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Phytoplankton Diversity and Abundance in Relation to Physico-chemical Parameters of Ifewara Reservoir, Southwestern Nigeria

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ABSTRACT

The phytoplankton abundance and physico-chemical parameters of Ifewara Reservoir, Southwestern Nigeria was studied for four months (February to December, 2015). Four sampling stations (designated Stations 1-4) were established along the horizontal axis of the reservoir - from inflow region to the dam site end. At each station, net plankton samples were collected by sieving 30 litres of water through a plankton net of 50 μm mesh size into 30 ml concentrate volume. These were then preserved in 5% formalin solution and later treated with Lugol's solution and reduced to 3 ml for microscope observation. The results of the physico-chemical parameters showed that some were above recommended limits of the National Environmental Standards and Regulations Enforcement Agencies (NESREA) for drinking water and aquatic life. Sixty-nine (69) species of phytoplankton were recorded from the four investigated sampling stations. The abundance of phytoplankton was in the following order; Bacillariophyceae (90.84%) > Chlorophyceae (44.67%) > Cyanophyceae (10.69%) > Charophyceae (0.31%) > Euglenophyceae (0.12%) > Dinophyceae (0.06%) > Chrysophyceae (0.03%). The most abundant phytoplankton species was *Fragilaria aceania*, accounting for 74.28% of the total, followed by *Cosmarium quadrum* (13.04%), *Rhizoclonium hieroglyphicum* (11.97%) and *Oscillatoria tenuis* (8.03%). With regard to the horizontal pattern of variation along the reservoir, the highest phytoplankton abundance was recorded at the inflow basin and the lowest abundance at the dam site. Almost all the phytoplankton groups also had their highest mean abundance during the rainy season rather then during the dry season.

***Keywords*:** physico-chemical parameter, Phytoplankton abundance, distribution, diversity

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1. INTRODUCTION

Water is one of the most important components of life, serves as habitat for numerous organisms and no life can exist without it [1]. Water quality is a complex subject which can be define clearly by physical, chemical, hydrological and biological (plankton and Microbial load of it) characteristics of waterbody [2]. The quality of water is, therefore, germane to the survival and well-being of all aquatic life in the ecosystem [3]. The presence of an algae species in an aquatic habitat readily reflects the characteristics of the aquatic environment in which they exist, showing that one or more ecological variables are within its tolerance range [4]. Phytoplankton are primary producer in an aquatic environment and represent the biological parameters measured when assessing water quality. As they are dependent on water quality parameters, especially nitrate and phosphates for optimum growth, reproduction, and survival, so also are all consumer aquatic life dependent on them at least at an early stage for their nutrition [3].

Phytoplankton *(Phyto*- plant, *planktos*- made to wander) is defined as free-floating unicells and colonies that grow photo-autotrophically in aquatic environments which are capable of movement by the use of flagella while others drift with currents [3]. They include diatoms, cyanobacteria, chloropphyta, chrysohyta, dinoflagellates which within the size ranges of microplankton (20 - 200 μm) and picoplankton (0.2 - 2 μm). Their composition and abundance is highly dependent on the availability of sunlight, carbon dioxide and nutrients.

These factors influence their density and distribution throughout the water column [5]. Phytoplankters serves as basic food in the aquatic ecosystem for all consumers such as zooplankton and fish of the aquatic food web.

Phytoplankton has immense values as they play a vital role in aquaculture feed since they form the primary food producers. They also serve as bio-indicators for water quality with their ability to detect changes in the environment. Phytoplankton are also reported to be a significant factor in controlling atmospheric carbon dioxide, a greenhouse gas, which in turn can influence heat retention in the earth atmosphere [6]. As beneficial as phytoplankton are, they could form harmful algae blooms (HABs) when certain algae dominate the aquatic ecosystem which produce bio toxins that are harmful to fish and man. Ifewara Reservoir is an impoundment reservoir that has been abandon over a decade ago and no information on the physico-chemical parameters and phytoplankton composition and distribution pattern of it, which is a major aspect of limnology and great water quality indicator. Hence, this study aimed at investigating the spatial and temporal variation between the physico-chemical parameters in relation to phytoplankton abundance and diversity of this reservoir for proper management and evaluation of it.

2. RESULT / EXPERIMENTAL

2. 1. Study area description

Ifewara Reservoir is located at Ifewara in Atakumosa West Local Government Area of Osun State, Nigeria as shown in Figure 1. It lies between longitude 004º40’56” E to 004º41’13” E and latitude 07º28’48” N to 07º28’58” N. The reservoir is about 67 km^2 in surface area with a catchment area of about 32.4 Ha. This reservoir is impounded in 2008 purposely for the supply of portable water to surrounding towns and for other recreations activities includes fishing, irrigation etc.

The banks of the reservoir were mostly cover with grass and other tropical marginal vegetation. Notable flora includes cattails, alligator weeds, sedges, rushes, water-shield, hydrilla, pondweeds, duckweeds and water hyacinths. The study area experienced two distinct seasons, the wet season (April to October) and dry season (November to March).

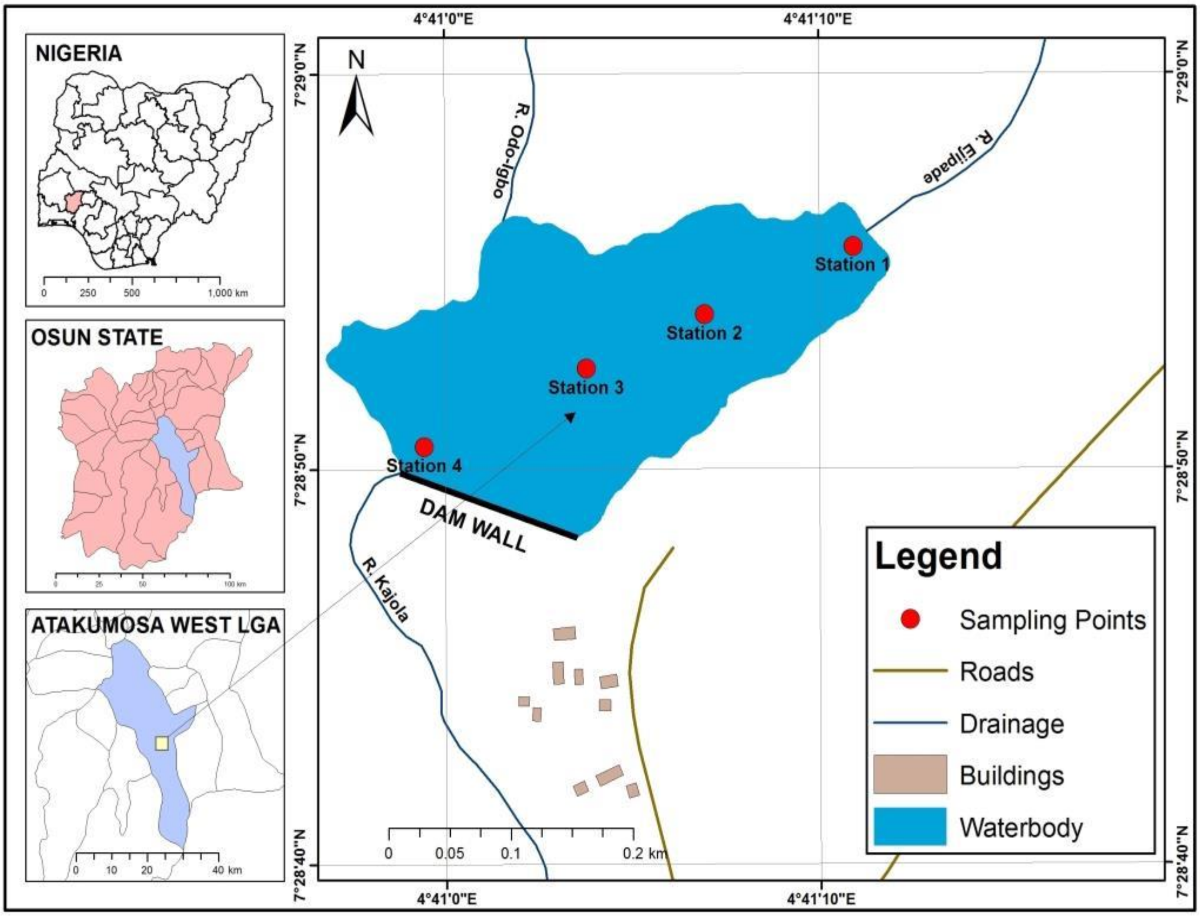

Figure 1. Map showing Ifewara Reservoir with the sampling stations

2. 2. Sampling station and collection

2. 2. 1. Phytoplankton collection and Analysis

Field survey of the sampling stations was conducted four times over the period of February 2015 to December 2015, covering both the dry and rainy seasons. Four sampling stations 1 (Upper basin), Station 2 and 3 (Middle basin) and station 4 (Lower basin) were established along the horizontal axis of the reservoir from inflow region to the dam site end. Water samples meant for physico-chemical laboratory tests were collected in 2-litre double-capped polyethylene bottles prewashed with detergent, dilute HNO_3 and doubly deionised distilled water, respectively. In the field, the sampling bottles and covers were rinsed three times with the water to be sampled prior to sampling. Phytoplankton were sampled by pouring 30 litres of reservoir water sample through a plankton net of 50 µm mesh size and the plankton contained strained into 30 ml universal bottles and preserved with 5% formalin solution and Lugol's solution for examination and identification using a light compound microscope. Identification is done using appropriate keys from [7-10] were used for identification of the phytoplankton species encountered.

2. 2. 2. Physico-chemical parameter analysis

During these sampling procedures, *in-situ* measurements were also made for some of the physico-chemical parameters such as ambient air and surface water temperature were measured using mercury-in-glass bulb thermometer, electrical conductivity, pH, using the PCE-PHD 1 conductivity meter and PCE-PHD 1 pH meter respectively, while depth and transparency was measured by 20 cm diameter Secchi disc. Total dissolved solids was determined using a conductivity bridge. Dissolved Oxygen and Biochemical Oxygen Demand were estimated using Winkler's method [11] and BOD was carried out after 5days incubation at 25 °C [12].

2. 2. 3. Statistical analysis

The data obtained for physico-chemical parameters and phytoplankton abundance were subjected to statistical analysis.Inter station comparisons were carried out to test for significant differences using Analysis of variance (SPSS version 23) while PAST Software (version 3) was used to determine the diversity index of the phytoplankton community and Correlation to show the relationship between the phytoplankton groups related and physico-chemical parameters.

3. RESULTS

3. 1. Physical and Chemical Properties

Table 1. Horizontal variation in physico-chemical water quality parameters of Ifewara Reservoir, February, 2015 – December, 2015.

Parameter	Upper Basin	Middle Basin	Lower Basin	ANOVA Statistics	
	(Station 1)	(Station 2 a nd 3)	(Station 4)		
	N= 4	N= 24	N= 12	F	P
	Mean ± S.E	Mean ± S.E	Mean ± S.E		
Air temp (°C)	29.4 ± 0.6	27.8 ± 0.5	27.3 ± 0.6	1.518	0.233
Water temp (°C)	28.7 ± 1.6	30.0 ± 0.6	31.1 ± 0.7	1.452	0.247
Depth (m)	1.50 ± 0.26	1.76 ± 0.24	1.85 ± 0.21	0.178	0.838
Transparency (m)	0.55 ± 0.14	0.73 ± 0.09	0.77 ± 0.13	0.403	0.671
pH	8.23 ± 0.37	8.22 ± 0.14	8.56 ± 0.23	0.923	0.406

Conductivity (µS/cm)	98.53 ± 2.62	99.27 ± 1.43	100.07 ± 2.15	0.089	0.915
TDS (mg/L)	65.55 ± 1.91	68.07 ± 1.05	69.20 ± 1.78	0.697	0.504
Turbidity (NTU)	95.75 ± 2.93	91.46 ± 1.19	91.58 ± 1.64	0.969	0.389
Acidity (mg/L $CaCO_3$)	6.00 ± 0.82	8.00 ± 0.74	7.83 ± 0.79	0.657	0.524
Alkalinity (mg/L $CaCO_3$)	46.50 ± 6.40	55.96 ± 1.08	54.50 ± 1.91	3.510	0.040
DO (mg/L)	9.40 ± 1.35	8.95 ± 0.70	8.23 ± 0.50	0.334	0.718
BOD_5 (mg/L)	4.60 ± 2.21	3.45 ± 0.54	2.93 ± 0.52	0.609	0.549

Air and water temperatures were in the range of 24 ºC to 35 ºC during the study period. Water temperature, depth and transparency showed the same trend characterised with increase in overall mean values towards the lower basin and also showed the higher mean values during the rainy season than the dry season. There is significant seasonal difference ($p < 0.05$) in water temperature. Turbidity estimates were higher at the upper basin and also were higher during the rainy season than the dry season. Total dissolved solids, conductivity, acidity and alkalinity had their respective lowest mean values at the upper basin of the reservoir.

pH value ranged from 6.91 to 9.41. They were all higher during the dry season than the rainy season expect for acidity and pH which had higher mean values during the rainy season than the dry season. Dissolved Oxygen and Biochemical Oxygen Demand had their respective highest mean value (9.40 ±1.35 mg/L and 4.60 ±2.21 mg/L) at the upper basin of the reservoir. With regards to seasonal variation, Dissolved Oxygen and Biochemical Oxygen Demand had their higher mean value during the dry season than in the rainy season. There was highly significant difference ($P \leq 0.01$) in total dissolved solids, acidity and conductivity while biochemical oxygen demand showed significant difference ($P \leq 0 .05$) in seasonal variation (Table 1 and 2).

Table 2. Seasonal variation in physico-chemical water quality parameters of Ifewara Reservoir, February, 2015 – December, 2015.

Parameters	**Dry Season**			**Rainy Season**			**ANOVA Statistics**	
	Min	**Max**	**Mean ± S.E**	**Min**	**Max**	**Mean ± S.E**	**F**	**P**
Air temp (ºC)	25.0	32.3	27.8 ± 0.5	24.8	33.4	27.8 ± 0.5	0.003	0.954
Water temp (ºC)	24.0	35.0	29.3 ± 0.7	29.2	34.0	31.1 ± 0.3	4.594	0.039*
Depth (m)	0.35	3.52	1.66 ± 0.22	0.52	3.70	1.87 ± 0.22	0.458	0.503
Transparency (m)	0.34	1.65	0.68 ± 0.09	0.28	1.68	0.77 ± 0.10	0.380	0.541

pH	7.11	9.20	8.09 ± 0.13	6.91	9.41	8.56 ± 0.17	4.946	0.032
Conductivity (µS/cm)	95.60	108.60	104.29 ± 0.88	85.20	108.50	94.59 ± 1.25	40.152	0.000**
TDS (mg/L)	65.00	75.00	71.32 ± 0.74	57.30	75.00	65.00 ± 1.15	21.322	0.000**
Turbidity (NTU)	84.00	99.00	93.85 ± 1.13	75.00	99.00	99.00 ± 1.33	4.853	0.034*
Acidity (mg/L $CaCO_3$)	3.00	12.00	6.20 ± 0.62	4.00	16.00	9.30 ± 0.65	11.880	0.001**
Alkalinity (mg/L $CaCO_3$)	44.00	68.00	56.55 ± 1.25	30.00	65.00	52.60 ± 1.76	3.354	0.075
DO (mg/L)	4.80	14.40	9.32 ± 0.69	4.80	16.00	8.24 ± 0.60	1.400	0.244
BOD_5 (mg/L)	0.80	11.20	4.24 ± 0.70	1.20	8.40	2.58 ± 0.37	4.417	0.042*

3. 2. Phytoplankton community

Sixty-nine (69) species of phytoplankton which belongs to 7 classes were identified during the months of study in Ifewara Reservoir. The abundance of phytoplankton was in the following order; Bacillariophyceae (90.84%) > Chlorophyceae (44.67%) > Cyanophyceae (10.69%) > Charophyceae (0.31%) > Euglenophyceae (0.12%) > Dinophyceae (0.06%) > Chrysophyceae (0.03%). The most abundant phytoplankton species was *Fragilaria aceania*, accounting for 74.28% followed by *Cosmarium quadrum* (13.04%), *Rhizoclonium hieroglyphicum* (11.97%) and *Oscillatoria tenuis* (8.03%).

Chlorophyta were the most abundant group having a total of thirty-six species belonging to twenty-four genra. This was followed by Bacillariophyta, with seventeen species from fourteen genera, Cyanophyta, with nine species from six genera, Euglenophyta, with three species from two genera, Dinophyta, with two species from two genera while Charophyta and Chrysophyta had one species each (Table 3).

3. 3. Spatial and Temporal distribution of phytoplankton

The horizontal pattern of variation showed an increase in the mean abundance of Chlorophyta and Cyanophyta at the upper basin. Euglenophyta showed a decrease trend from the upper basin towards the lower basin. Charophyta, Chrysophyta and Dinophyta showed an increase trend from the upper basin towards the lower basin. Only Bacillariophyta had the highest mean value at the middle basin of the reservoir as shown in Table 4.

There was highly significant difference ($P \leq 0.01$) in Cyanophyta across the horizontal variation of the reservoir. In seasonal variation, Chlorophyta, Chrysophyta, Dinophyta and Euglenophyta had the higher mean value during the rainy season than the dry season. While Bacillariophyta, Cyanophyta and Charophyta had the higher mean value during the dry season than the rainy season as shown in Table 5. There was highly significant seasonal difference ($P \leq 0.01$) in Chlorophyta and Euglenophyta.

Table 3. Percentage abundance of phytoplankton species encountered during the study period

Plankton diversity	Upper Basin	Middle Basin	Lower Basin	Total abundance	%	Composition
Bacillariophyceae						
Achnanthes sp.	2300	19300	600	22200	6.78	90.84
Asterionella Formosa	-	-	100	100	0.03	
Coscinodiscus sp.	-	10200	-	10200	3.12	
Cyclotella sp.	-	100	-	100	0.03	
Cymatopleura solea	-	-	100	100	0.03	
Eunotia sp.	-	-	100	100	0.03	
Fragilaria oceania	-	180600	62600	243200	74.28	
Gomphonema sp.	-	-	100	100	0.03	
Guinardia delicatula	-	100	-	100	0.03	
Hyalodiscus radiates	100	-	-	100	0.03	
Navicula cuspidata	-	100	-	100	0.03	
Navicula sp.	-	-	100	100	0.03	
Pinnularia sp.	-	1600	-	1600	0.49	
Stephanodiscus sp.	-	3200	-	3200	0.98	
Synedra acus	-	14600	1100	15700	4.80	
Synedra ulna	-	-	100	100	0.03	
Thalassiosira angustelineata	-	300	-	300	0.09	
Sub-total	**2400**	**230100**	**64900**	**297400**		
Charophyceae						
Chara sp.	-	200	800	1000	0.31	0.31
Sub-total	**-**	**200**	**800**	**1000**		

Chlorophyceae						
Actinastrum hantzschia	-	200	200	400	0.12	44.67
Actinastrum lagerhi	-	700	100	800	0.24	
Chlamydomonas sp.	-	100	-	100	0.03	
Chlorella sp.	-	4600	-	4600	1.41	
Closterium gracile	100	-	-	100	0.03	
Closterium incurvum		13300	-	13300	4.06	
Closterium moniliferum	100	24900	5400	30400	9.29	
Closterium parvulum	100	-	-	100	0.03	
Coelastrum microsporum	-	200	-	200	0.06	
Cosmarium obtusatum	-	-	100	100	0.03	
Cosmarium speciosum	-	-	2000	2000	0.61	
Cosmarium quadrum	-	39100	3600	42700	13.04	
Desmidium coarctatum	200	-	-	200	0.06	
Dictyosphaerium sp.	-	100	-	100	0.03	
Euastrum anstum	-	100	-	100	0.03	
Eudorina sp.	100	-	-	100	0.03	
Hyalotheca undulate	-	-	100	100	0.03	
Micrasterias crux-melitensis	100	600	-	700	0.21	
Micrasterias foliacea	-	2400	600	3000	0.92	
Micrasterias moebii	100	-	-	100	0.03	
Mougeotia sp.	-	-	200	200	0.06	
Oedogonium sp.	-	-	3000	3000	0.92	
Oocystis crassa	-	-	600	600	0.18	
Oocystis elliptica	100	-	-	100	0.03	

Pediastrum dupiex	-	-	100	100	0.03	
Pleurotaenium trabeculla	500	-	-	500	0.15	
Rhizoclonium hieroglyphicum	-	-	39200	39200	11.97	
Sphaerocystis sp.	-	100	-	100	0.03	
Spirogyra sp.	-	-	100	100	0.03	
Staurodesmus convergens	-	1000	500	1500	0.46	
Staurastrum triangularis	-	-	100	100	0.03	
Tetraedron minimum	-	100	-	100	0.03	
Ulothrix sp.	-	900	300	1200	0.37	
Volvox aureus	100	-	-	100	0.03	
Volvox globulus	-	100	-	100	0.03	
Volvox sp.	-	-	100	100	0.03	
Sub-total	**1500**	**88500**	**56300**	**143600**		
Chrysophyceae						
Dinobryon sp.	-	-	100	100	0.03	0.03
Sub-total	**0**	**0**	**100**	**100**		
Cyanophyceae						
Anabaena sp.	-	100	-	100	0.03	10.69
Gloeotrichia echinulata	-	100	-	100	0.03	
Lyngbya martensiana	-	100	-	100	0.03	
Lyngbya sp.	-	-	100	100	0.03	
Microcystis aeruginosa	-	1000	-	1000	0.31	
Microcystis flosaquae	-	-	1200	1200	0.37	
Oscillatoria tenuis	24300	2000	-	26300	8.03	

Oscillatoria sp.	-	5000	1000	6000	1.83	
Spirulina sp.	100	-	-	100	0.03	
Sub-total	**24400**	**8300**	**2300**	**35000**		
Dinophyceae						
Peridiniopsis thompsonii	-	-	100	100	0.03	0.06
Peridinium sp.	-	100	-	100	0.03	
Sub-total	**-**	**100**	**100**	**200**		
Euglenophyceae						
Euglena oxyuris	-	-	100	100	0.03	0.12
Euglena viridis	-	100	-	100	0.03	
Trachelomonas sp.	100	100	-	200	0.06	
Sub-total	**100**	**200**	**100**	**400**		
Grand total	**327400**	**124500**	**480300**	**327400**		

Table 4. Horizontal variation in the abundance of phytoplankton of Ifewara Reservoir, February, 2015 – December, 2015.

Taxonomic Group	**Upper Basin (Station 1)**	**Middle Basin (Station 2 & 3)**	**Lower Basin (Station 4)**	**ANOVA Statistics**	
	N= 4	**N= 24**	**N= 12**	**F**	**P**
	Mean ± S.E	**Mean ± S.E**	**Mean ± S.E**		
Bacillariophyta	16850 ± 9177	19967 ± 4703	18250 ± 4979	0.053	0.949
Charophyta	0 ± 0	29 ± 13	75 ± 39	1.515	0.233
Chlorophyta	57650 ± 23186	31158 ± 5419	34233 ± 7241	1.508	0.235
Chrysophyta	0 ± 0	75 ± 46	400 ± 391	0.837	0.441
Cyanophyta	7050 ± 5818	1033 ± 343	1392 ± 398	4.745	0.015**
Dinophyta	0 ± 0	975 ± 962	4608 ± 4581	0.692	0.507

Euglenophyta	6900 ± 6800	2692 ± 1425	1042 ± 678	1.101	0.343
Total	**88450 ± 44981**	**55929 ± 12911**	**60000 ± 18307**	**10.451**	**2.723**

Table 5. Seasonal variation in the abundance of net phytoplankton of Ifewara Reservoir, February, 2015 – December, 2015.

Taxonomic Group	**Dry Season**	**Rainy Season**	**ANOVA**	
	Mean ± S.E	**Mean ± S.E**	**F**	**P**
Bacillariophyta	24655 ± 5687	13625 ± 2825	3.017	0.090
Charophyta	60 ± 26	20 ± 12	2.027	0.163
Chlorophyta	19840 ± 3730	49620 ± 6851	14.575	0.000**
Chrysophyta	5 ± 5	325 ± 237	1.828	0.184
Cyanophyta	2000 ± 1218	1485 ± 371	0.164	0.688
Dinophyta	0 ± 0	3935 ± 2924	1.811	0.186
Euglenophyta	15 ± 15	5220 ± 2032	6.564	0.014*
Total	**46575 ± 10681**	**74230 ± 15252**	**29.986**	**1.325**

3. 4. Diversity Indices

High values of Shannon-Wiener Index H were recorded for Chlorophyta (2.64) followed by Bacillariophyta (2.18) and low values for Chrysophyta (0). Highest values for species dominance (D) were recorded for Chrysophyta (1) followed by Cyanophyta (0.53) and lowest for Chlorophyceae (0.12). Evenness ranged from (1) in Euglenophyta and Dinophyta to (0.94) in Euglenophyta and Chlorophyta (0.28) (Table 6).

3. 5. The Relationship between Physico-chemical Variables and Plankton Abundance

The Canonical correspondence analysis (CCA) ordination diagram was employed to show the relationships existing between biological assemblage and the physicochemical variables. Phytoplankton groups such as bacillariophyta and chlorophyta clustering with the physico-chemical variable (Figure 2). The pyhsico-chemical variables were positively correlated with each other i.e. air temperature, water temperature, depth, transparency, pH, conductivity, TDS, Turbidity, acidity, alkalinity, DO and BOD ($p \leq 0.001$) while Euglenophyta was positively correlated with DO and BOD ($r = 0.38$, $r = 0.35$, $p \leq 0.05$), Cyanophyta was positively correlated with BOD ($r = 0.32$, $p \leq 0.05$) and Euglenophyta was positively correlated with Dinophyta ($r = 0.79$, $p \leq 0.001$) as presented Table 7.

Table 6. Phytoplankton diversity index of Ifewara Reservoir

Index	Bacillario phyta	Charop hyta	Chlorop hyta	Chrysop hyta	Cyanop hyta	Dinop hyta	Eugleno phyta
Taxa S	27	4	50	1	7	2	3
Individuals	296500	1000	143600	100	34500	200	400
Dominance (D)	0.1564	0.3	0.124	1	0.5229	0.5	0.375
Simpson (1-D)	0.8436	0.7	0.876	0	0.4771	0.5	0.625
Shannon (H)	2.176	1.28	2.637	0	1.034	0.6931	1.04
Evenness (e^H/S)	0.3262	0.899	0.2795	1	0.4018	1	0.9428
Brillouin	2.175	1.27	2.636	0	1.033	0.6788	1.024
Menhinick	0.04959	0.1265	0.1319	0.1	0.03769	0.1414	0.15
Margalef	2.064	0.4343	4.126	0	0.5742	0.1887	0.3338
Equitability (J)	0.6601	0.9232	0.6742	0	0.5314	1	0.9464
Fisher alpha	2.294	0.5303	4.857	0.1544	0.6427	0.3089	0.4403
Berger Parker	0.2334	0.4	0.2611	1	0.7043	0.5	0.5
Chao 1	27	4	50	1	7	2	3

Table 7. Correlation coefficient of physico-chemical paramters and phytoplankton of Ifewara Reservoir.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	0															
B	0	0														
C	0	-0.01	0													

D	E	F	G	H	I	J	K	L	M	N	O	P
-0.01	0.14	0.16	0.07	0.06	0.14	0.16	0.17	0.16	0.06	0.17	0.14	0.26
0.79***	0.14	0.16	0.05	0.06	0.13	0.15	0.13	0.13	0.13	0.15	0.23	0.14
0.28	0.21	0.21	0.2	0.29	0.22	0.22	0.21	0.22	0.12	0.19	0.22	0.32*
0	0.24	0.27	0.1	0.14	0.24	0.26	0.23	0.24	0.25	0.24	0.38*	0.35*
	0	0.99***	0.86***	0.84***	0.99***	0.99***	0.99***	0.99***	0.91***	0.98***	0.93***	0.78***
		0	0.85***	0.84***	0.99***	0.99***	0.99***	0.99***	0.93***	0.99***	0.94***	0.77***
			0	0.94***	0.85***	0.87***	0.86***	0.87***	0.80***	0.83***	0.72***	0.52***
				0	0.85***	0.85***	0.84***	0.86***	0.80***	0.83***	0.77***	0.55***
					0	0.99***	0.99***	0.99***	0.92***	0.99***	0.95***	0.78***
						0	0.99***	0.99***	0.91***	0.99***	0.94***	0.79***
							0	0.99***	0.90***	0.99***	0.94***	0.79***
								0	0.91***	0.99***	0.94***	0.78***
									0	0.91***	0.87***	0.63***
										0	0.95***	0.78***
											0	0.86***
												0

* = significant, *** = very highly significant

A = Chrysophta, **B** = Cyanophyta, **C** = Dinophyta, **D** = Euglenophyta, **E** = Air temperature, **F** = water temperature, **G** = Depth, **H** = Transparency, **I** = pH, **J** = Conductivity, **K** = TDS, **L** = Turbidity, **M** = Acidity, **N** = Alkalinity, **O** = DO, **P** = BOD

4. DISCUSSION

Air and water temperatures were in the range of 24 ºC to 35 ºC during the study in Ifewara reservoir were above NESREA recommended range limits 25 – 31 °C for surface waterbody in the tropical region this could be attributed to seasonal variation and rainfall pattern [13]. The mean turbidity value was highest in rainy season (99.0±1.33 NTU) than dry season value (93.85 ±1.13 NTU) and sudden decrease in mean turbidity was observed from upper basin to lower basin. Higher turbidity values were observed during the rainy season period due to increased suspended solids loads laden run-offs and the mean values observed during this study was above than [14] recommended limits of 5.00 NTU. This indicate that the water may not be safe for drinking and this might be caused due to runoff from the adjourning environment and the surrounding settlements. The mean Dissolved Oxygen value observed in all the stations and seasonal were higher compared to the [15] limits of 5.0 mg/L for surface water. This indicates a high oxidized aquatic ecosystem. The higher dissolved oxygen level in the river may also be attributed to the less vegetative decomposition of plants that have been exacerbated by a heavy point source of fresh water inflows carrying excess nutrients into this river system [13]. Biological oxygen demand is an important parameter that is required for the degradation of organic matter. The value of the biological oxygen demand of Ifewara Reservoir ranged between 0.8 and 11.20 mg/L. However, other physicochemical parameters of the river such as pH, conductivity, TDS, and transparency were within recommended limits as stipulated by NESREA for aquatic life. The mean pH concentration observed for lower basin and rainy season exceed the freshwater local and international standard limits (of 6.5-8.5). The pH range in this study indicates that the water was generally alkaline condition a characteristic of tropical water. Electrical conductivity mean values ranged between 85.20 µ S/cm and 108.60 µS/cm. A sudden increased in conductivity was observed in all the stations from upper basin to lower basin. Conductivity is primarily determined in water by the presence and levels of concentration of sodium and magnesium ions and to some extent calcium ions. These ions help buffer the effect of bicarbonate and carbonate ions, thus maintaining the pH [16]. Conductivity recorded in Ifewara reservoir is an indication of negligible impact of human activities in the area and the values are far below WHO maximum limit of 1000 µ S/cm. The mean values of total dissolved solids ranged from 57.30 mg/L to 75.00 mg/L.

The total dissolved solids recorded in this study have been recorded elsewhere in Nigeria, [17]. Higher mean values were however recorded in the dry season than in the rainy season which contradict a phenomenon common in most Nigerian inland waters. This could probably be due to the fact that during the rainy season, more run-offs and allochthonous materials are washed into the water bodies. However, the trends observed mean of alkalinity concentration in all the stations are similar. According to [18] alkalinity is regarded as a measure of productivity of natural waters. Total alkalinity ranges from 30.00 mg/L to 68.00 mg/L. Alkalinity was higher during the dry season than in the wet season [16].

Sixty-nine (69) species of phytoplankton were recorded from all the investigated sampling stations in this study. The flora comprised 36 species of Chlorophyta (Green Algae), 17 species of Bacillariophyta (Diatoms), nine species of Cyanophyta (Blue-green Algae), two species of Dinophyta (Dinoflagellates), one species of Chrysophyta (Golden-brown Algae), three species of Euglenophyta (Euglenoids) and one species of Charophyta (Stoneworts or Brittleworts). Most of the phytoplankton species recorded in this study (which include *Closterium* spp., *Cosmarium* spp., *Oscillatoria* spp., *Microcystis* spp. and *Chroococcus* sp.) are common to many African freshwaters and have been documented to occur most especially in Nigerian reservoirs [19-22]. The most abundant family, chlorophyceae of the Division Chlorophyta has been reported previously by [22] in Kainji Reservoir and [23] in Owalla Reservoir to dominate the phytoplankton flora of Nigerian freshwater ecosystems. Similarly, the desmids which were the richest group in this study were also reported as being the richest in River Okhuo Benin and Bay of Bengal by [22] and [23] respectively. The high diversity of desmids in Ifewara reservoir may be an indication that the water body is unpolluted [24] and/or that it is a dilute freshwater influenced largely by high rainfall regime [25]. The highest phytoplankton abundance recorded at the upper basin of the reservoir, this could be as a result of high inflow of nutrient into the reservoir from a nutrient reservoir. These observations different to that of [23] on Bay of Bengal and [26] on Opa Reservoir which had the highest phytoplankton abundance at the dam site basin as a result of less disturbance of water current and high transparency. The fact that almost all the phytoplankton groups had higher mean abundance during the rainy season than in the dry season may be due to an increase in ionic dilution during this period as well as an increase in nutrient inflow and introduction of organic matter from the surrounding vegetation [27]. It is worthy of note that the significant variation in number of species recorded during rainy season than the dry season is an indication that more species could survive changes in nutrients and increase in volume of the water which varies with season.

Generally, phytoplankton have been identified to be of great importance in bio-monitoring of trophic status as well as water quality [28-30]. Notable bio-indicator phytoplankton species recorded were *Anabaena* sp., *Microcystis aeruginosa*, *Oscillatoria* sp. which produce algal toxins which can cause serious illness in both humans and some other mammals according to [31] and [32]. Other pollution indicator species that were recorded in this study include *Closterium* sp., *Peridinium* sp. and *Euglena* sp. suggesting likelihood of pollution in the reservoir [32]. The high percentage of desmids (*Closterium*, *Cosmarium*, *Micrasterias* and *Staurastrum* spp.) in the investigated water body, is an indication of a clean, oligotrophic unpolluted water body. This has also been postulated by [33], that desmids, indicator species inhabit clean, oligotrophic (nutrient-poor) and unpolluted water bodies.

An important application of diversity indices in phytoplankton studies is in the assessment of pollution. According to [34] and [35], the Shannon-Weiner diversity index for clean fresh water bodies are proposed as diversity index greater than 4; between 3-4 is proposed as mildly polluted water while less than 2 as heavily polluted water [36, 37]. The Shannon-Weiner diversity index ranged between 0 and 2.64 indicating mildly polluted water.

5. CONCLUSIONS

Ifewara Reservoir showed seasonal variations in the physicochemical parameters may be attributed to rainfall patterns, while the spatial variations are due to the influence of various anthropogenic activities from the major stream that empty into the river. Although the some physico-chemical parameters were above limits as recommended by NESREA for tropical aquatic life, the presence of certain high phytoplankton diversity including some species which can serve as indicator of water quality and trophic status indicating it to be an oligotrophic water such as *Closterium* sp., *Cosmarium* sp., *Oscillatoria* sp., *Microcystis* sp. and *Chroococcus* sp. suggests a high inflow of nutrient into the reservoir from a nutrient reservoir.

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