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AN INVESTIGATION OF PHYSICOCHEMICAL PARAMETERS AND PHYTOPLANKTON COMMUNITY STRUCTURE OF EKO-NDE RESERVOIR IN OSUN STATE, NIGERIA

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ABSTRACT
This research was carried out to determine the relationship between physicochemical variables and phytoplankton community of the Eko-Nde reservoir. Changes in physicochemical parameters of aquatic ecosystems have significant impact on the species that live therein. Eko-Nde reservoir is of socio-economic significance to communities that surround it, which necessitates a proper study of the phytoplankton composition and environmental status of the reservoir. Water samples were collected from two stations in the reservoir from January 2019 to August 2019 and analysed for physicochemical parameters, phytoplankton composition and abundance. Analysis of variance (ANOVA) was performed on correlation models to assess their prediction of phytoplankton community diversity. A total of 2039 cells ml^{-1} belonging to four (4) major divisions were dominant in the order; Bacillariophyta (898 cells ml^{-1}) > Charophyta (788 cells ml^{-1}) > Chlorophyta (302 cells ml-1) > Cyanophyta (51 cells ml^{-1}). Principal Component Analysis and Canonical Corresponding Analysis showed that certain physicochemical variables such as temperature, pH and total hardness were key drivers of the phytoplankton community structure of the reservoir. Diversity indices showed moderate abundance and distribution of phytoplankton species, with the highest diversity of species in the months associated with the rainy season. The appearance of pollution tolerant species such as Anabaena circinalis, Oscillatoria limosa, Nitzschia gracilis, Cymbella mexicana, Pediastrum boryanum, Synedra ulna, Cyclotella meneghiniana and Gomphonema spp. suggest that the reservoir was on the verge of pollution. Anthropogenic activities around the reservoir should be closely monitored to avoid health risks to humans and endangerment of aquatic organisms.

Keywords: Species diversity, Physicochemical parameters, Water quality

INTRODUCTION

Phytoplankton is the bedrock of the food chain of almost all aquatic ecosystems (Babatunde et al., 2014). They serve a crucial role in maintaining the balance between living organisms and environmental factors since they are primary producers. Water is a major component of the biosphere and essential for continuous existence of living organisms. Ayanwale et al., (2012) describes water quality as a sum total of the physical, chemical and biological properties of water with regards to their usefulness for living organisms. The physicochemical parameters of water (such as pH, temperature, turbidity, total hardness, total dissolved solids, total suspended solids, dissolved oxygen, biochemical oxygen demand, conductivity and nutrient composition) have considerable impacts on water quality and phytoplankton community of aquatic ecosystems (Inyang et al., 2016) which makes phytoplankton useful in monitoring the ecosystem.

Phytoplankton are indicators of water quality because they have a fast turnover rate and are sensitive to environmental challenges. Thus, a phytoplankton survey can assist in determining the ecosystem's trophic state and level of organic contamination (Ramchandra and Solanki, 2007). Many researchers have stated that algae are trustworthy indicators of contamination (Palmer, 1969; Patrick, 1970; Nandan and Patel, 1986; Salmaso et al., 2006; Katsiapi et al., 2011). Increased eutrophication of West African rivers has been documented in scientific studies (Chia et al., 2011; Ibrahim et al., 2021) which leads to the formation of harmful algal blooms with adverse influence on human health.

The phytoplankton flora composition in the reservoirs of Southwestern Nigeria have been studied in recent years. Dimowo (2013) studied the composition and abundance of algae in River Ogun, Abeokuta, located in southwestern part of Nigeria. Akin-Oriola (2003) investigated the phytoplankton flora and physicochemical properties of the Awba reservoir in Ibadan with findings that Microcystis aeruginosa was the most prevalent phytoplankton species, which has been linked to harmful blooms in freshwaters. Although a few studies have investigated the ecology of some reservoirs in the southwestern region of the country, these studies constitute a tiny fraction of the numerous reservoirs, making it difficult to understand the true state of aquatic ecosystems of the southwestern region. The Eko-Nde Reservoir in Osun state supplies potable water to the communities that surround it. The study of physicochemical parameters in relation to phytoplankton community of the reservoir will help understand its current ecological state (Rani and Sivakumar, 2012). Thus, this study aimed to investigate physicochemical parameters of water that are key drivers of the phytoplankton community of Eko-Nde Reservoir, Osun state, Nigeria.

MATERIAL AND METHODS

Study Area

Eko-Nde town is located in the western part of Ikirun, Osun State. The coordinates are 7^0 55′ 60″ N and 4^0 34′ 60″ E in DMS or 7.93333 and 4.58333. It has a tropical climate with an average temperature of 26^0C and an annual rainfall of 1,254 millimeters with peaks in July and September (Osun State Water Corporation Report, 1994). There is little or no rain between November and February. The town is located at an elevation of 377 meters above sea level with a population of 138, 367 (Osun State Water Corporation Report, 1994). Eko–Nde Reservoir (built on Otin River) is located in Eko-Nde town, an agrarian community in Ifelodun Local Government Area of Osun State (Fig. 1). It was created to supply potable water to the communities of Oba, Eko-Nde, Eko-Ajala, Ikirun, Iragbiji and Okuku (Adediji and Ajibade, 2008). The reservoir is surrounded by a diverse cultivation of crops such as maize, cassava, yam, cocoa, kolanut and palm trees (Oladejo, 2016).

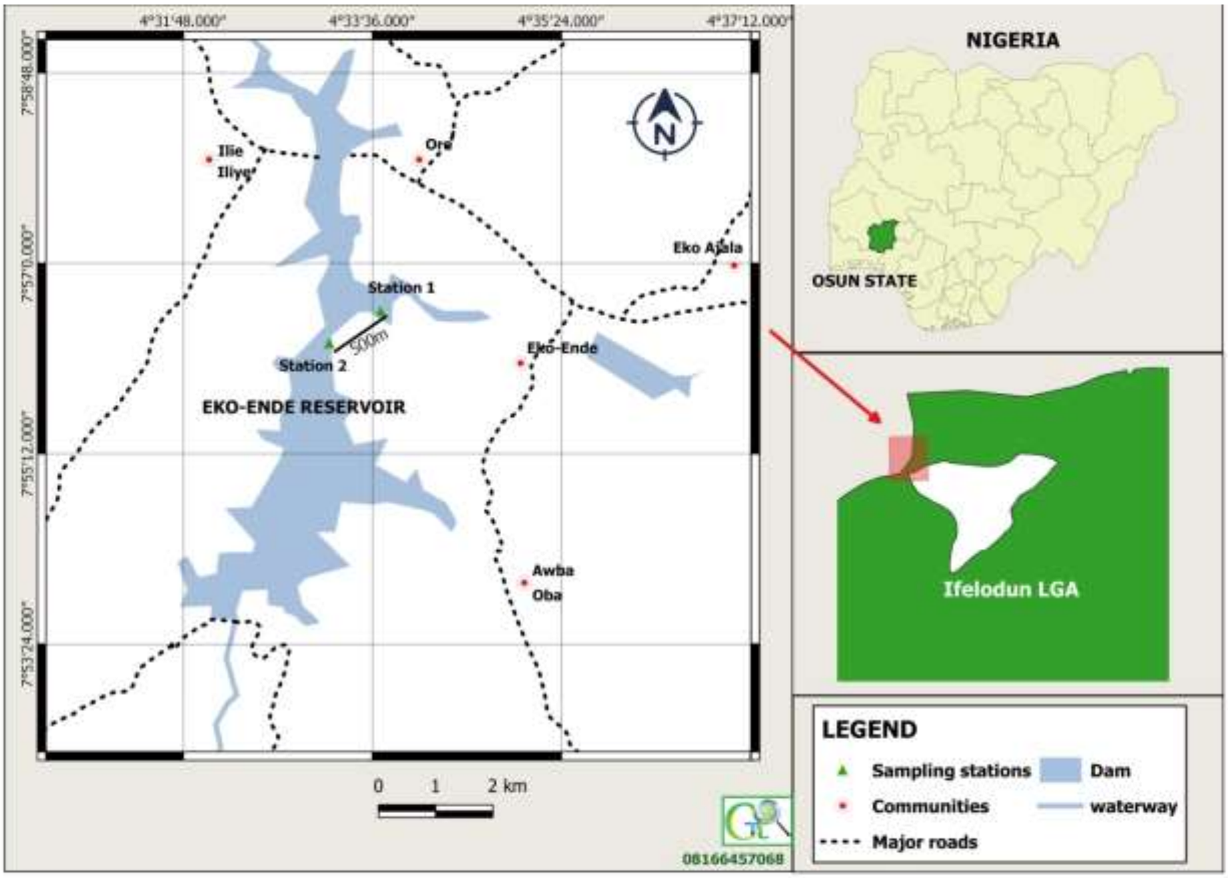

Figure 1: Map showing the Sampling Stations of Eko-Nde Reservoir, situated in Ifelodun LGA, Osun State, Nigeria

Sampling and Analysis

Water and phytoplankton samples were collected monthly from January to August 2019 at two stations created within the reservoir body. Sampling stations were chosen based on accessibility and the various activities that take place around the reservoir. Sampling stations were established along the length of the reservoir. The first station was located towards the reservoir's exit while the second station was located close to the reservoir inlet characterized by high water flow rates. The two stations (at a distance of 500m apart) are under high anthropogenic activities like fishing, farming and bathing. Water samples from the stations were analyzed for physicochemical parameters.

Temperature: The water temperature was measured in-situ with a digital thermometer.

pH: pH of the water was measured using a PH meter (Hanna Model H 1-98107).

Turbidity: Turbidity was determined with the use of a Secchi disc.

Silica: Silica was measured as described by APHA (2005).

Dissolved Oxygen (DO): The dissolved oxygen concentration was measured with an oxygen meter.

Biochemical Oxygen Demand (BOD): Biochemical oxygen demand was measured after the fifth day of incubation.

Total hardness, Calcium hardness and Magnesium hardness: Total hardness, Calcium hardness and Magnesium hardness were determined using titrimetric method (APHA, 2005).

Total Alkalinity, Carbonate and Bicarbonate: Total Alkalinity, Carbonate and Bicarbonate were also determined by the titrimetric method (APHA, 2005).

Phosphate and Nitrate: Phosphate and nitrate were determined spectrophotometrically according to APHA (2005).

Potassium: Potassium was determined using CORNING'S flame photometer.

Calcium: Calcium was determined using the EDTA method.

Chloride: Titrimetric method described by APHA (2005) was employed for the analysis of chloride content of the water sample.

Electrical Conductivity (EC): A conductivity meter was used to determine the conductivity of the water sample.

Collection of phytoplankton sample

Samples for phytoplankton were collected into 250ml plastic bottles using a plankton net with a mesh size of 55µm. The water samples were stored and fixed with 4% formalin in-situ before transportation to the laboratory. They were then viewed under a 3000/LED trinocular microscope with a digital camera.

Identification of Phytoplankton

Phytoplankton species were identified using identification keys, available literature and standard books (Bellinger and Sigee, 2010).

Statistical procedure

Correlation models were used to evaluate the association between stations and sampling time with the community diversity indices used in this study. The segregation of phytoplankton into environmental gradients was explored using canonical correspondence analysis. Also, analysis of variance (ANOVA) was performed on the models to assess their prediction of phytoplankton community diversity. Species richness was defined as the total number of phytoplankton species sampled; the Shannon-Weiner index was employed to measure the species diversity weighted by relative abundance (Magurran, 2004) and rarefied species richness was used to account for differences in abundance of phytoplankton between the months (Heck *et al.*, 1975).

Community structure analysis and ordination methods used in the present study were done using the 'vegan' R package (Oksanen *et al.,* 2015). Canonical correspondence analysis was performed to establish the relationship between physicochemical variables and the phytoplankton of the reservoir. The abiotic variables that made independent and significant contributions to the variations of phytoplankton composition and abundance of the stations were identified using permutation tests and then selected by a variance inflation factor (VIF). Only variables with a VIF of less than 20 were used in performing CCA.

Physicochemical characteristics data were evaluated for normality and homogeneity of variance with Shapiro Wilk and Levene's tests respectively. Differences in mean of water quality parameters were determined using a two-way analysis of variance. Separation of significantly different means was done using the LSD test function of the 'agricolae' R package. All statistical analyses were done using R version 4.1.0 GUI 1.76 High Sierra build for macOS at a 5% significance level.

RESULTS

Physicochemical parameters

Variations in the physicochemical parameters of Eko-Nde Reservoir within the sampling period are shown in Table 1 and Figure 2. The PCA (Figure 3) demonstrated the significance of some physicochemical parameters (BOD, DO, EC, temperature, turbidity, hardness, alkalinity and pH) which had tremendous impact at the stations.

The highest pH value (8.4) was recorded in July at Station 1, while the lowest value (7.0) was recorded in February at Station 1. Total hardness was highest (90.4 mgl^{-1}) in August at Station 2 and the lowest value (30.4mgl^{-1}) was recorded at Station 1 in January. Total alkalinity was highest (66.1mgl^{-1}) in June at Station 1 and the lowest value (49.1mgl^{-1}) was at Station 1 in January. BOD was highest (0.18 mgl^{-1}) in March at Station 1 and the lowest (0.11 mgl^{-1}) was in August at Station 2. Dissolved Oxygen had the highest value (2.84 mgl^{-1}) in May at Station 1 (rainy season) while the lowest value (1.00 mgl^{-1}) was in January at Station 2. The water temperature recorded was highest (27.4^{0}C) in August at Station 1, while the lowest (20.0 ºC) was at Station 2 in January. Turbidity was highest (19.04 NTU) in July at Station 2 and the lowest value (9.4 NTU) was at Station 1 in March. Conductivity values ranged from 283.1- 392.1 $uScm^{-1}$ with the lowest and highest values recorded in August and May respectively in Station 1.

Table 1: Physicochemical parameters of Eko-Nde Reservoir, Osun State, Nigeria (Mean ±SD)

PARAMETERS	STATION 1	STATION 2	P VALUE
Temperature (^{0}C)	25.73 ± 1.44	25.15 ± 1.95	0.3485
pH	7.934 ± 0.47	7.885 ± 0.35	0.7405
BOD (mg/L)	0.1369 ± 0.03	0.1338 ± 0.02	0.6966
DO (mg/L)	1.821 ± 0.41	1.821 ± 0.42	1.0000
Turbidity (NTU)	14.16 ± 2.51	14.37 ± 2.99	0.8284
Total Hardness (mg/L)	61.75 ± 16.98	60.69 ± 16.72	0.8596
Total Alkalinity (mg/L)	55.71 ± 5.50	56.59 ± 4.84	0.6331
Calcium Hardness (mg/L)	54.23 ± 12.17	52.76 ± 12.24	0.7360
Magnesium Hardness (mg/L)	10.68 ± 2.72	11.05 ± 2.91	0.7150
Phosphate (mg/L)	0.9181 ± 0.28	0.9394 ± 0.30	0.8385
Potassium (mg/L)	1.804 ± 0.51	1.703 ± 0.69	0.6436
Nitrate (mg/L)	0.2638 ± 0.21	0.2113 ± 0.09	0.3531
Carbonate (mg/L)	47.37 ± 10.68	47.50 ± 10.83	0.9726
Silica (mg/L)	0.20 ± 0.18	0.2631 ± 0.22	0.3943
Chloride (mg/L)	19.87 ± 3.34	19.44 ± 2.78	0.6887
Calcium (mg/L)	22.01 ± 12.17	21.40 ± 12.24	0.6441
Conductivity (µS/cm)	343.4 ± 37.17	322.2 ± 28.39	0.0798
Bicarbonate (mg/L)	84.43 ± 8.56	83.88 ± 6.51	0.8396

Table 1 shows the mean, SD and range of the parameters taken at Stations 1 and 2 from January to August 2019 at Eko-Nde Reservoir. There was no significant difference ($p<0.05$) for both Stations in this study.

SD: Standard deviation

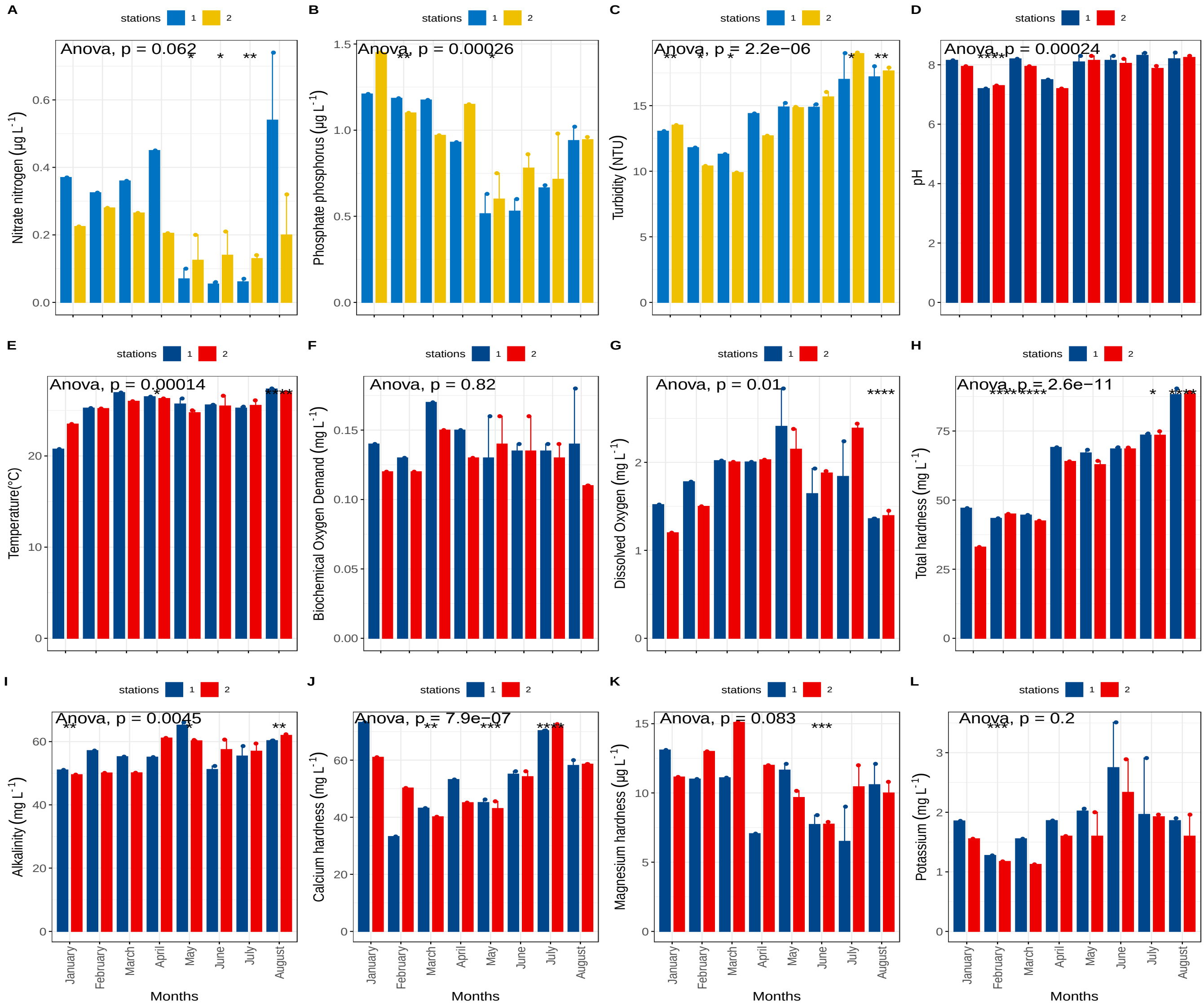

Figure 2: Monthly physicochemical parameters of Eko-Nde Reservoir

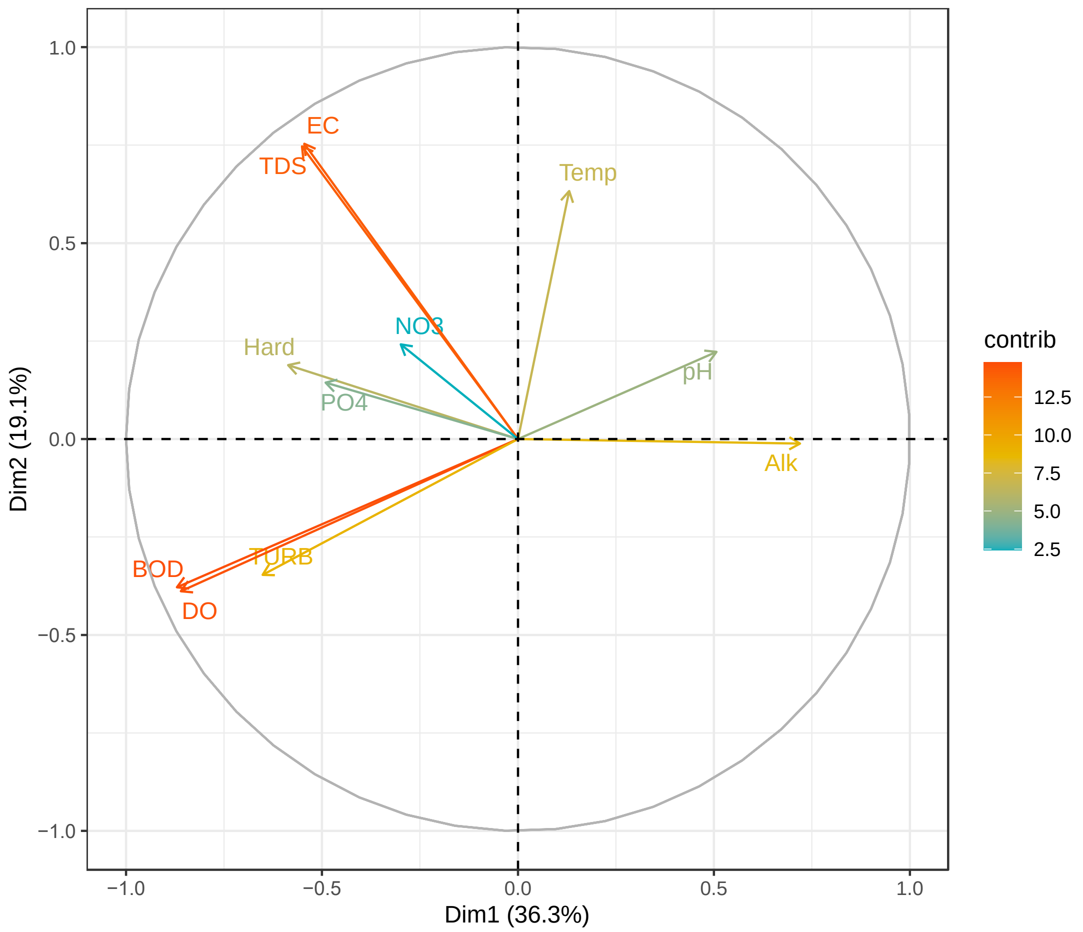

Figure 3: Principal Component Analysis (PCA) of Physicochemical Parameters in Sampling Stations

Phytoplankton Species and Density

A total of 2039 cells ml^{-1} belonging to four (4) major divisions namely Bacillariophyta (898 cells ml^{-1}) > Charophyta (788 cells ml^{-1}) > Chlorophyta (302 cells ml^{-1}) and Cyanophyta (51 cells ml^{-1}) were recorded for the 2 stations of the reservoir (Figure 4). At both stations, *Pediastrum boryanum* (Turpin) Meneghini (Chlorophyta) was the most dominant (207 cells ml^{-1}) followed by *Cosmarium punctulatum* Brebisson (181 cells ml^{-1}) and *Pleurotaenium* spp. (Ehrenbergii) Nageli (144 cells ml^{-1}) of Charophyta.

Bacillariophyta was represented by *Gomphonema augur* Ehrenberg, *Gomphonema parvulum* (Kutzing) Kutzing, *Cymbella mexicana* (Ehrenberg) Cleve, *Synedra ulna* (Nitzsch) Ehrenberg, *Gyrosigma acuminatum* (Kutzing) Rabenhorst, *Pinnularia viridis* (Nitzsch) Ehrenberg, *Nitzschia gracilis* Hantzsch and *Cyclotella meneghiniana* Kutzing among others (Figure 4). The taxa of division Cyanophyta was represented by *Anabaena circinalis* Rabenhorst and *Oscillatoria limosa* (Roth) C.Agardh.

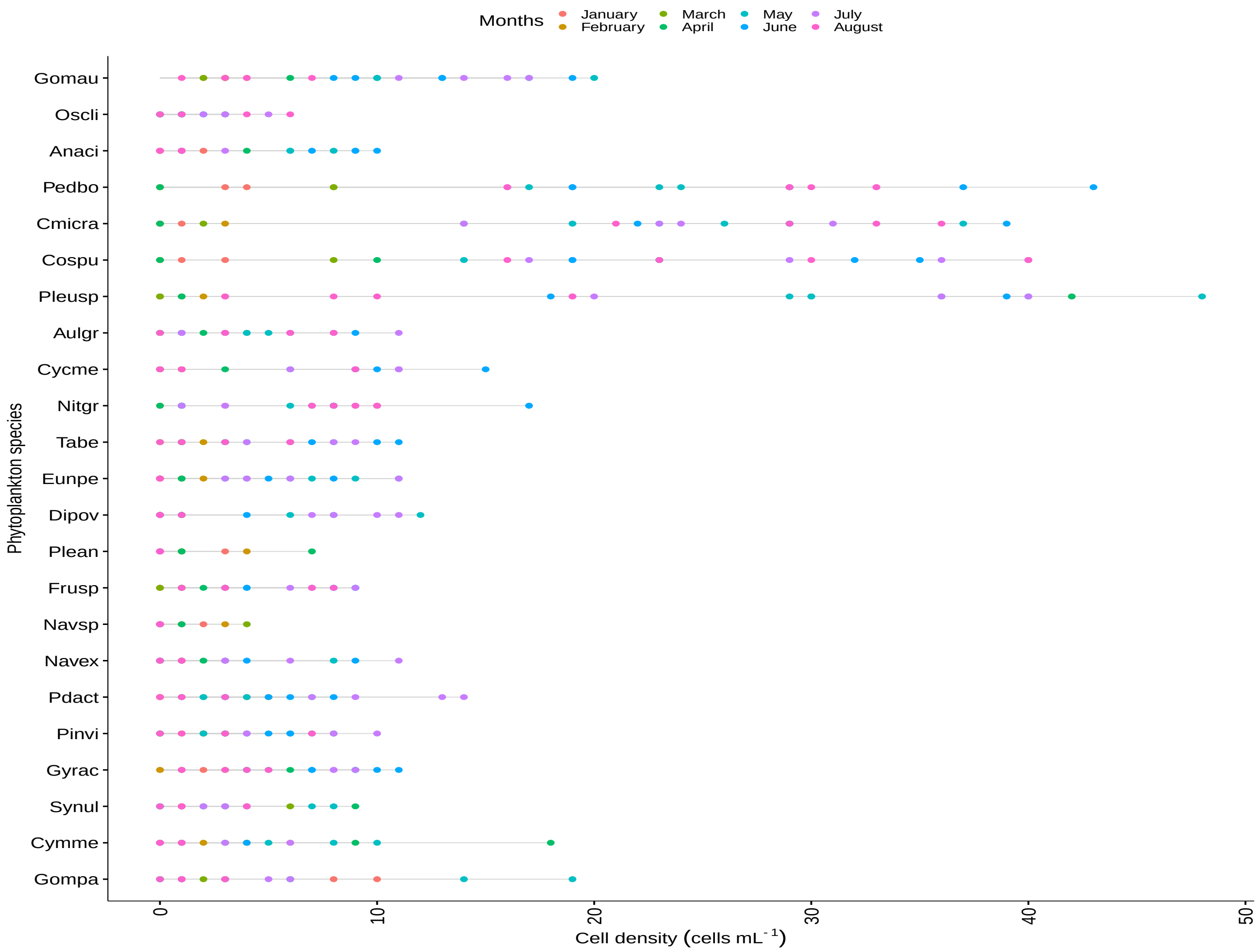

Figure 4: Monthly Cell Density of Species found in Eko-Nde Reservoir

Phytoplankton Diversity (Figure 5)

Shannon-Wiener Index was 1.8 - 2.78 across the stations. Species richness and rarefied indices were 10.25 - 21 and 1.82 – 1.93 respectively. Shannon- Wiener Index showed significant variations in March, May, July and August; Species richness Index showed significant differences in March, May and July; while rarefied index showed significance in only August.

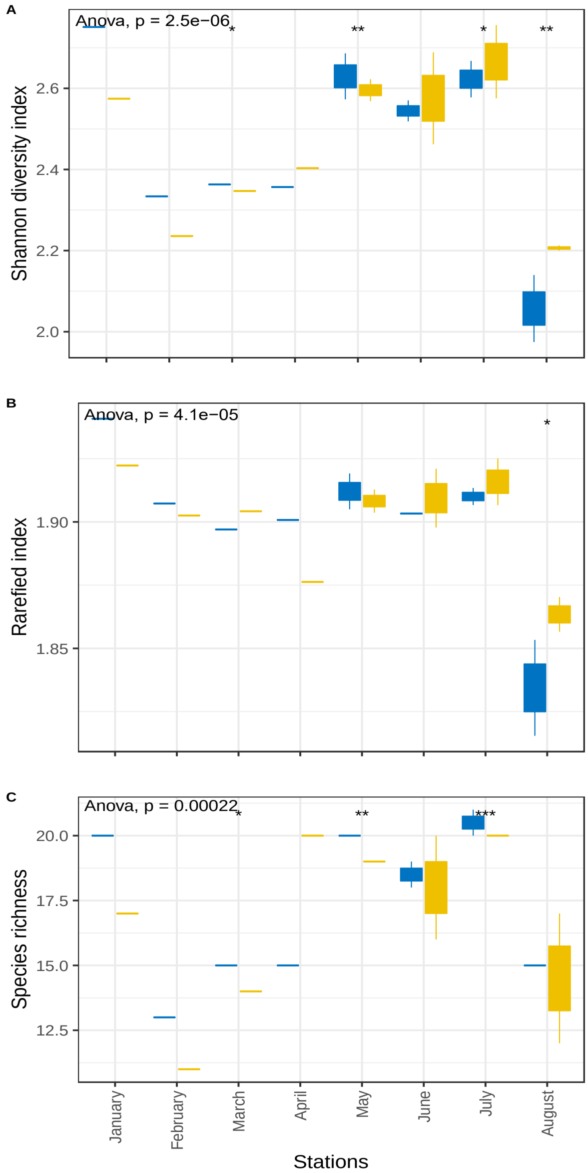

Figure 5: Monthly Diversity Indices of Species found in Eko-Nde Reservoir

Canonical Corresponding Analysis of Environmental Variables and Phytoplankton Community

Figure 6 shows positive correlation (P< 0.05= 0.008) between some physicochemical parameters and phytoplankton community of the reservoir. The environmental variables of major impact on the communities were pH (P< 0.05= 0.004**), temperature (P< 0.05= 0.027*) and total hardness (P< 0.05= 0.013*).

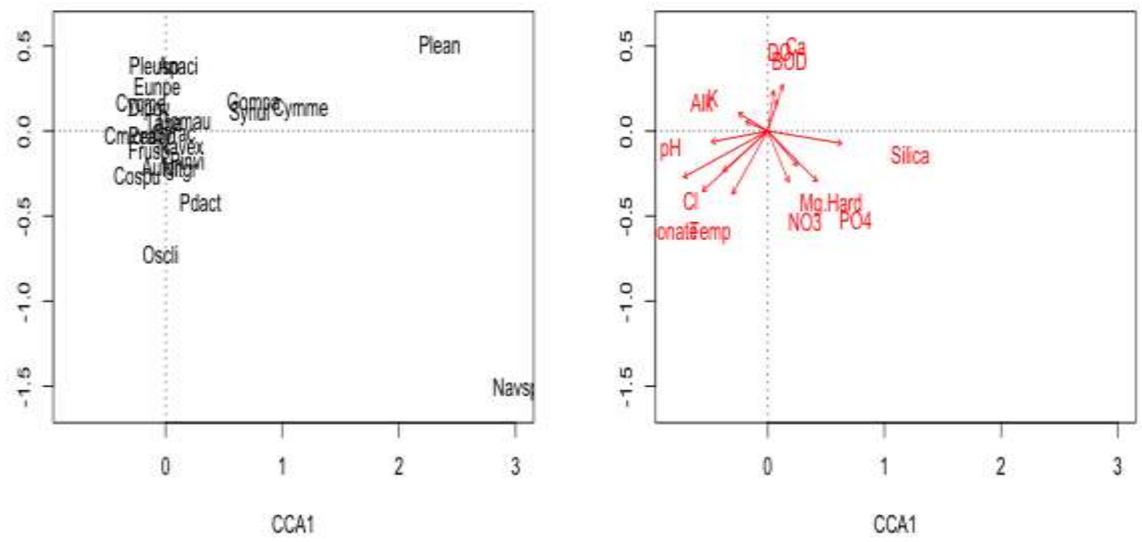

Figure 6: Canonical Corresponding Analysis of Taxa found in Eko-Nde Reservoir

DISCUSSION

The values of pH recorded in both stations were slightly similar to the results of Usman *et al*., (2017) in Ajiwa reservoir who recorded pH range of 6.67 – 7.34. According to U.S.E.P.A. (2005), a pH range of 6.0 to 9.0 is suitable for aquatic organisms and bottom dwelling invertebrates. Algae require a certain pH range to flourish (Reed and Klugh, 1924). This is due to a reduction in their ability to photosynthesize in basic water. As alkalinity rises, the amount of carbon dioxide accessible for photosynthesis decreases (Singh, 1974). During the immersion of photosynthetic plants in water with a high pH, only carbonate and bicarbonate ions are accessible (Carr and Whitton, 1973). The water temperature recorded was highest (27.4^{0}C) in August at Station 1, while the lowest (20.0 ºC) was at Station 2 in January (Fig. 2E). Kumar and Bahadur (2009) posited that high water temperature decreases the ability of water to hold essential dissolved gases like oxygen which causes death of fish and other invertebrates , and thus a stressor in aquatic ecosystems. High water temperature during the wet season in aquatic habitats may be due to characterized tropical weather conditions (Usman *et al*., 2017). Temperature plays key role in phytoplankton dominance as reported by Zhu *et al.*, (2021). According to the findings of this study, a gradual increase in water temperature and an influx of debris containing minerals can contribute to pH change during the rainy season. The total hardness ranged between 39.4 and 90.4 mgl^{-1}. Soft water has a hardness range of 10–50mgl^{-1}, slightly hard water has a hardness range of 50–100 mgl^{-1}, hard water has a hardness range of 100–200 mgl^{-1} and very hard water has a hardness range of > 200 mgl^{-1} (APHA, 2005). Total hardness was found to be high during the rainy season, indicating a high concentration of bicarbonates and carbonates in the underlying rocks or soils of the ecosystem under study. This is in line with the work of Kadiri (2000) on the Ikogosi warm springs in the western part of Nigeria. Environmental variables including BOD, DO, EC, temperature, turbidity, hardness, alkalinity and pH were found to have a significant impact on the reservoir as demonstrated by principal component analysis. This is in complete agreement with Chia *et al.*, (2011), who found a relationship between meteorological conditions, solubility and agricultural activity in the catchment areas, including surface runoff of fertilizers and pesticides.

The months associated with the rainy season had the highest species diversity which demonstrated the effect of seasonal and physicochemical parameters on species abundance and distribution. This result agreed with the findings of Mohammad and Saminu (2012) on Salanta River diversity in Kano. The following classifications apply to the relationship between species diversity and aquatic ecosystem pollution: >3 = clean water, 1-3 = moderately polluted, and 1 = extremely polluted (William *et al.*, 2002). This indicated that the Eko-Nde reservoir is moderately polluted. A total of 23 algal species spanning four phyla were collected during two seasons, with Bacillariophyta (13 species, 44.46%) having the highest density, followed by Charophyta (3 species, 38.86 %), Chlorophyta (1 species, 14.18%), and Cyanophyta (2 species, 2.503 %). Bacillariophyta dominance has also been observed in various freshwater habitats as reported by Okpanachi *et al.*, (2015) in Wikki warm spring and Kadiri (2002) in Ikogosi warm spring. According to Arumugam *et al.*, (2016), considerable variances in phytoplankton diversity can be linked to changes in biological percentage distributions of types of organisms as well as climatic and geographical variability. This could explain why phytoplankton levels are higher during the wet season than during the dry season. Cyanophyta being the least abundant of the phytoplankton taxa observed is consistent with Opute's (1991) findings in freshwater zones of the Warri forcadoes estuary and Okpanachi *et al.*, (2015) in Wikki warm spring, Yankari game reserve, Bauchi. The presence of blue-green algae (Cyanobacteria) indicates that the spring is moderately nutrient-rich (mesotrophic eutrophic) (Okpanachi *et al.*, 2015). The main factors driving the dynamics of the phytoplankton community were pH, water temperature and total hardness and the correlation with the first ordination axis showed that they are the most significant factors. Temperature, pH and total hardness had positive correlation with species belonging to Bacillariophyta: *Gomphonema augur*, *Gomphonema parvulum*, *Cymbella mexicana*, *Synedra ulna*, *Gyrosigma acuminatum*, *Pinnularia viridis* , *Pinnularia dactylus*, *Navicula exigua*, *Pleurosigma* *angulatum*, *Nitzschia gracilis* and Cyanobacteria: *Anabaena circinalis*. They were negatively correlated with some diatom species; *Frustulia* sp., *Diploneis ovalis*, *Eunotia pectinalis*, *Tabellaria* sp., *Cyclotella meneghiniana*, *Aulacoseira granulate* and a Cyanobacteria specie, *Oscillatoria limosa*. Meanwhile; pH, temperature and total hardness showed a negative correlation to all chlorophytes and desmids; *Pleurotaenium* sp., *Cosmarium punctulatum*, *Micrasterias* sp. *C.* Agardh ex Ralfs and *Pediastrum boryanum*. Desmids had a negative relationship with pH, hardness and temperature. This demonstrates that desmids in general, support growth in an acidic system; but fluctuations in the ionic content of calcium and magnesium as a result of rainfall have caused an influx of the water system, making it alkaline. The desmids discovered are calcium-loving and thus, adapts to the environmental conditions. Several studies have found that desmid thrives in acidic environment (Moss, 1973) as well as that some taxa are stress-tolerant (Grime, 1977). Diatoms such as *Eunotia* and *Frustulia spp.* (benthic) are also acid-driven. This is supported with the fact that it had a negative connection with the important environmental variables.Pollution-tolerant species reported in this study include *Anabaena circinalis, Oscillatoria limosa, Nitzschia gracilis, Cymbella mexicana, Pediastrum boryanum, Synedra ulna, Cyclotella meneghiniana* and *Gomphonema* spp. (Palmer, 1969).

CONCLUSION

The diversity and abundance of phytoplankton could be used to monitor changes in the Eko-Nde reservoir. The reservoir had four (4) major taxa Bacillariophyta > Charophyta > Chlorophyta > Cyanophyta during the study period. Temperature, pH and total hardness were found to have major influence on the phytoplankton community structure of the reservoir. Eko-Nde reservoir has demonstrated the appearance of pollution-tolerant species, indicating that the reservoir is on the verge of being polluted as a result of increased human activities in and around the reservoir.

RECOMMENDATIONS

- Anthropogenic activities that may likely contribute to pollution of the reservoir should be discouraged.
- The water body should be regularly monitored to ensure proper conservation practices.
- Fertilizer application especially in farmlands surrounding the reservoir should be done optimally and not in excess.

DATA AVAILABILITY STATEMENT

All data generated/analysed during the study are included in this manuscript.

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Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this article.

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