330$, TDS ($r = -0.642$), SO_4 ($r = -0.716$) and rainfall ($r = -0.652$). Total suspended solids (TSS) reached a peak value (170mg/L) recorded in February and its lower value (1.0mg/L) recorded in April, with a mean value of 61.02 mg/L. TSS showed positive correlation with rainfall, phyto evenness and peri evenness (r = 0.652, 0.670 and 0.538) respectively. Total dissolved solids showed significant correlation with peri individual ($r = 0.836^*$; $P < 0.05$), NO_3 ($r = -0.878^*$; $P < 0.05$) and COD (r 0.855^*; $P < 0.05$). It also correlates strongly with rainfall, phyto individual, peri Shannon-Wiener index, peri evenness and peri Margalef index (r = 0.678, 0.791, 0.589, -0,720 and 0,751) respectively. TDS peaked 161 mg/L in March and lower value of 0.65 mg/L in December, with a mean value of 97.94 mg/L. Conductivity reached a peak value (0.35 µs/cm) recorded in May and minimum value (0.006 µs/cm) recorded in March, with a mean value of 0.184 µs/cm. Conductivity showed a strong correlation with rainfall (r = 0.701) and salinity (r = -0.790). It also showed significant correlation with surface water Chl. *a* (r = 0.827*; P < 0.05) and PO_4 (r = -0.839*; P < 0.05). The water remained fresh throughout the study period with salinity value $S \leq 0.01$‰. Salinity showed significant correlation with PO_4 (r = 0.917**; P < 0.01) and peri Shannon-Wiener index (r = -0.865*; P < 0.05). It also correlate with peri taxa and phyto taxa (r = 0,753 and 0.550) respectively. Rainfall pattern showed significant correlation with surface water Chl. *a*, (r = 0.862*; P < 0.05), phyto evenness (r = -0.865*; P < 0.05) and peri evenness (r = -0.820*; P < 0.05). Rainfall peaked 340.8 mm in May and lower value of 0mm in February, with a mean value of 99.57mm. It showed a strong correlation with peri individual (r = 0.781).

The micronutrients varied throughout the study periods with reactive nitrate (NO_3-N ≤ 0.32 mg/L), reactive phosphate (PO_4-P ≤ 0.78mg/L), silicate (SiO_3 ≤ 0.80 mg/L), and sulphate (≤ 1.30 mg/L). The reactive nitrate, reactive phosphate and sulphate showed a strong positive correlation with biochemical oxygen demand (r = 0.688, 0.659 and 0.512) respectively. Sulphate significantly correlate with dissolved oxygen (r = 0.967**; P < 0.01). It also strongly correlate with phyto individual and peri individual (r = 0.616 and 0.707) respectively. Surface water Chl. *a* peaked 0.07 mg/L in May and lowered value 0.004mg/L in March, with a mean value of 0.022 mg/L. Periphyton Chl. *a* reached a peak value (0.003 mg/L) recorded in February and April while its lower value (0.001 mg/L) was recorded in March. Periphyton Chl. *a* showed strong correlation with phyto individual and peri. Individual (r = 0.666 and 0.599) respectively. Biochemical oxygen demand (BOD) value ranged between 0.4mg/L (January) and 4.8 mg/L (December), with a mean value of 2.317 mg/L.

Table 1. Status of environmental characteristics at Ejirin, part of Epe Lagoon, from December 2012 to May 2013

Parameters	Dec.	Jan.	Feb.	March	April	May	Mean	Standard deviation
Air Temperature (°C)	29.5	26	31.5	31	33.7	34.2	30.98	3.00
Water Temperature (°C)	29.3	28.3	29	30.6	29.3	33.1	29.93	1.72
Depth (cm)	25	28	30	27	30	26	27.67	2.066
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 (µs/cm)	0.192	0.154	0.2	0.006	0.2	0.35	0.18	0.11
Total Suspended Solids (mg/L)	55	66	170	73	1	1.1	61.02	62.09
Total Dissolved Solids (mg/L)	0.65	79	87	141	119	161	97.94	56.95
Rainfall (mm)	13.2	0	28	50.1	165.3	340.8	99.57	132.25
Salinity (‰)	0	0	0	0.01	0	0	0.0017	0.0041
Iron (mg/L)	0.012	0.01	0.037	0.029	0.035	0.072	0.033	0.022
Lead (mg/L)	ND	0.001	0.003	ND	ND	0.011	0.005	0.0053
Copper (mg/L)	0.014	0.011	0.054	0.022	0.011	0.021	0.022	0.016
Nitrate (mg/L)	0.32	0.11	0.083	0.081	0.118	0.072	0.13	0.09
Phoshate (mg/L)	0.78	0.65	0.59	1.076	0.71	0.59	0.73	0.18
Sulphate (mg/L)	1.2	0.8	1.26	1.30	1.21	1.26	1.17	0.19
Silicate (mg/L)	0.4	0.8	0.11	0.05	0.05	0.062	0.25	0.30
Surface water 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)	4.8	0.4	2	3.7	2.2	0.8	2.32	1.68
Chemical Oxygen Demand (mg/L)	15	16	20	37	32	32	25.33	9.46
Dissolved Oxygen (mg/L)	6.13	10	4.5	5	5.8	6	6.24	1.95
Periphyton Chl. *a* (mg/L)			0.003	0.001	0.003	0.002	0.0022	0.00096

Chemical oxygen demand (COD) reached a peak value of 37 mg/L recorded in March and lower value of 15 mg/L recorded in December, with a mean value of 2.31 mg/L. COD correlate significantly with phyto individual (r = 0.935**; P < 0.01) and peri individual (r = 0.954**; P < 0.01). Dissolved oxygen ranged between 4.5mg/L (February) and 10mg/L (January), with a mean value of 6.24 mg/L.

The checklist for the phytoplankton and periphyton species between December, 2012 and May, 2013 are presented in Table 2 and 3 respectively. A total of 19,307 individuals with 104 species were recorded for phytoplankton community. The total number of taxa varied from 19 in December, 44 in January, 35 in February, 53 in March, 54 in April, and 28 in May, Fig. 4. Diatom populations throughout the study were dominated by 12 centric diatoms and 33 pennate diatoms. Five divisions were recorded with their percentage of occurrence: Bacillariophyta (82.45%), Cyanobacteria (9.99%), Chlorophyta (6.08%), Euglenophyta (1.32%), and Chrysophyta (0.12%), Fig. 3. Phytoplankton individual shows a strong significant correlation with peri individual (r = 0.904*; P < 0.05). The species richness index (Margalef) remained, d ≤ 6.089, whereas Shannon-Wiener index remained, $H_s \leq 3.393$, Table 6.

Periphyton community has a total of 14,519 individuals with 104 species were recorded throughout the study period. The total number of taxa varied from 24 in December, 26 in January, 23 in February, 63 in March, 41 in April and 49 in May, Fig. 4. Diatom populations during the study period were dominated by 10 centric forms and 34 pennate forms. Four divisions were recorded with their percentage occurrence: Bacillariophyta (82.67%), Cyanobacteria (10.54%), Chlorophyta (5.64%), and Euglenophyta (1.15%). The periphyton individual showed significant correlation with peri evenness (r = 0.971**; P < 0.01) and a strong positive correlation with peri species richness (r = 0.774). Periphyton taxa, individual, evenness index, and species richness index increased during wet months. The peri Shannon-Wiener index remained $H_s \leq 3.371$, Table 7.

Table 2. Species composition and abundance distribution of phytoplankton at ejirin part of Epe Lagoon from Dec., 2012-May, 2013

Phytoplankton Taxa	Dec. (Cells/mL)	Jan. (Cells/mL)	Feb. (Cells/mL)	March (Cells/mL)	April (Cells/mL)	May (Cells/mL)
Phylum: Cyanopbacteria						
Class: **Cyanophyceae**						
Order I: Chroococcales						
Chroococcus major					52	31
Chroococcus gardneri		16				34
Chroococcus occidentalis		21			22	26
Chroococcus deltoids		27			68	
Chroococcus mediocris		12		47	43	38
Chroococcus prestotii Dr. & Daily		28				
Chroococcus mipitanensis		14		54		41
Chroococcus minutissimus				21	31	28
Merismopedia punctata Meyen		26		51		
Chlorogloea gardneri		16	47			
Aphanocapsa conferta				36		31
Order II: **Nostocales**						
Anabaena sp. Bory ex Bornet		9	37	27	41	38

Order III: Oscilatoriales						
*Arthrospira jenneri (*Kutz.*)* Stizenberger		6				
Aphanizomenon flos-aquae (L.) Ralfs		23				
Phormidium articulatum		21	67	29		
Lyngbya intermedia Agardh ex Gomont		47	187	140	312	172
Phylum: Euglenophyta						
Class: **Euglenophyceae**						
Order I: **Euglenales**						
Euglena caudata Hubner		3			8	
Euglena spirogyra Ehr.				7	5	
Euglena oxyuris var. *charkowiensis*		7	13		7	
Phacus caudatus Hubner	6		16		14	
Phacus longicuuda (Ehr.)	7					
Phacus triquecter					12	16
Stombomonas sp. Delflandre		3		28	22	
Trachelomonas sp. Ehrenberg			28	38	26	
Phylum: Bacillariophyta						
Class: **Bacillariophyceae**						
Order I: Centrales						
Aulacoseira granulata var. *anguastissima* f. *curvata* Simon	181	48	379	454	572	675
Melosira granulate var. *anguastissima* f. *spiralis* O. Mull.	172	131	367	542	687	703
Melosira islandica subsp. Helvetica O.Mull	107	49	167	201	312	376
Aulacoseria granulata (Ehr.)	207	178	466	598	748	812
Aulacoseria italic (Ehr.)	21	52	178	383	307	378
Hemidiscus cuniciformis		43	33	52	52	47
Cyclotella stelligera Kutz. ex BrØbisson		41	105	172	123	
Coscinodiscus excentricus	7				23	
Coscinodiscus radiates			21		18	
Rhizosolenia longiseta			14	11	14	
Rhizosolenia hebetata Bail				20	19	
Rhizosolenia eriensis			17	22	24	

H. L. Smith						
Order II: **Pennales**						
Eunotia sp. Ehrenberg			51	98	110	28
Diadesmis sp. Kutzing	13	17	27	52	42	17
Diatoma sp. Bory		17	207	145	185	
Cymbella lanceolata Ehrenberg				189	197	
Cymbella turgida Greg.		12		18	34	
Cymebella ventricosa Agardh				62	57	
Surirella debessi Turpin	16	10	42	41	17	
Surirrela tenera var. *nervosa* A. Schmidt	17	11	32	42	37	21
Surirrela robusta var. *splendida*	14	8	44			22
Surirrela robusta var. *armata*				71	63	27
Surirrela didyma	12		38	47	51	18
Surirrela linearis f. *constricta* Turpin				58	49	
Surirrela arctissima A. Schmidt				57		
Synedra acus Kutzing	13			18	38	13
Synedra ulna(Nitz.) Ehr compr.				81	21	68
Asterionella formosa Hassall				23	13	8
Gyrosigma scalproides Hassall		32	78	231		72
Gomphonema spp. Ehrenberg	18	13		28	42	
Nvicula spp. Bory	12	13		203	94	
Nitzschia capitellata Wolle		21	57	61		
Nitzschia spiculum Hassall	13		47	68	54	
Bacillaria paradox Gmel.	42	23	57	62	64	
Nitzschia lacustris		12	17			
Nitzscia acicularis			101	112		
Nitzschia palea			67	105	110	
Nitzschia dissipata	17					
Nitzschia closterium				102	97	
Nitzschia gracilis			23	50	78	
Pinnularia acrosphaeria (Breb.) W. SSM. var. *minor* Kutz.				50	78	
Pinnularia spp. Ehrenberg	19	32				
*Amphora ovalis*Kutzing		13	36			

Epithemia spp. Grun.		49				
Rhopalodia operculata Müller		21				
Phylum: Chlorophyta						
Class: Chlorophyceae						
Order I: **Chlorococcales**						
Ankistrodesmus falcatus Ralfs var. *mirabilis* West f. *longiseta* Nygaard				19		
Ankistrodesmus falcatus Ralfs var.spirilliformis *West*				22	24	
Ankistrodesmus gracilis				23	19	
Ankistrodesmus braianus					27	
Actinastrum Hantzschii Lagerheim		7				
Scenedesmus armatus Chodt		13			31	
Scenedesmus perforates		15	26	41		
Scenedesmus dispar f. *canobe 2-cellulaire*				19		11
Scenedesmus quadricauda (Tarp.) Brebisson				21		33
Tetrastrum heteracanthum			18			
Tetraedron minimum					16	
Tetraedron regulare var. *incus*		4				
Schroederia setigera		7		22	18	
Pediatrum Boryanum Meneghine		11				
Pediastrum biradiatum var. *longicornutum*					21	23
Pediastrum simplex Meyen		9	18		27	32
Pediastrum simplex var. *duodenarium*	18		27		33	
Pediastrum sturmii Reinsch			13			
Pediastrum duplex Meyen				38		
Pediastrum tetras var. *tetraodon* (Corda.) Rabenhorst		13				
Sphaerocystis schroeteri Chodt			52			
Order II: Zygnematales						
Spirogyra sp. Link	8	7		19		
Closterium leibleinii				57		
Closterium kutzingii				55		

Bred.						
Staurastrum involum		11				
Staurastrum tetracerum Ralf var. *validum* West				14	17	
Staurastrum pingue Meyen ex Ralf				22		
Staurastrum pseudocyclacanthum					13	18
Saurastrum cyclocanthum var. *ubacanthum vue apicale*				18	19	
Staurastrum leptocladum var. *cornutum* f. *typique*			13		9	
Staurastrum richianum var. *lichotypique*				17	14	
Staurastrum leptostauron			33	17	13	
Mougeotia sp.				15		
Order III: Chaetopherales						
Stigeoclonium sp.				47		
Phylum: Chrysophyta						
Class: Tribophyceae						
Order I: Mischococales						
Ophiocytium capitatum Wolle		6		19		
Total species diversity (S)	**19**	**44**	**35**	**53**	**54**	**28**
Total species abundance (cells/ml)	**897**	**1171**	**3110**	**5117**	**5228**	**3784**

Table 3. Species Composition and Abundance distribution of Periphyton at Ejirin part of Epe Lagoon from Dec., 2012 – May, 2013

Periphyton Taxa	Dec. ($Cellsml^{-1}$)	Jan. ($Cellsml^{-1}$)	Feb. ($Cellsml^{-1}$)	March ($Cellsml^{-1}$)	April ($Cellsml^{-1}$)	May ($Cellsml^{-1}$)
Phylum: Cyanobacteria						
Class: Cyanophyceae						
Order I: Chroococcales						
Chroococcus major	24				47	
Chroococcus gardneri				23		23
Chroococcus occidentalis				28		
Chroococcus deltoids					51	
Chroococcus mediocris					33	37
Chroococcus mipitanensis						36
Merismopedia punctate Meyen	7					21

Chlorella subsala Lemm.				14		
Chlorogloea gardneri				23		
Cyanothece sp.				14		
Gomphosphaeria sp.				22		
Aphanocapsa conferta					43	32
Anacystis sp		14				
Aphanothece comasii						22
Aphanothece variabilis		8				
Order II: **Nostocales**						
Anabaena sp. Bory ex Bornet			42	18	37	46
Order III: Oscillatoriales						
Lyngbya intermedia Agardh ex Gomont		58	179	147	201	187
Phormidium articulatum				42		34
Komvophoron sp.						18
Phylum: Euglenophyta						
Class: **Euglenophyceae**						
Order I: **Euglenales**						
Euglena oxyuris var *charkowiensis*	8			13	8	11
Euglena gracilis Klebs				12		
Phacus orbicularis Hubner				14		
Phacus caudatus Hubner				13		
Phacus triquecter	13					
Trachelomonas affinis (Lemm.)				12		12
Trachelomonas ensifera dady				9	16	
Trachelomonas gibberosa Playf.				13		13
Phylum: Bacillariophyta						
Class: **Bacillariophyceae**						
Order I: Centrales						
Aulacoseira granulata var. *anguastissima* f. *curvata* Simon	172	41	301	342	407	524
Aulacoseira granulate var. *anguastissima* f. *spiralis* O. Mull.	181	101	309	498	587	651
Aulacoseira islandica subsp. Helvetica O.Mull	98	40	134	192	271	285
Aulacoseria	189	115	337	414	541	702

granulata (Ehr.)						
Aulacoseira italica (Ehr.)	13	33	103	175	203	198
Hemidiscus cuniciformis		29		35		21
Cyclotella meneghiniana Kütz. ex BrØ.	72	18			108	67
Cocconeis pediculus Ehr.	48		62	48	98	72
Rhizosolena longiseta				12	11	
Rhizosolenia hebetata Bail					14	
Order II: Pennales						
Eunotia arcus Ehr.	72			37	27	37
Diatoma tenuis Bory			117	121	113	67
Cymbella ventricosa Agardh	31	21		24	27	34
Surirella debessi Turpin				24		27
Surirrela robusta var. *splendida*						21
Surirrela robusta var. *armata*						17
Surirrela linearis Turpin	19		47	38	27	31
Synedra acus Ehr.		21				31
Synedra ulna var. *contracta* Ehr.	22		18	21		38
Staurosirella leptostauron						14
Asterionella formosa Hassall		21		207		
Gyrosigma scalproides Hassall					19	
Gryosigma tenuatum Hassall		16	13			
Gomphonema parvulum Ehr.	21	17		24	36	31
Navicula lancrolata Bory				98		
Navicula pupula Kütz. var. *rectangularis* GRUN. Compr.					32	
Navicula radiosa	19		28	52		
Navicula margalithi	23		57	38	37	
Stauroneis anceps						27
Nitzscia acicularis Kütz.				52	37	33
Nitzschia dissipata		18		28	27	
Nitzschia intermedia	31	31	34	54	42	41
Nitzschia	31		32		38	51

incospicua						
Nitzschia closterium					31	32
Nitzschia gracilis			31		29	44
Pinnularia acrosphaeria (Breb.) var. *minor* Kütz.		27		36		
Pinnularia gibba		17	31			
Pseudostaurosira brevistriata		11				
Amphora ovalis Kütz			47	52		
Epithemia argus var. *longicornis* Grun.				39	19	
Epithemia sorex				47		
Rhopalodia operculata (Ehr.) Müler				21		
Achnanthidium lanceolatum Kütz.	21	16				
Achnanthidium linearis Kütz.		12	27			
Phylum: Chlorophyta						
Class: Chlorophyceae						
Order I: **Chlorococcales**						
Ankistrodesmus falcatus Ralfs var. *mirabilis* West f. *longiseta* Nygaard						29
Ankistrodesmus falcatus Ralfs var.spirilliformis *West*				32		
Ankistrodesmus falcatus Ralfs				18		
Ankistrodesmus falxatus Ralfs var. *setiformis* Nygaard f. *brevis* Nygaard				22		
Ankistrodesmus gracilis Corda					21	
Ankistrodesmus braianus					24	
Scenedesmus armatus Chodat	19	23		11	13	
Scenedesmus perforates Meyen			31			
Scenedesmus dispar f. *canobe 2-cellulaire*		11		14	12	22
Scenedesmus quadricauda				11	19	17
Actinastrum Hantzschii				11		

Lagerheim						
Kirchneriella sp. Schmidle				7		
Tetrastrum stauroeniaeforme		16				
Tetrastrum heteracanthum f. *epine par cellule*					14	13
Selenastrum gracile Reinsch						13
Pediastrum simplex Meyen						17
Pediastrum duplex Meyen				17		
Pediastrum biradiatum var. *longicornutum*				16		
Pediastrum tetras Ralfs				17	11	
Quadrigula closterioides				11		
Crucigenia tetrapedia (Kirch) West et G.S.				14		17
Crucigenia minima Brunnthaler	14			16		
Order II: Zygnematales						
Spirogyra sp. Link		3	7			
Closterium kutzingii f. *sigmoides*			22	26		
Closterium jenneri Ralfs				21		
Closterium parvulum Nag.				32		
Staurastrum pingue Meyen ex Ralfs					19	18
Staurastrum cyclocanthum var. *ubacanthum vue apicale*	21				13	
Staurodesmus dickiei var. *maximus*						14
Cosmarium sp. Corda ex Ralfs				13		
Cosmarium scottii				18		
Cosmarium trachypleurum						12
Cosmarium sinostegos var. *obstusius*						7
Total Species Diversity (S)	**24**	**26**	**23**	**63**	**41**	**49**
Total Species Abundance (cells/ml)	**1169**	**738**	**2009**	**3490**	**3363**	**3767**

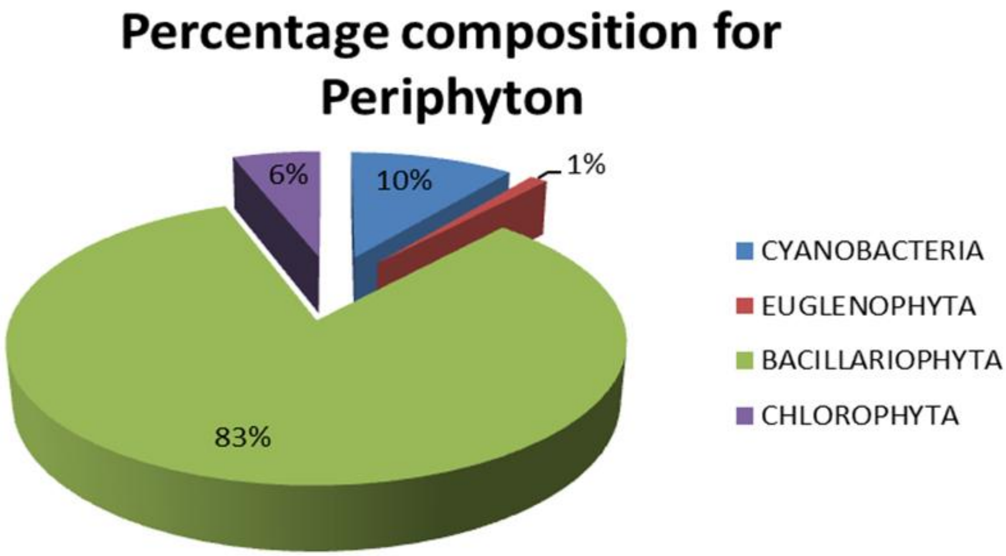

Fig. 2. Percentage composition for periphyton phyla from Dec. 2012 – May, 2013 at Ejirin part of Epe Lagoon

Furthermore, the Principal Component Analysis (PCA) is present in Table 4 and 5, with three components extracted from Fig. 5. Table 4 gives explanation for total variance with eigenvalues. With three components extracted, the cumulative percentage of variance is 87% with 13% loss of information. The first component is most highly correlated with water temperature, pH, TDS, rainfall, sulphate, COD, peri individual, peri species richness index, and phyto individual, whereas the second component correlated with salinity, phosphate, peri Shannon-Wiener index, phyto Shannon-Wiener index, and phyto species richness index. The third component showed correlation with nitrate, phosphate, sulphate and BOD, Table 5.

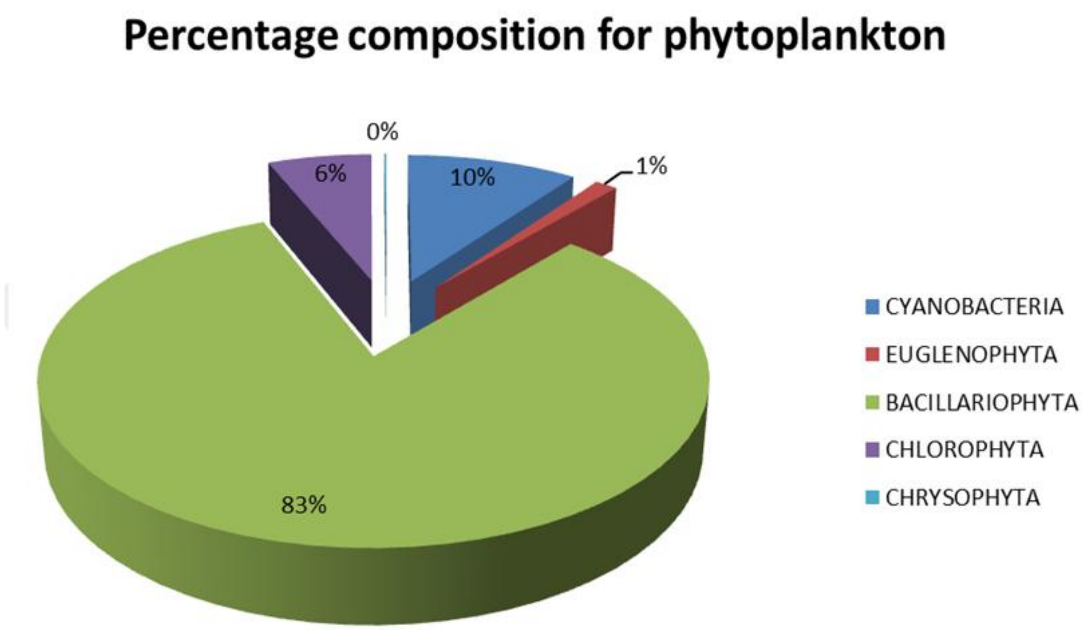

Fig. 3. Percentage composition for phytoplankton phyla from Dec. 2012 – May, 2013 at Ejirin part of Epe Lagoon

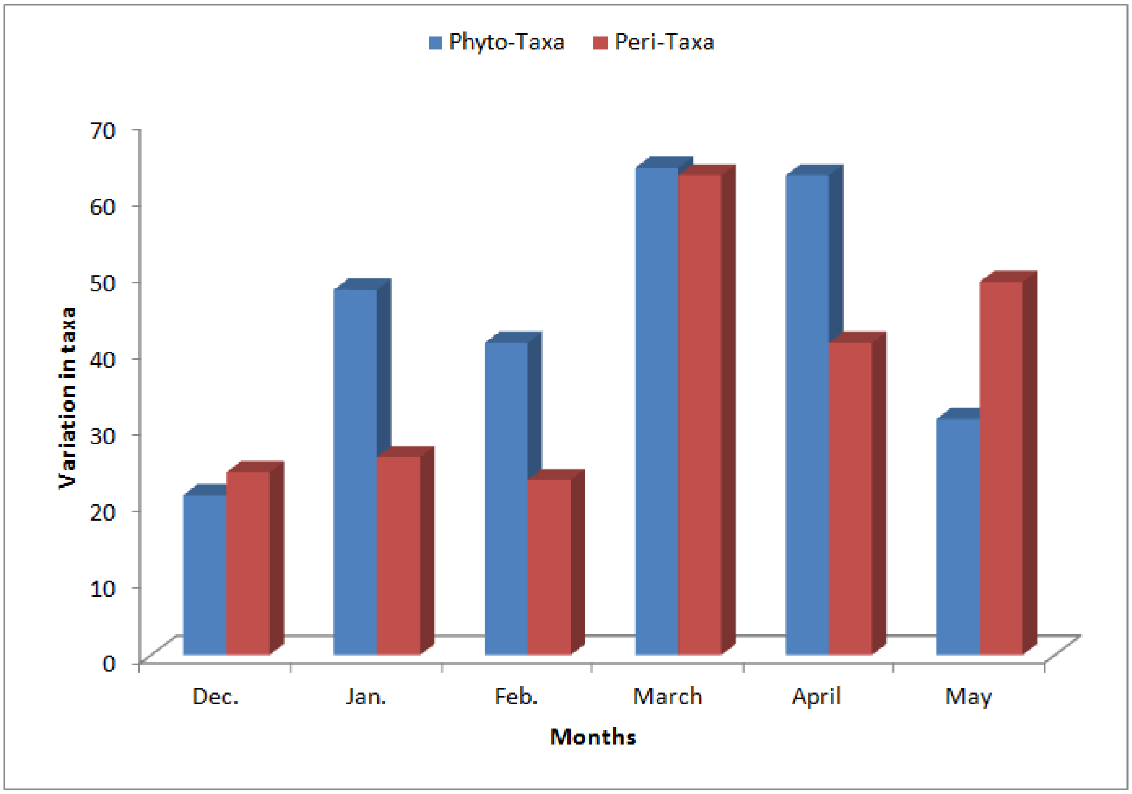

Fig. 4. Variation in taxa for phytoplankton and periphyton communities from Dec. 2012 – May, 2013 at Ejirin part of Epe Lagoon

4. DISCUSSION

The high air temperature recorded could be due to high insulation and low cloud cover while the low temperature recorded maybe as a result of NE Trade Wind that ushered in the harmathan, a cooled dusty wind that shielded sun rays and lowered insulation. Moreover the higher water temperature in January maybe as a result of time of collection and heat capacity of water. The positive significant correlation that exists between surface water temperatures with rainfall could explain the possible effect of precipitation on surface water temperature. Surface water temperature correlates significantly with surface water Chl. *a*. This may explain the possible effect of water temperature on phytoplankton biomass. The range value for air and surface water temperature reported are notable for tropics.

[44] reported that there are two main seasons in Nigeria: dry season (November – April) and wet season (May – October). The rainy season is ecologically more important in coastal waters and is bimodal in distribution. Floods caused by rainfall enrich the coastal environmental gradients (horizontal and vertical). With this seasonal pattern, it was observed that transparency, total dissolved solids and total suspended solids increased with the onset of rainfall. The micronutrients concentration level increased as precipitation rate increased probably due to input from settlements and wetlands.

[45] correlated 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 [30,16] for Epe lagoon. The pH value could be mainly control by freshwater swamp exudates that regulate the acidity of the water body. Change in pH value has a profound effect on the conductivity level of the water and the biological components.

Table 4. The eigenvalues, variability and cumulative value at Ejirin part of Epe Lagoon from Dec. 2012 – May, 2013

Total Variance Explained									
Component	**Initial Eigenvalues**			**Extraction sums of squared loadings**			**Rotation sum of squared loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	10.904	47.407	47.407	10.904	47.407	47.407	6.087	26.465	26.465
2	5.701	24.785	72.193	5.701	24.785	72.193	5.060	21.998	48.463
3	3.471	15.092	87.285	3.471	15.092	87.285	4.942	21.488	69.951

Extraction Method: Principal Component Analysis

Table 5. Factor loading for environmental characteristics and biological indexes at Ejirin part of Epe Lagoon from Dec. 2012 – May, 2013

	Component		
	1	2	3
Water Temperature	.769	-.380	-.115
Transparency	-.877	.382	-.177
Turbidity	-.972	.000	-.172
pH	.842	-.219	214
Conductivity	.064	-.931	-.375
TSS	-.496	.296	.185
TDS	.786	.183	-.557
Rainfall	.726	-.558	-.386
Salinity	.467	.768	.306
Nitrate	-.432	-.333	.720
Phosphate	.350	.705	.548
Sulphate	.709	-.186	.536
BOD	.060	.117	.986
COD	.960	.260	-.102
DO	-.571	.107	-.538
Periphyton Individual	.986	-.020	.091
Periphyton Shannon	.548	.714	-.090
Periphyton Evenness	-.975	.216	-.007
Periphyton Margalef	.833	.423	-.051
Phytoplankton Ind.	.869	.308	-.085
Phyto Shannon	.016	881	-.332
Phyto Evenness	-.713	671	-.085
Phyto Margalef	.182	825	-.341

Table 6. Biological indexes for phytoplankton at Ejirin part of Epe Lagoon from Dec. 2012 – May, 2013

Biological Indexes	Dec.	Jan.	Feb.	March	April	May
Taxa (S)	19	44	35	53	54	28
Individuals	897	1171	3110	5117	5228	3784
Shannon (H)	2.244	3.349	3.014	3.393	3.212	2.38
Evenness	0.496	0.647	0.582	0.562	0.460	0.386
Margalef	2.647	6.086	4.228	6.089	6.190	3.277

Table 7. Biological indexes for periphyton at Ejirin part of Epe Lagoon from Dec. 2012 – May, 2013

Biological Indexes	Dec.	Jan.	Feb.	March	April	May
Taxa (S)	24	26	23	62	41	49
Individuals	1169	738	2009	3473	3363	3767
Shannon (H)	2.704	2.956	2.640	3.371	2.903	2.930
Evenness	0.622	0.739	0.609	0.470	0.445	0.382
Margalef	3.256	3.786	2.893	7.482	4.926	5.829

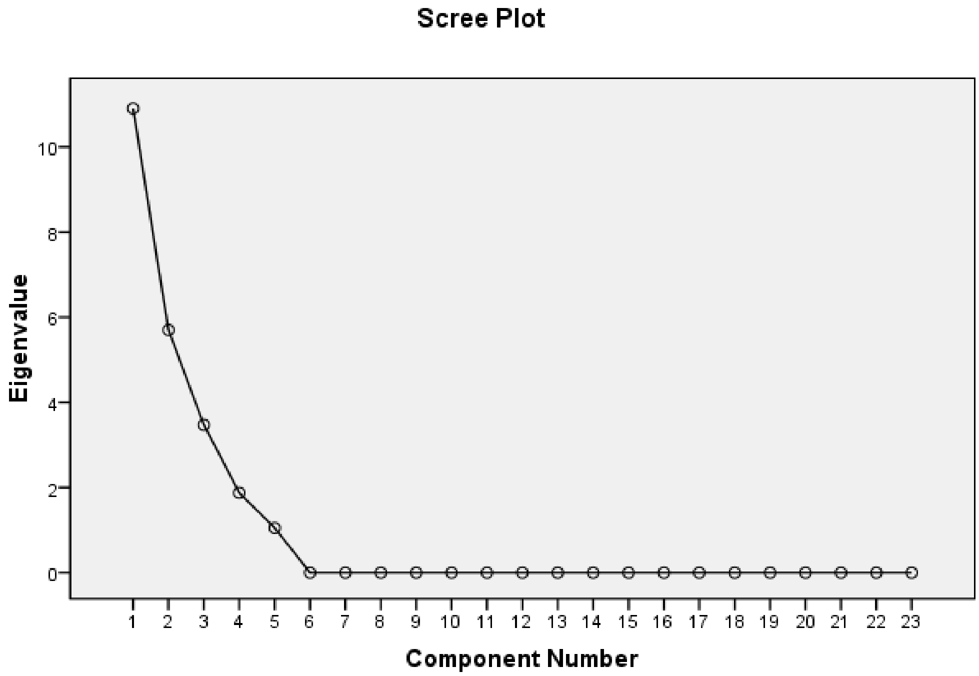

Fig. 5. The scree plot for physiochemical parameters and biological indexes from Dec. 2012 – May, 2013 at Ejirin part of Epe Lagoon

The strong correlation of pH and conductivity with phytoplankton individual and periphyton individual suggest it possible effect on the species range found in this environment. The depths of light penetration or water transparency values were high in the dry months and low in the wet months. This corresponded to the rainfall pattern encountered during the study period. Water transparency adversely affect periphyton individual as it showed a strong negative significant correlation. It therefore means that the periphyton biomass would increase as water transparency increases. It also affects phytoplankton individual as well as other physiochemical variables such as COD, DO, sulphate and pH. This explains the importance of water transparency to phytoplankton and periphyton biomass in aquatic ecosystem. The relationship of water transparency with turbidity is significant. This is because increased in turbidity might have led to a decrease in water transparency. A strong positive significant correlation of turbidity with periphyton individual reported implies the controlling effect of turbidity on periphyton biomass. Increased rainfall increases total suspended solids that in turns increase turbidity level which finally affect the phytoplankton and periphyton biomass.

However, strong sulphate correlation with phytoplankton and periphyton confirm the importance of the nutrient to the phytoplankton and perihyton species and why it should be measured when study freshwater environment.

The relatively higher concentration of heavy metals observed during wet month might be due to high precipitation couple with a high discharge of storm water from the littoral community into the channel. However the observed values of heavy metals analyzed falls within the range value recommended by [46] for water quality standards for aquatic life in different aquatic environment. [47] reported that BOD values between 1 – 2 mg/L or less represent clean water, 4 – 7 mg/L represent slightly polluted water, and more than 8mg/L represent 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 high significant correlation reported between COD with phytoplankton and periphyton individual may attribute to the response of these organisms to the physiochemical factors of the area. The Shannon-Wiener index of diversity of 1 – 3 according to [48] signify moderately polluted water and above 3 signify clean water situation. In this regards Shannon-Weiner index in

December and March in periphyton community, and December and May in phytoplankton community may point towards moderate pollution at this period.

A significant relationship exists between the biotic communities and other aquatic ecosystem components; periphyton contributes substantially to primary productivity especially in shallow aquatic ecosystems and thus provides an important energy input to both benthic and pelagic food chains of the ecosystem as well as phytoplankton. The observed chlorophyll *a* level for both periphyton and phytoplankton communities has a significant role in the productivity of the system. Periphyton has a significant role of providing food for fish and other fauna in natural and controlled environment. It serves as a diet of wide range of aquatic organisms like fish, snails, chironomids mayflies, oligocheates, crustanean etc. [49]. Generally periphyton is very rich in nutrients. Periphyton can be nutrient limited [50,12] by nitrogen and phosphorus concentrations, light limited [51] and water temperature limited [52]. Periphyton and phytoplankton are considered as an important food component for fish in aquaculture. The development of a periphyton based aquaculture technology in the area like this would appear to be feasible and it can bring about major advance in the development of low cost farming in aquaculture with no additional feed and reduction of pollution.

Moreover, the surface water Chl. *a* and peri Chl. *a* showed a rhythmic pattern with micronutrients level and a strong positive correlation with rainfall. This may explain the influence of micronutrients and precipitation on periphyton and phytoplankton communities. The periphyton and phytoplankton abundance in the wet months differs significantly with that of dry months ($t^* = 8.799$; $P > 0.05$) and ($t^* = 2.723$; $P > 0.05$) respectively. This could be as a result of favouring conditions during this time that resulted in multiplication of algal cell and additional input of planktonic forms by the floods.

The algal spectrum observed shows that diatoms were the dominance species in both phytoplankton and periphyton communities. [53] reported the limited growth of attached diatoms in the dry season to the rapid growth of marcophyte tissue. This may explain why more species were observed on macrophyte tissues in the wet months. Some of the algae that were common member of the plankton but where found in periphyton community were often trapped by the mesh-like roots of the water hyacinth. This species can be called transit visitor. Base on the observations that diatoms dominate the periphyton community on water hyacinth confirm earlier reports [28] that diatoms were more abundant in the algal spectrum of the Lagos Lagoon complex. The abundance of pennate diatoms in the plankton community during wet months suggests their dislodgement from the substratum probably during high water discharge and speed boat disturbance. [54] observed the abundance of *Eunotia* sp on *Lemna* roots whereas [53] reported the dominance of *Achnanthes* and *Cocconeis* sp on the roots and leaves of *Lemna* respectively. *Cocconeis pediculus* (Ehr.) and *Achnanthidium* sp were only found in the periphyton community with *Cocconeis pediculus* (Ehr.) occurring all through the months suggesting a strong coexistence. *Cocconeis pediculus* (Ehr.) occurred in a range conditions from clean to moderately enrich to high enriched waters [16]. It presence and others (euglenoids, blue green algae, *Nitzschia palea*, *Surirella* sp, *Pinnularia* sp, *Gomphonema parvulum*, *Mougeotia* sp, *Spirogyra* sp, *Trachelomonas affinis* (Lemm.), *T. ensiferadady; T. gibberosa* (Playf.); *Phormidium articulatum; Lyngbya intermedia* (Agardh ex Gomont)*; Cymbella ventricosa; Eunotia arcus; Surirrela linearis* f. *constricta; Asterionella Formosa* Hassall; *N. acicularis; Amphora ovalis* Kutz; *Ankistrodesmus falcatu; Scenedesmus armatus* Chodat and *Closterium parvulum* Nag.) may suggest pollution by organic materials whereas the present of *Stigeoclonium* sp suggest pollution by heavy metals. A high species level for blue green algae and euglenoids in the periphyton community may reveal it suitability in monitoring environmental stressor in coastal waters.

Furthermore, the following species could be said to be common and widely spread for both phytoplankton and periplankton communities throughout the study period: *Aulacoseria granulata* var. *anguatissima* f. *curvata* (Simon); *Aulacoseria granulata* var. *anguatissima* f. *spiralis* (O. Mull); *Aulacoseria islandica* subsp. Helvetica (O. Mull); *Aulacoseria italic* (Ehr.); *Lyngbya pediculus* (Ehr.); *Cymbella ventricossa*, *Chroococcus major*, *Chroococcus mediocris*, whereas the following might be endemic: *Aulacoseria granulata* var. *anguatissima* f. *curvata* (Simon); *Aulacoseria granulata* var. *anguatissima* f. *spiralis* (O. Mull); *Aulacoseria islandica* subsp. Helvetica (O. Mull); *Aulacoseria italic* (Ehr.); *Phormidium articulatum*;

Frailariformis visscens; *Surirrela tenera* var. *nervosa* (A. Schmidt.); *Gomphonema acquatoriate*; *G. wulaiense*; *Nitzischia capitellata* (Wolle); *Nitzschia palea*; *N. acicularis*; *N. closterium*; *Amphora ovalis* (Kutz.); *Pinularia microstrauron*; *Achnanthidium linearis*; *Ankistrodesmus falcatus* Ralfs var. *mirabilis* West f. *longiseta*; *A. falcatus* Ralfs var. *setiformis* f. *brevis* Nygaard; *Ankistrodesmus falcatus* Ralfs var. *spirilliformis*; *A. gracilis*; *A. brianus*; *Actinastrum* Hantzschii Lagerheim; *Scenedesmus quadricauda*; *Tetrastratrum heteracanthum*; *Pediastrum* duplex Meyen; *Staustrum* sp (for phytoplankton community), and *Chlorella subsala* (Lemm.); *Cyanothece* sp; *Aphanothece* sp; *Gyrosigma* sp; *N. intermedia*; *Achnanthidium* sp; *Cocconeis pediculus* (Ehr.); and *P. tetra* (Ralfs) (for periphyton).

Moreover, PCA has showed the influence of the following environmental characteristics on planktonic component of Ejirin part of Epe lagoon: water temperature, pH, TDS, rainfall, sulphate, COD, BOD, nitrate, phosphate and salinity. It therefore means that in future environmental survey the above factors should be given more attention as well as phytoplankton and periphyton abundance.

5. CONCLUSION

Periphyton community has responded promisingly to the statistical analysis applied more than phytoplankton community, indicating its possible use as biological monitor. Following the reported changes in the environmental variable measured, periphyton has responded significantly than phytoplankton in some important variable such as water temperature, transparency, turbidity, pH, TDS and rainfall. This confined to the stated hypothesis. It was noted that *Cocconeis pediculus* (Ehr.) was found only in periphyton community.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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