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EVALUATION OF LIMNOLOGICAL CHARACTERISTICS OF OPA RESERVOIR TRIBUTARIES IN RELATION TO PHYTOPLANKTON COMMUNITY STRUCTURE IN ITS CATCHMENT AREA, SOUTHWEST, NIGERIA

[*1]Adewumi, E. A., [1]Adewumi, P. O., [2]Adesakin, T. A., [1]Oyewumi, J. O. and [3]Adedeji, A. A.

[1]Department of Animal and Environmental Biology, Federal University Oye-Ekiti, Ekiti State, Nigeria.
[2]Department of Biology, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
[3]Department of Zoology, Obafemi Awolowo University, Ile Ife, Osun State, Nigeria

*Corresponding authors' email: emmanuel.adewumi@fuoye.edu.ng

ABSTRACT
The study assessed the taxonomic composition and community structure of phytoplankton organisms in relation to changes in physicochemical quality of Opa reservoir tributaries. We obtained samples of water and phytoplankton monthly for a period of a year (September 2017 and August 2018) from six prominent tributaries of the Opa Reservoir's catchment area. The collected planktonic biota samples were examined under microscope and photographs of all organisms encountered were taken. The recorded organisms were identified using pertinent identification keys. Eighty-two phytoplankton species were identified, categorized into seven divisions. *Anabaena* sp, a toxic pollution tolerant is the most abundant species in all rivers while *Luticola* sp, a Charophyta and *Dinophysis caudata*, a Myzozoa were recorded only at Parakin, throughout the sampling period. Bacillariophyta had the highest number of phytoplankton species (35 species, 42.68%) followed by Cyanobacteria with 15 species (18.30%) and Charophyta with 15 species (18.30%). *Leptocylindricus danicus* had spatial variation in Parakin, Esinmirin, Obudu and PG river ($p \leq 0.05$). Conductivity, air temperature, water depth and alkalinity were significant spatially and seasonally, and significant variables were pH, sulfate, phosphate, turbidity, and water depth. *Anabaena* sp and *Closterium* sp (pollution indicator) varied significantly. The high abundance of *Anabaena* sp recorded in this study indicates high concentrations of limiting nutrients which encourage their growth. The corresponding rise in phosphate, sulfate and organic matter concentrations is associated with the observed phytoplankton abundance during the dry season (38,470 Org/m^3). However, *canonical correspondence analysis* (CCA) revealed notable relationship between phytoplankton and physicochemical parameters.

Keywords: Bio-indicator, Diversity, Phytoplankton, Reservoir, Water Quality

INTRODUCTION
As the primary producer of greatest significance in the freshwater ecosystem, phytoplankton is heavily influenced by the water quality parameters, both in terms of dispersion and community structure. According to Basualto *et al.* (2006), the interaction of chemical, physical, and biological components determine the structure of phytoplankton communities in lakes. Meanwhile, phytoplankton is very important for the existence of all water ecosystems (Molles, 2005). Phytoplankton is the major biological component of food chain through which energy is transferred to the higher organisms (Rajesh *et al.,* 2002, Ananthan *et al.,* 2004; Tas and Gonulo 2007; Shektar *et al.,* 2008). Biomass and production of phytoplankton are important in regulating the diversity of organisms at higher trophic level. Phytoplankton serves as bio-indicators with reference to water quality and thus serves as a tool for assessing the health of the aquatic ecosystems. Furthermore, the measurement of primary productivity of aquatic ecosystem is required to forecast fishery potential of an area (Raj Kumar *et al.,*2009).
The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics, to assess the monitoring of these parameters is essential to identify magnitude and source of any pollution load (Venkatesharaju *et al.,* 2010). The structure and abundance of the phytoplankton populations are mainly controlled by inorganic nutrients such as nitrogen, phosphorus, and silica (Daniel, 2001) and mainly available nitrogen as nitrate, nitrite and ammonia, phosphorus as soluble orthophosphate (USEPA, 2000) and silicone as silicate forms. In addition to being a crucial component of aquatic ecosystems, phytoplankton also directly contributes to lake pollution and purification and regulates the structure and function of ecosystems by moving materials and transferring energy within lakes (Lijin *et al.,* 2014). Mostly, the species of dinoflagellates and diatoms share certain basic requirement for growth (light, carbon dioxide, nutrients, trace element, habitable, temperature and salinity), they can differ considerably in their optimal requirement for these factors.
The stability of physical-chemical traits is a major regulating factor for life in aquatic environments. Due to these qualities, phytoplankton has been able to adapt widely, leading to improvements in sustained productivity and regulation of its metabolism (Olele & Ekelemu, 2008). Being the foundation of the productivity pyramid, phytoplankton is essential to the overall health of the lake biota (Usman, 2016). Thus, the purpose of this study was to evaluate how changes in the physicochemical water quality of a selected prominent streams in the Opa reservoir's catchment region affected the diversity of phytoplankton. The information gleaned from this study will provide details into the trophic and health status of the selected tributaries.

MATERIALS AND METHODS
Description of Sampling Stations
Selection of Sampling Station
Opa reservoir was impound to supply drinking water to OAU main campus and environs. These tributaries of Opa Reservoir include Parakin River, Esimirin River, Opa River (20 C), Obudu River (20 A), Amafa River and River behind

OAU Postgraduate College. Opa River, Amafa River, Obudu River, River behind OAU Postgraduate College were located within OAU main campus while Parakin River and Esimirin River were located within Ife Town but flow into Opa Reservoir. During the dry season, the Esimirin River's principal tributaries drain into the Opa Reservoir. It drains more than half of Ife Town and in reality, it is the town sewer (Ogunkoya 2013). The Obudu River (20C) is quite shallow, with a predominant *Musa sapietum* plantation bordering its shoreline.Obudu river soil type is characterized as sandy. Opa River is the largest river to flow into Opa Reservoir and it is named after this River. It is deep and highly turbid during raining season, with low water clarity but less turbid in the dry season. Consistent farming operations comprising the cultivation of turmeric, *Zingiber officinal*, *Musa sapientum*, *Manihot esculentum*, *Bambusa vulgaris*, and breeding of pigs are another characteristic of this station. Mixed plantations of *Musa sapientum*, *Zea may*, and *Spinacia oleraceare* among the agricultural activities that define the Parakin River, an Olojumeta tributary. At the upper region of this tributary, there is a fish pond. Amafa, this tributary is shallow, characterized with rocky basin. Though the area is surrounded with abandoned land, cultivated land is some meter away from the tributary. The PG tributary has loamy soil, and farming activities like as the cultivation of *Musa sapientum* and *Manihot esculentum* have been reported along its shore. It has rocky basin with high water clarity during both raining and dry season.

For a year (September 2017 to August 2018), monthly samples of water and phytoplankton were taken from each of the six tributaries of Opa Reservoir.

Physicochemical Water Quality Analysis

Water samples for physicochemical analysis were collected into 2-Litres sterilized containers at each station. A mercury-in-glass thermometer was used to measure the water's temperature (^{0}C); a pH-EC-TDS meter that had previously been calibrated using buffer solutions was used to measure the pH; a conductivity meter calibrated with potassium chloride solution was used to measure the electrical conductivity. These measurements were made in-situ in accordance with APHA (2005). The dissolved oxygen content of water samples was fixed on site by addition of Winkler's A and B solution (manganese sulphate solution and alkali-iodide reagents) to the collected sample. The samples were then transported to the laboratory where they were titrated with sodium thiosulphate solution. Water samples were also collected in the dark oxygen bottle for the determination of Biological Oxygen demand and these were incubated in a cupboard for 5 days at room temperature. Thereafter, the oxygen content of the sample was determined titrimetrically. Spectrophotometric method was used to determine Phosphate and Nitrate level of the samples (APHA, 995). Total dissolved solids (TDS) were determined by gravimetric method at 105^{0}C and 108^{0}C respectively (APHA, 2001). Chromic acid digestion was used to examine the organic matter in the samples, while turbidimetric/spectrophotometric analysis was used to determine the samples' sulphate level (APHA, 1995). Water depth was determined using a Secchi disc and velocity was determined using a floating object and stop watch.

Phytoplankton Analysis

Water samples for net plankton samples were captured z straining 30 litres of water through plankton net of 50µm mesh size and the planktonic contents was emptied into a 30mls universal bottle. The concentrate was preserved with two drops of 5% formaldehyde and 2 – 3 drops of Lugol's solution and transported to the Laboratory for subsequent examination and then identification. The formaldehyde was used to preserve the structure of the organisms while the Lugol's solution enhanced the sedimentation of the planktonic organisms in the sample for clear examination.

Identification of Phytoplankton Species

A subsample is taken as an average volume 1.5ml of the sample and placed in the plankton chamber by gently decanting the sample in the universal bottle and mixing the rest before drawing the water sample with rubber micropipette. This preserved subsample containing plankton was examined in the laboratory using Omax binocular light compound photo-microscope (Model Number: G013050830) and their scaled pictures taken. Identification of the plankton species was based on standard identification guides and keys including the works of Janse Van Vuuren *et al*. (2006); Brierley *et al*. (2007); Yamaguchi and Gould (2002); Witty (2008); Suthers and Rissik (2009); Bellinger and Sigee (2010); Ekhator *et al.* (2014) and Fernando (2002).

Estimation of Phytoplankton Abundance

In order to determine phytoplankton abundance, the count records of the subsample's final concentrate volume in relation to the initial volume of water filtered through a plankton net were used. The outcome was then stated in organisms per cubic meter of the original water sample. To determine the species abundance, the following formula was applied.

Statistical Analysis

Statistical analysis was carried out using SPSS version (2012). ANOVA statistics was performed to determine spatial mean variation of phytoplankton encountered and physicochemical parameters. Moreso, canonical correspondence analysis (CCA) was used to check for relationship between phytoplankton and physicochemical parameters. Specie richness index was determined using Shannon , Margalef and Evenness specie Indices.

$$A = \frac{ab}{c} \times 1000 \quad \text{(Goswami, 2004)}$$

Where:

A – Abundance of species per litre of original water source
a – Abundance of species in the sample
b – Total concentrate volume of water used (1.5ml)
c – Original volume of water (20 L)

Table 1: Grid Location of selected sampling stations

Stations	Latitude	Longitude	Elevation (Meters)	Depth (Meters)
Parakin river	4.542°E	7.505°N	255	0.78
Esinmirin River	4.550° E	7.514°N	260	1.72
Opa River Rd. 20A	4.543°E	7.526°N	251	0.30
Opa River Rd. 20C	4.549°E	7.530°N	248	0.76
Amafa Stream	4.932°E	7.519°N	266	0.59
Postgraduate College Stream	4.526°E	7.513°N	264	0.33

RESULTS AND DISCUSSION

Physico-chemical Parameters

The Amafa River had the highest DO mean concentration recorded (7.67 ± 2.06 mg/l) while the lowest value was observed at Parakin River water sample (6.58 ± 3.34 mg/l) as presented in Table 1. BOD, conductivity, TDS, pH, water temperature, air temperature, water depth and alkalinity (3.62 ± 2.65 mg/l, 297.92 ± 50.46 µS/cm, 222.25 ± 50.80 mg/l, 7.14 ± 0.56, 22.70± 4.19 °C, 22.57± 4.89 °C, 0.52± 0.46 m and 155.42 ± 67.17 $CaCO_3$mg/L) mean values were in Esimirin river water samples and there are significant differences in mean of conductivity, air temperature and alkalinity across all the stations (Table 1). Turbidity value (112.54 ± 100.35 NTU) was higher in Obudu River water sample while phosphate and chemical oxygen demandconcentrations (12.00 ± 19.55 mg/l and 12.84 ± 11.25 mg/l) obtained in this study were higher at Opa River water sample. The PG River water sample had the highest recorded values of nitrate, water velocity, total organic carbon organic matter and sulphate (0.57 ± 0.65 mg/l, 0.27 ± 0.26 m/s, 5.38 ± 5.84 mg/l, 9.28 ± 10.06 mg/l, and 1.00 ± 1.32 mg/l) (Table 1).

The dry season is associated with the greatest seasonal mean values of air temperature, alkalinity, conductivity, organic matter, pH, phosphate, sulphate, TDS, total organic carbon and water temperature as though BOD, DO, turbidity, water depth and water velocity were higher in wet season than in dry season and there were very highly significant differences ($p < 0.0001$) among the mean values of air temperature, nitrate, pH and turbidity (Table 2).

Spatial and Temporal Abundance of Phytoplankton

A total number of 158 phytoplankton species was recorded during the study period belonging to 7 phyla namely: Bacillariphyta (79), Chlorophyta (33), Charophyta (25), Cyanophyta (14), Euglenophyta (5), Myxozoa (1) and Ochrophyta (1). The most represented taxon was Bacillariophyta with relative species occurrence of 42.68% followed by Cyanophyta (18.30%), Charophyta (18.30%), Euglenophyta (6.09%) and least were Myzozoa and Ochrophyta with 1.22% each. *Anabaena* sp is the most common species and members of the division Bacillariophyta. The highest overall phytoplankton abundance was recorded in Parakin River (18,675 Org/m^3) and with mean abundance of 397 Org/m^3, followed by 13,525 Org/m^3 with mean abundance of 409 Org/m^3 observed in Esimirin River and the least abundance was recorded at Opa River (2,925 Org/m^3) with mean abundance of 154 Org/m^3 as presented in Table 3. ANOVA statistics showed that only *Leptocylindricus danicus* had significant variation in abundance spatially ($p \leq 0.05$) in Table 5. The highest evenness value was recorded in Opa River (0.697) followed by PG river (0.665) and least was observed at Obudu River (0.220). The highest Shannon index was observed in PG River with value of 2.851 and least was recorded at Amafa River (1. 621) (Table 4). There is positive close relationship between water temperature, phosphate, organic matter, water depth, air temperature, chemical oxygen demand, Euglenophyta, water velocity, turbidity, total dissolved solids, Chlorophyta, alkalinity, conductivity, pH, Charophyta clustered together with PG, Opa River and Esimirin as presented in Figure 2. There is strong negative correlation between dissolved oxygen, Cyanophyta, nitrate clustered with Obudu River and Amafa river while Myzoza, Ochrophyta clustered with Parakin River (Figure 2).

Seasonally, the highest phytoplankton organisms were recorded during dry season (38,470 Org/m^3) as compared to wet season (16,075 Org/m^3). *Closterium sp* and *Anaebana* sp showed significant differences ($p < 0.05$) in seasonally mean variation (Table 6). Dominance index, Shannon index, Evenness index, and Margalef (0.3553, 3.900, 0.705, and 7.131) were higher during the wet season compared with the dry season while Simpson and Berger- Parker's (0.972 and 0.586) were higher in dry season (Table 4). There is strong correlation between air temperature, alkalinity, Cyanophyta, Ochrophyta, phosphate clustered with dry season while Myzozoa, nitrate, water depth, Euglenophyta, turbidity, water temperature, total organic carbon, pH, water velocity, Chlorophyta, biological oxygen demand, sulphate, Bacillariophyta, conductivity showed a negative relationship with wet season (Figure 3).

Table 2: Spatial variations of Physicochemical Water Quality Parameters of Opa Reservoir Tributaries

Parameters	Stations						ANOVA	
	Parakin	Esinimirin	Obudu	Opa	Amafa	PG		
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	F-Value	Prob
DO (mg/L)	6.58 ± 3.34	6.74 ± 3.74	6.755 ± 2.50	6.53 ± 2.69	7.67 ± 2.06	6.937 ± 2.90	0.243	0.942
BOD (mg/L)	3.01 ± 2.40	3.62 ± 2.65	2.755 ± 1.47	3.52 ± 2.03	2.96 ± 2.03	3.483 ± 2.05	0 .339	0.877
Conductivity (µS/cm)	232.92 ± 35.73	297.92 ± 50.46	109.10 ± 21.18	113.83 ± 18.23	142.60 ± 39.77	168.16 ± 31.44	55.410	0.000***
TDS (mg/L)	165.50 ± 18.11	222.25 ± 50.80	76.36 ± 15.69	77.58 ± 12.46	99.06 ± 30.46	123.48 ± 17.61	0.339	0.887
pH	7.13 ± 0.40	7.14 ± 0.56	7.06 ± 0.53	6.99 ± 0.51	6.94 ± 0 .62	7.12 ± 0.38	0.337	0.889
Nitrate (mg/L)	0.55 ± 0.67	0.45 ± 0.59	0.59 ± 0.71	0.37 ± 0.32	0.49 ± 0.59	0.57 ± 0.65	0.250	0.938
Air temperature (°C)	23.95 ±4.27	22.70 ± 4.19	15.70 ± 2.10	22.25 ± 4.02	21.43 ± 4.37	21.96 ± 6.00	55.410	0.000***
Water temperature (°C)	22.36 ± 4.87	22.57 ± 4.89	20.96 ± 4.53	20.92 ± 4.66	20.52 ± 5.24	20.81 ± 4.69	0.395	0.851
Water depth (m)	0.38 ± 0.21	0.52 ±0.46	0.14 ± 0.09	0.35 ± 0.23	0.35 ± 0.16	0.19 ± 0.11	3.89	0.004**
Water Velocity (m/s)	0.20 ± 0.24	0.11 ±.14	0.14 ± 0.07	0.13 ± 0.09	0.16 ± 0.23	0.27 ± 0.26	1.152	0.342
Turbidity (NTU)	106.07 ± 76.40	85.34 ± 18.22	112.54 ± 100.35	73.18 ± 69.47	93.38 ± 40.93	96.87 ± 45.91	0.582	0.714
Alkalinity ($CaCO_3$mg/L)	116.50 ± 49.81	155.42 ± 67.17	52.05 ± 18.54	63.83 ± 24.36	59.25 ± 35.41	77.59 ± 35.38	11.270	0.000***
Phosphate (mg/L)	6.96 ± 13.21	2.89 ± 5.80	3.02 ± 4.23	12.00 ± 19.55	3.66 ± 4.71	4.60 ± 4.34	1.366	0.242
TOC (mg/L)	3.21 ± 3.43	3.21 ± 4.29	3.83 ± 0.50	4.81 ± 4.91	4.82 ± 4.22	5.38 ± 5.84	0 .542	0.744
Organic matter (mg/L)	5.53 ± 5.91	5.53 ± 7.40	6.59 ± 4.32	8.29 ± 8.47	8.29 ± 7.27	9.28 ± 10.06	0.542	0.744
COD (mg/L)	8.56 ± 9.14	8.56 ± 11.45	10.21 ± 0.68	12.84 ± 13.10	12.84 ± 11.25	14.37 ± 15.57	0.542	0.744
Sulphate (mg/L)	0.54 ± 0.67	0.54 ± 1.11	1.64 ± 0.93	1.83 ± 2.68	0.50 ± 0.62	1.00 ± 1.32	1.927	0.102

Table 3: Seasonal Variations of Physico-chemical Water Quality Parameters of Opa Reservoir Tributaries

Parameter	Season				Anova		Overall	
	Dry Season		Rainy Season					
	Range	Mean± SD	Range	Mean± SD	F	P	Range	Mean± SD
Air temperature (°C)	12.00 - 31.00	23.043 ± 5.55	0.00 - 28.00	20.63 ± 4.69	3.90	0.05*	12.00 - 31.00	21.63 ± 5.17
Alkalinity ($CaCO_3$)	32.00 – 217	88.42 ± 51.14	8.00 - 293.00	86.72 ± 57.78	0.428	0.515	8.00 - 293.00	87.43 ± 57.74
BOD (mg/L)	0.20 - 6.6	2.48 ± 1.74	0.20 - 9.2	3.757 ± 2.16	1.661	0.202	0.20 - 9.20	3.22 ± 2.08
COD (mg/L)	0.00 - 46.96	13.46 ± 12.82	0.00 - 38.17	11.46 ± 10.28	1.499	0.225	0.00 - 46.97	12.29 ± 11.35
Conductivity (µS/cm)	90.00 - 330.00	183.43 ± 76.80	77.20 - 382.00	173.14 ± 76.07	0.002	0.969	77.20 - 382.00	177.40 ± 76.01
DO (mg/L)	1.40 - 10.0	5.741 ± 2.12	2.40 - 14.80	7.68 ± 3.04	4.128	0.046	1.44 - 14.8	6.80 ± 2.80
Nitrate (mg/L)	0.02 - 0.64	0.16 ± 0.15	0.04 - 2.24	0.75 ± 0.65	32.735	0.000***	0.02 - 2.24	0.50 ± 0.58
Organic matter (mg/L)	5.05 - 30.35	8.69 ± 8.28	0.00 - 24.66	7.40 ± 6.64	1.499	0.225	5.05 - 30.35	7.94 ± 7.30
pH	5.40 - 8.30	7.20 ± 0.67	6.00 - 7.60	6.96 ± 0.28	23.112	0.000***	5.40 - 8.30	7.06 ± 0.49
Phosphate (mg/L)	0.60 - 67.84	8.49 ± 13.36	0.00 - 44.84	3.41 ± 7.42	4.988	0.029*	0.00 - 67.84	5.52 ± 10.53
Sulphate (mg/L)	0.01 - 6.70	1.30 ± 1.82	0.00 - 4.01	0.88 ± 1.08	6.852	0.011**	0.00 - 6.70	1.00 ± 1.40
TDS (mg/L)	71.00 - 350.00	138.95 ± 66.59	50.30 - 259.00	119.09 ± 51.98	0.956	0.331	50.30 - 350.0	127.37 ± 58.80
TOC (mg/L)	0.00 - 17.61	5.05 ± 4.80	0.00- 44.84	4.29 ± 3.85	1.499	0.225	0.00 - 17.61	4.61 ± 4.25

Turbidity (NTU)	16.00 - 96.90	78.12 ± 20.35	49.00 - 430.00	106.32 ± 79.55	8.942	0.004**	16.00 - 430.00	94.56 ± 63.40
Water depth (m)	0.50 - 0.42	0.19 ± 0.13	0.10 - 1.75	0.42 ± 0.29	4.674	0.034*	0.10 - 1.75	0.32 ± 0.26
Water temperature (°C)	19.00 - 32.00	23.79 ± 3.66	10.00 - 27.00	19.62 ± 4.64	3.072	0.084	10.00 - 32.00	21.35 ± 4.71
Water Velocity (m/s)	0.02 - 0.98	0.16 ± 0.23	0.05 - 0.75	0.18 ± 0.15	0.207	0.651	0.02 - 0.98	0.16 ± 0.19

Table 4: Spatial and Temporal Abundance and Distribution of Phytoplankton Species of Opa Reservoir Tributaries

Organisms	**Spatial variation**						**Temporal variation**	
	Parakin	**Esinimirin**	**Obudu**	**Opa**	**Amafa**	**PG**	**wet season**	**Dry season**
Bacillariophyta	3200	5325	1725	1350	1125	975	6075	8075
Charophyta	3025	1800	600	375	75	450	2025	4350
Chlorophyta	1350	1675	375	300	225	450	2500	1875
Cyanophyta	10050	3750	7875	825	3095	1350	3600	23345
Euglenophyta	150	975	525	75	750	225	1875	825
Mzozoa	225	0	0	0	0	0	225	0
Ochrophta	675	0	0	0	0	0	150	525
Overall Abundance	**18675**	**13525**	**11100**	**2925**	**5270**	**3450**	**16075**	**38470**
Number of Species Identified	**47**	**33**	**22**	**19**	**15**	**22**	**70**	**88**
Mean Abundance	**397**	**409**	**505**	**154**	**351**	**157**	**229**	**962**

Table 5: Spatial and Temporal Diversity Indices of phytoplankton species of Opa Reservoir Tributaries

Diversity Indices	**Spatial**						**Temporal**	
	Parakin	**Esinimirin**	**Obudu**	**Opa**	**Amafa**	**PG**	**Wet Season**	**Dry season**
Taxa index (S)	**47**	**33**	**22**	**19**	**15**	**22**	**70**	**88**
Dominance index (D)	0.237	0.104	0.417	0.125	0.369	0.104	0.027	0.353
Simpson index (A)	0.762	0.895	0.583	0.874	0.630	0.896	0.972	0.646
Shannon index (H)	2.501	2.797	1.623	2.413	1.621	2.851	3.900	1.969
Evenness index (E)	0.259	0.482	0.220	0.697	0.337	0.665	0.705	0.188
Margalef index (R1)	4.677	3.473	2.362	1.879	1.634	3.069	7.131	3.501
Berger-Parker's (P)	0.473	0.252	0.635	0.256	0.587	0.282	0.080	0.586

Table 6: Significant Spatial Variation among observed Phytoplankton is shown using ANOVA Statistics

Organism	**Parakin**	**Esinimirin**	**PG**	ANOVA
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**P**
Leptocylindricus danicus	18.75±33.92	6.25±21.65	12.50±29.19	0.04

Table 7:. Seasonal Variation among recorded phytoplankton

Organisms	**Dry season**		**Rain season**		**t-test**	**P**
	Min – Max	**Mean ± SD**	**Min – Max**	**Mean ± SD**		
Closterium sp	0.00 - 75.00	15.63 ± 31.11	0.00 - 75.00	1.56 ± 10.83	7.975	0.006**
Anaebana sp	0.00 - 6000.00	930.21 ± 1575.39	0.00 - 750.00	26.56 ± 121.32	15.83	0.000***

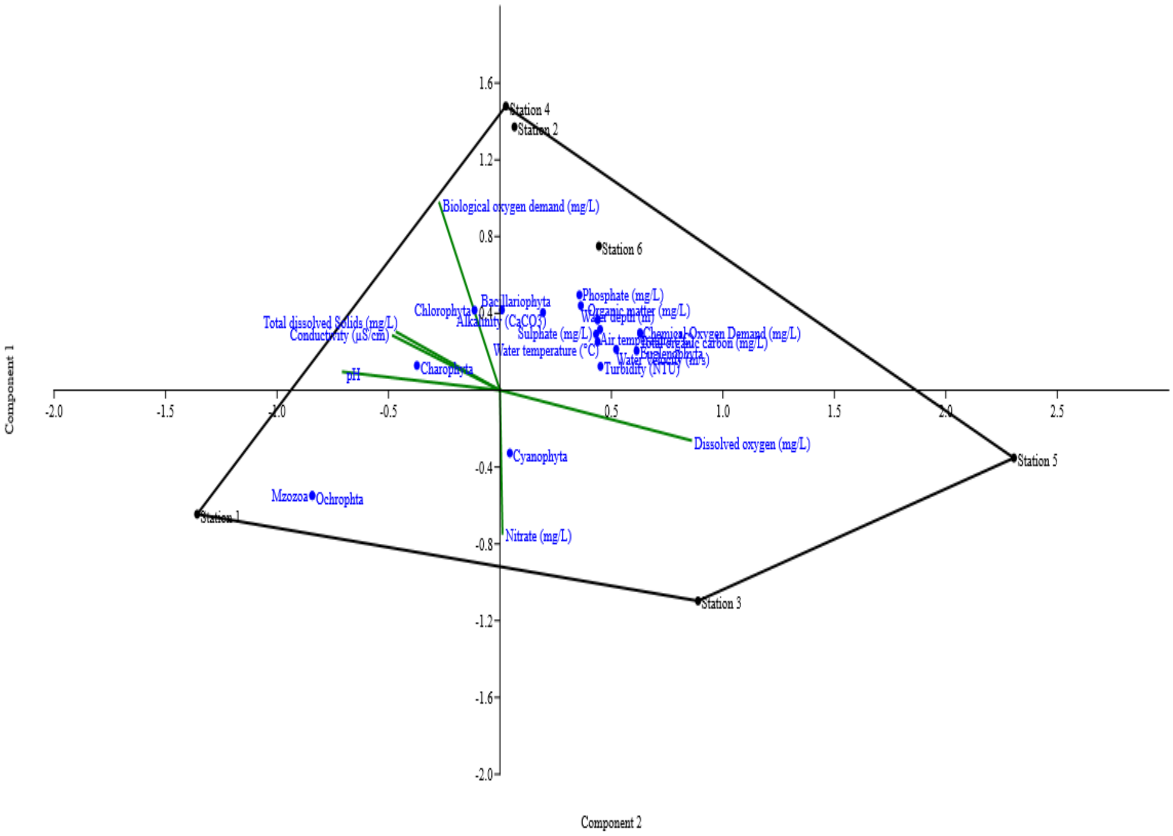

Figure 2. Canonical Correspondence Analysis (CCA) showing relationship between phytoplankton groups and environmental variables across the stations

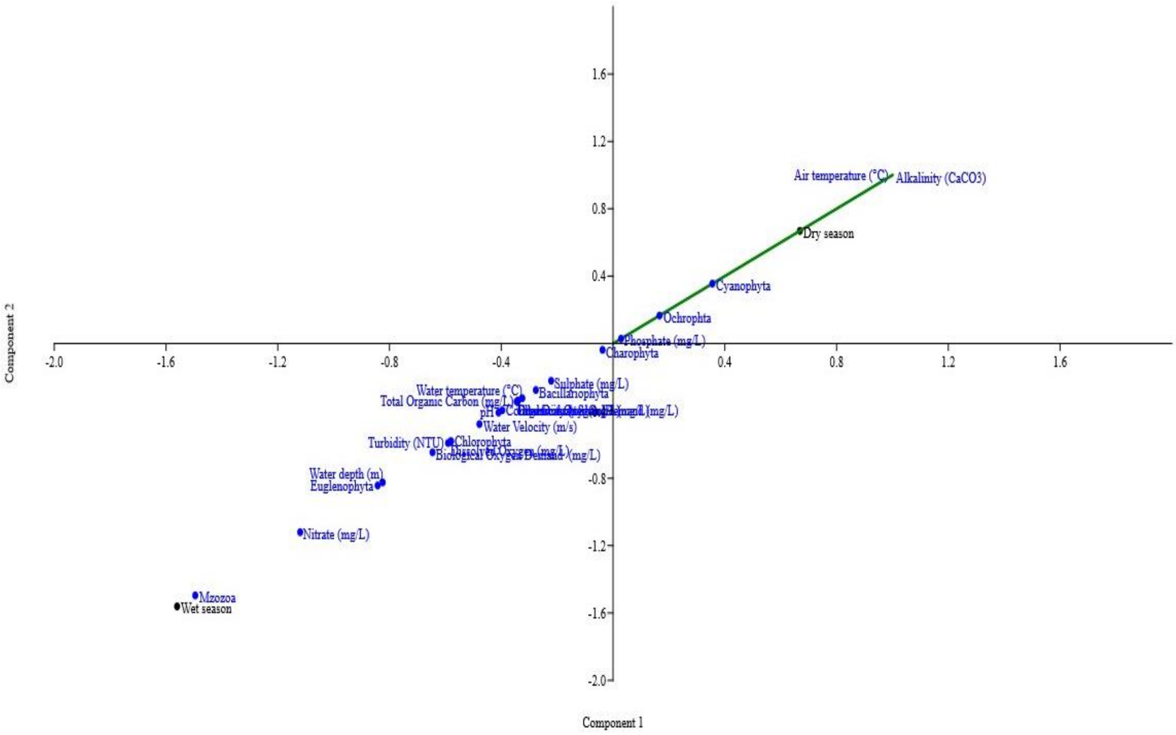

Figure 3. Canonical Correspondence Analysis (CCA) showing relationship between phytoplankton groups and environmental variables between the seasons

Discussion

There is fluctuation in the results of physico-chemical parameter and phytoplankton structure of Opa reservoir tributaries examined during this study, this could be due to influence of human activities around/ within these tributaries Total dissolved solids, pH water temperature, air temperature, water depth and alkalinity in the Esimirin. The higher mean values of BOD, conductivity, River might be due to high discharge of domestic wastes from Ife town into the river influence the variation observed in water quality. Changes in physicochemical parameters of aquatic ecosystems have significant impact on the species that live therein (Akinyemi *et al*.,2022). The significant differences observed in mean values of conductivity, air temperature and alkalinity across all the stations maybe due to the impact of dredging of water body during period of sample collection. The Highest DO mean concentration recorded from Amafa River, fall within DO range reported by Begum *et al.* (2012) and the lowest DO mean concentration observed in Parakin River, is also in compliance with the minimal suggested standard (5 ppm) suitable for aquatic organisms (USEPA 2008; Yajurvedi 2008). Highest turbidity observed in Obudu River was due to the presence of high suspended matter (Meesukko *et al.,* 2007). Additionally, highest concentration of Phosphate and COD in Opa River could be attributed to surface water influx that carried fertilizers from the nearby agricultural area (Tilahun *et al.,* 2015).

Phytoplankton abundances is related to the higher quantity of phytoplankton during the rainy season (Lawal *et al.,* 2020) and the high rate of evaporation during the dry season (Araoye, 2008). The dry season generated the highest mean values of air temperature, alkalinity, COD, conductivity, organic matter, pH, phosphate, sulphate TDS, total organic carbon, and water temperature while BOD, DO, nitrate, turbidity, water depth and water velocity were higher in wet season. Seasonal change can alter/ influence the physicochemical parameters of waterbody. The findings corroborated those of Atobatele and Ugwumba (2008), who reported elevated pH, electrical conductivity, and total dissolved solids in the Aiba River during the dry season. Variations in the physicochemical parameters in the tributaries under study may account for the temporal and geographical variability in phytoplankton composition and abundance. The six divisions that contain the phytoplankton species found in this study are Bacillariophyta, Cyanophyta, Charophyta, Euglenophyta, Myxozoa, and Ochrophyta. The highest phytoplankton abundance was observed in Parakin, followed by river Esinmirin, this trend of abundance could be connected to the impacts of anthropogenic activities, seasonal changes (Emeka *et al.,* 2021) and garbage management, which could have influenced the prevalence of tolerant phytoplankton species. Least abundance of phytoplankton recorded in Obudu and Opa Rivers correlated with perturbation from artisanal fishing and runoffs from farmland into the river and confirmed low organic contamination in its watershed. *Leptocylindricus danicus* (the most spatially significant species) in this study revealed organic pollution in the studied tributaries (Gonzalo *et al*., 2012 and Adedeji *et al.,* 2017). High concentrations of silicates in the water brought on by sand mining activities (Ekwu *et al.,* 2014) are responsible for the dominance of division Bacillariophyta recorded during the time of sampling, it also suggests organic pollution and disruption in the waterbody. Several diatom species could withstand temperatures of up to 35°C. The negative correlation of Bacillariophyta with wet season was an indication that, Bacillariophyta was depleted during the wet season, however, Bacillariophyta may be season dependent in this study. *Anabaena* sp. was the predominant species during the sampling period and significantly seasonal due to the concentration of nitrate, phosphate, and sulphate (Moshood, 2010). The nutrients have been known to be limiting in phytoplankton growth. This is evident from the positive close relationship between limnological variables and biological variables. Highest phytoplankton abundance in Parakin River was linked to higher inputs of nutrients in the river coming from farmland and sediments, with the river located in the riverine zone and residential area. The preponderance of *Closterium sp* being seasonally significant might have occurred in response to the availability and utilization of nitrate and phosphate ions.

The highest Shannon-Wanner index values was recorded in PG, Esinmrin and Parakin Rivers (2.851, 2.797 and 2.501) as well in the wet season (3.900) likewise, the Margalef index was in PG, Esinmrin and Parakin Rivers (3.069, 3.473 and 4.677) as well in the wet season (7.131). This indicates that, there is high diversity of phytoplankton species at these sampling locations, Therefore, greater diversity is indicated by a higher Shannon index value. Water bodies that have an algal Shannon index of less than one is categorized as highly polluted (1-3); moderately polluted (> 3); and clean (> 1) (Islam *et al*, 2010 and Tanimu *et al.,* 2011). This result obtained is aligned with the work of Adesalu (2010) who reported that high value of Shannon index in Kainji Lake. The highest Simpson index were observed in Esinmirin, Opa and PG (0.895, 0.874 and 0.896) as well in in the wet season (0.972). When Simpson value tend toward to zero indicate there is high diversity in that population and when tends towards one indicates no diversity. The Simpson index values for Esinmirin, Opa and PG rivers as well in wet season tends toward 1 to represent a community with one species. The value of evenness varies between 0 and 1. The closer the value to 1, the more even the population of phytoplankton species that form the community. High evenness values were observed in Esinmrin, Opa and PG rivers (0.482. 0.697 and 0.665). The diversity indices recorded during this study were similar to the work of Lawson *et al.* (2004) in Majidun Creek, Lagos, Nigeria and Ogaba *et al.* (2017) in Ikoli Creek, Niger Delta, Nigeria.

CONCLUSION

Sampled tributaries showed phytoplankton richness. The presence of Bacillariophyta, Cyanophyta, Charophyta and Myzozoa in the tributaries revealed that, the main reservoir may be faced with eutrophication threat. However, significant seasonal variation of *Anabaena sp and Closterium sp* could mean that the tributaries are polluted as a result of anthropogenic activities and municipal waste. This may resultantly lead to deterioration of the main reservoir since the sampled tributaries flows into it.

REFERENCES

Adesakin, T. A., Adedeji, A. A. Aduwo, A. I. and Y. F. Taiwo, "Effect of discharges from rechanneled rivers and municipal runoff on water quality of Opa reservoir, Ile-Ife, Southwest Nigeria," *African Journal of Environmental Science and Technology,* vol. 11, pp. 56-70,2017. https://doi.org/10.5897/ajest2016.2086

Ananthan G, (2004). Observations on environmental characteristics of Ariyankuppam estuary and Verampattinam coast of Pondicherry. *J. Aqua. Biol. 19, 67–72.*

Arayoye P. A. (2008). Physical factors and their influence on fish species composition in Asa Lake Ilorin, Nigeria. *International Journal of Tropical Biological, 57(1-2): 167-175*

Atobatele O.E (2008). Seasonal Variation in the Physico-chemistry of a small Tropical reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology, 7(12): 62-171*

Begum R, (2012). Limnology of a Conserved man-made lake in Bangladesh. Physical and chemical factors. Dhaka University Journal of Biological Science 21 (2), 131-1

Bellinger, E.G. and Sigee, D.C (2010): Freshwater algae: Identification and use as bio-indicators. *John Wiley and Sons, Ltd*. Pp 137-254

Brierley, B., Carvalho, L., Davies, S., and Krokowski, J. (2007): Guidance on the quantitative analysis of phytoplankton in freshwater samples. Report to SNIFFER (Project WFD80), Edinburgh.

Daniel V (2001) Phytoplankton. Encyclopedia of life sciences. *Macmillan Publishers Ltd, Nature Publishing Group, New York, pp 1–5*

Ekhator, O., Opute. F. I and Akoma, O. C (2014): A checklist of the Phytoplankton Flora of A Southern Nigerian Lotic Ecosystem. *Current Research journal of Biological Sciences 6(1) 2014 : 1-6*

Ekwu A. O. and N. D Udo, Plankton Communities of Ikpa River, Southeast Nigeria Exposed to Sand dredging Activities," Journal of Fisheries and Aquatic Science, vol. 9, no. 5, pp. 345- 351

Fernando C.H. (2002): A guide to tropical freshwater zooplankton: identification, ecology and impact on fisheries. Backhuys Publishers, Leiden, The Netherlands.

Akinyemi, S. A., Chia, M. A., Jimoh, M. A., Okpanachi, I. Y., Oyeleke, D. O, An investigation of physicochemical parameters and phytoplankton community structure of Eko-Nde reservoir in Osun State, Nigeria. *FUDMA Journal of Sciences (FJS)* Vol. 6 No. 1, 2022, pp 44 – 53.

Gonzalo, C. and J.A. Camargo. 2012. Fluoride bioaccumulation in the signal crayfish *Pacifastacus leniusculus* (Dana) as suitable bioindicator of fluoride pollution in freshwater ecosystems. Ecological Indicators 20: 244-251.

Goswami H. V. (2004): *Marine Ecology*. University of California, USA. Pp205-211 Impact of physicochemical parameters on phytoplankton compositions and abundances in Selameko Manmade Reservoir, Debre Tabor, South Gondar, Ethiopia, *Appl Water Sci (2017) 7:1791–1798 DOI 10.1007/s13201-015-0352-5*

Janse Van Vuuren, S., Taylor, J., Gerber, A. and Van Ginkel, C. (2006): Essay identification of the most common freshwater algae. In: *A guide for the identification of microscopic algae in South African Freshwaters*. Resource Quality (RQS), U.S.A.

Lacuna *et al.,* 2012 Phytoplankton diversity and abundance in Panguil Bay, Northwestern Mindanao, Philippines in relation to some physical and chemical characteristics of the water. Advances in Environmental Sciences - *International Journal of the Bioflux Society*

Lawal, N *et al.*, (2020) Phytoplankton Population in Relation to Physicochemical Parameters of Gwaigwaye Reservoir Katsina State, Nigeria *J. Appl. Sci. Environ. Manage. Vol. 24 (1) 73-78*

Lawson, E. (2004). Physico -Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research, International Digital Organization for Scientific Information Publications 5(1): 08-21*.

Lijin, Ji Fenfen, Hua Jianghuan. Community structure of phytoplankton and the water quality assessment in spring in Lake Ci[J]. *Journal of Hubei* Normal University (Natural Science), 2014, (03):1-7.

Meesukko C, *et al.*, (2007) Relationships between seasonal variation and phytoplankton dynamics In Kaeng Krachan reservoir. Phetchaburi Province, Thailand. *Nat Hist J Chulalongkorn Univ 7(2):131–143*

Molles, M. (2005): *Ecology: Concepts and Applications*. Boston, McGraw Hill. 608 p.

Moshood K (2010) Seasonal Influence of Limnological Variables on Plankton Dynamics of a Small, Shallow, Tropical African Reservoir. *ASIAN J. EXP. BIOL. SCI., VOL 1 (1) 2010:60-79*

Ogunkoya (2013): 'All Rivers Run Into the Sea: Yet the Sea is Not Full……' *Inaugural Lecture Series 256*

Olele, N.F. and Ekelemu, J.K. (2008). Physicochemical and Phytoplankton Study of Onah Lake, Asaba, Nigeria. *African Journal of General Agriculture, **4**(3): 25 - 32.*

Rajesh, K.M, G. Gowaa and M.R. Mendon, 2002. Primary productivity of the brackish water impoundments along Nethravahi estuary, Mangalore in relation to some physico-chemical parameters. *Fish Technol., 39:85-87*

Rani, R. and Sivakumar, K. (2012) Physico-chemical parameters and phytoplankton richness in certain ponds of Chidambaram, Cuddalore district of Tami Nadu. International Journal of Research in Environmental Science and Technology,2(2).35-44

Shekhar STR, Kiran BB, Puttaiah T, Shivraj Y, Mahadevan KM (2008). Phytoplankton as index of water quality with reference to industrial pollution. *J. Environ. Biol. 29(2):233-236*

Suthers L.M. and Rissik D. (2009): Plankton: A guide to their ecology and monitoring for water quality. CSIRO Publishing, Oxford University Press, London.

Tanimu.Y, Tanimu, J., Bako, S.P., Adakole, J.A (2011): Phytoplankton as bioindicators of water quality in Saminaka Reservoir, Northern-Nigeria. *Science press USA*.Pp 318-322.

Tas, B. Arif, and Gonulo, I. (2007). An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey. Journal of Environmental Biology, 28:439-445

Tilahun A. and Ayale, W. (2016) "Analysis of water quality of Selameko man-made reservoir using physico chemical parameters for fishery, Debre Tabor, South Gondar (Ethiopia)," *International Journal of Water Resources and Environmental Engineering*, vol. 8, no. 6, pp. 74–80, 2016.

USEPA (2008) Nutrient criteria technical guidance manual wetlands. EPA document: EPA-822-B 08-001 U

USEPA (United State Environmental Protection Agency) (2000) Limnology, water quality parameters, conditions, and ecoregions 1–3

Usman, L. U. (2016). Some Limnological and Biological Aspects of Ajiwa Reservoir, Katsina State, Nigeria. (M.Sc. Dissertation). Department of Biological Sciences, Ahmadu Bello University, Zaria. Pp 112-118.

Venkatesharaju K, (2010) Study of seasonal and special variation in surface water quality of Cauvery River stretch in Karnataka, *Journal of ecology and the natural environment 2(1): 001-009.*

Wehr, D. J., Sheath, R. G., 2003; Freshwater Algae of North America Ecology and Classification

WHO (2006) "Guidelines for Drinking Water", 1st Addendum to 3rd edition, Vol.1, Recommendations, Geneva.

Witty, L.M (2008): Practical guide to identifying freshwater crustacean zooplankton. Cooperative freshwater ecology unit, 2004, 2nd Edition .http//www.marex.uga.edu/aquarium

Yajurvedi HN (2008) A study of growth on co-efficient and relative condition of factor of the major carp (Catla catla) in two lakes differing in water quality. Department of Zoology, University of Mysore, Mysore

Yamaguchi, E. and Gould, A. (2002): Phytoplankton Identification Guide. The university of Georgia Marine Education Centre and Aquarium. *http://www.marex.uga.edu/aquarium*