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Influence of Physicochemical Parameters on Distribution and Abundance of Plankton in Lake Geriyo, Yola, Adamawa State, Nigeria

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Abstract: The objective of this paper was to evaluate the influence of physicochemical parameters on the distribution and abundance of plankton in Lake Geriyo, Yola, Adamawa State, Nigeria using appropriate standard procedures. The physicochemical parameters showed that the pH of the lake ranged from 6.35±0.07 to 8.56±0.08, Temperature from 6.35±0.07 to 29.22±1.07, Electrical conductivity 147.77±15.75 to 582.22±8.39, Total Soluble Solid 0.02±0.01 to 0.33±0.07, Dissolved Oxygen 2.19±0.20 to 7.76±0.25, Biological Oxygen Demand 1.01±0.22 to 4.89±1.21, Chemical Oxygen Demand 1.27±0.03 to 5.53±1.22, and ammonia recorded 0.24±0.04 to 0.45±0.04. Eight thousand, one hundred and eighty plankton were recorded across all Sites. This comprises of 4756 phytoplankton and 3424 zooplankton. The phytoplankton analysis showed that a total of nine (9) families and zooplanktons had seven (7) groups. Phytoplankton showed that Euglenophyceae, Rhodophyceae, Bacillariophyceae, Dinophyceae, Fragilariophyceae and Cyanophyceae had a positive correlation to pH, D.O, B.O.D, C.O.D, and Ammonia. While, Chlorophyceae, Zygnematophyceae and Ulvophyceae are negatively correlated to pH, Temperature, T.D.S and conductivity. The influence of the environment on the zooplankton composition revealed that malacostraca and Ostracoda showed a positive correlation with Temperature, pH, conductivity, TDS, TSS, while copepoda, monogonta, bdelloidea, insect, and branchiopoda are negatively correlated to temperature, D.O, B.O.D, C.O.D, ammonia.

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Planktons are collections of diverse organisms that live in water bodies and cannot swim against the current; they serve as primary producers in the water. (Carboni, 2006). The productivity and sustainability of any aquatic ecosystem depend on the amount of plankton present in the water body (Guy, 1992). Both phytoplankton and zooplankton form fundamental biological components from which energy is transferred to higher organisms through a systematic food chain (Tas and Gonulal, 2007). The fauna found

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in an aquatic ecosystem directly or indirectly relies on plankton. They also serve as bioindicators and are a reliable tool for determining the status of water pollution (Contreras *et al.*, 2009). Plankton is known to be a vital component for the functioning of ecosystems. As such, they support a wide range of ecosystem services, forming the basis of food webs that support the production of higher trophic levels and act as a sink of CO_2 (Tweddle *et al.*, 2018). The general distribution and abundance of plankton are affected by seasons and physicochemical parameters of the water body (Raymond, 1983). Seasonal changes in the water in terms of any of its parameters eventually affect the plankton diversity and abundance and thus alter the ecosystem services offered by this valuable resource.

In recent years, there has been an increasing concern about the rate at which wastes are discharged through run offs into streams and lakes, as in Lake Geriyo, therefore leading to euthrophication which affect the specific composition of planktons and variation of physicochemical parameters as well as changing the qualities of these water bodies. (Chapman and Romberg, 2008). The aim of this study was to determine the effects of the physicochemical parameters on the diversity and distribution of plankton in Lake Geriyo, Yola, Adamawa State, Nigeria

MATERIALS AND METHODS:

*Study Area:*The lake is flooded by the river during the rainy season such that it receives an influx of water which includes pollution load originating from River Benue and the urban waste dumpsite at the surrounding of the lake. It is a shallow water body of about 250 hectares with a mean depth of about 3 meters. Aquatic vegetation on the lake consists of a mass of floating weeds such as water spinach, water hyacinth, water Lilly, and water lettuce which move around the lake surface due to the prevailing wind (Ekundayo *et al.,* 2014). The area is in the Sahel region of Northern Nigeria generally semiarid with low rainfall, low humidity, and high temperature. The area experiences two distinctive wet and dry seasons. The wet season starts from May to October, while the dry season commences from November to April, mean daily temperature fluctuates with the season from 25°C to 45°C, and the mean annual rainfall received is in the range of 150–1000 m. Cold and dusty weather from December to January is followed by intense heat from March to April. The climate is characterized by high evapotranspiration, especially during the dry season (Adebayo and Tukur, 1999). The area is characterized by a dry season which spans from October to March, and a wet season that spans from April to September (Okunlola *et al.*, 2016)

Lake Geriyo occupies a natural depression near the upper Benue River in northeastern Nigeria. The water from the lake is primarily used in intensive irrigation, and fishing and source of water for cattle farmers in the areas, the lake also serves as a source of water for domestic uses to the inhabitants around the lake. Lake Geriyo is exposed to contamination from the refuse dumps and automobile mechanic workshops along the path of the water inlet, also agrochemicals used by farmers around the lake add to the contamination of the lake.

Three sites were picked; Site A, located on latitude 09°17'31" N and longitude 12°26'06" E (Point of water entry during flooding), Site B, located on latitude 09°18'08" N and longitude 12°25'38" E (Middle point of the lake) and Site C, located on latitude 09°18'50" N and longitude 12°25'06" E (The endpoint of the lake).

Plankton collection: Plankton was collected from each site (A, B, and C) using well-labeled plastic bottles of 750 ml with full details of the site of the sample and the date of collection as described by Indabawa, (2012). The sampling bottles were sterilized in the laboratory. On the field, for each sampling site, the bottle was rinsed several times with the water that was sampled. Each bottle was opened at a depth of 30cm from the surface in the direction of the water current to be filled with the water. The resultant concentrated plankton sample was preserved with 4% formalin solution and Lugols iodine solution according to the method of Anene, (2003), in the field. The sample was transported to the Zoology laboratory of Modibbo Adama University, Yola, Adamawa State, in a sampling box.

Physicochemical analysis of water sample: Water samples were collected from three stations. Sampling bottles of 250ml capacity were used; the bottles were rinsed before being filled with water for physicochemical analysis in the laboratory. Only temperature and transparency were measured in situ.

Temperature determination: Temperature readings (water and air) were measured using a mercury-in-glass thermometer. Temperature readings were taken directly at sampling sites (in situ). The bulb was placed in water and allowed for about two minutes for equilibration before the readings were taken as recommended by Boyd, (1981).

pH determination: The pH of the water was determined using a pH meter (model: HANNA instrument model No HI 98107). The electrode of the meter was standardized using a buffer solution, the electrode was placed into the water for about 5 minutes for equilibration before taking the reading as recommended by Boyd, (1981).

Dissolved Oxygen Determination: Dissolved oxygen was determined using a portable HANNA electronic dissolved oxygen meter (model: I 2400). The electrode was placed in to water for five minutes before taking the readings.

Fig. 1: Map of Lake Geriyo showing the sampling sites**.**
Source: Google Earth Map

Conductivity determination: Electric conductivity was determined as described by (Goltermann *et al.*, 1978), using a portable HANNA electronic conductivity meter (model: EC 215). The electrode was immersed in the water for five minutes before taking the readings.

Determination of free carbon dioxide: Free carbon dioxide was determined as described by Saxena, (1990). 50ml of water samples were put into a flask and three drops of phenolphthalein indicator (reagent) were added. If the color turns pink free carbon dioxide is absent in the sample. If the sample remained colorless it was titrated against sodium hydroxide solution (reagent) until a pink color appeared.

$$\text{Free CO2}\left(\frac{\text{mg}}{\text{l}}\right) = \text{Vt} * \frac{1000}{Vs} \quad (1)$$

Where; Vt = volume of titrant; Vs = Volume of the sample

Ammonia: Ammonia was measured using a test tab water investigation kit as recommended by Cambell and Wilberger, (2001). A test tube was filled with water to the 5ml line. One ammonia testab 1 (3968A) will be added. The test tube was capped and mixed until the tablet had disintegrated fully. One tablet of ammonia testab 2 (3969A) will be added again, the tube was capped and mixed until the tablet has integrated fully. It was allowed to wait for 5 minutes. The color of the sample was compared with the color chart (5894-CC). The result was recorded as milligrams per liter (mg/l) of Ammonia.

Alkalinity: Alkalinity was measured using a tested water investigation kit as recommended by Cambell and Wilberger, (2001). A test tube (0788) was filled with water to 100ml line. An alkaline testab (3920A) was added one at a time until the color of the solution changed from green to pink. This was matched with the alkaline color chart (5893-CC). Total alkalinity was determined by multiplying the number of tablets by 40.

Plankton analysis: The Plankton sample was concentrated to 50 ml volume before the analysis of organisms. Identification and counting of the phytoplankton and zooplankton samples was done using a compound microscope. The concentrated sample was agitated to homogenize before placing a drop of the sample on a slide, covered with a cover slip, and examined with a compound microscope at a magnification of x 4, x 10, and x 40 objective lenses as described by Ahmed and Indabawa, (2015). The planktons (phytoplankton and zooplanktons) were identified and a total number of species was recorded using keys for species identifications provided by the standard work of Umar *et al.* (2013), and using dichotomous keys for the identification of algae following the method of York *et al.* (2002). Count was made and expressed as the total number and percentage abundance of plankton.

*Statistical Analysis:*A Principal Component Analysis (PCA) biplot was used to determine the relationship between the distribution and composition of plankton and the environmental parameters of the lake, the type of angles formed between the variables shows the correlation between them; an acute angle indicates a positive correlation, an obtuse angle indicates a negative correlation, while a right-angle indicates no correlation.

RESULTS AND DISCUSSION

The physicochemical parameters in the dry season showed that the highest mean pH of 7.51 was recorded in Site B the least mean pH of 7.38 was recorded in Site C, the highest mean Temperature of 20.63 ^{0}C recorded was in Site A, while the least 20.23 ^{0}C was in Site C. As for the Electrical conductivity, the highest mean of 383.33 μS cm^{-1} was recorded in Site C and the lowest mean of 325.71 μS cm^{-1} was recorded in Site A., Total Dissolved Solute (TDS) had its highest mean of 192.38 mg L^{-1} in Site C and the least 158.24 mg L^{-1} in Site A, the Total Suspended Solute (TSS) recorded its highest mean 0.11 mg L^{-1} in Site A while Site C had the least mean 0.08 mg L^{-1}, as for Dissolved Oxygen (D.O) the highest mean 3.46 mg L^{-1} was recorded in Site B and the least mean 2.71 mg L^{-1} was recorded in Site C. Biological Oxygen Demand (BOD) had its highest mean 1.76 mg L^{-1} in Site B and its least mean 1.56 mg L^{-1} in Site C. Then, the Chemical Oxygen Demand (COD) had 2.50 mg L^{-1} as its highest means in Site B 2.42 mg L^{-1} as its lowest mean in Site C. Finally, Ammonia recorded 0.97 mg L^{-1} in Site C as its highest mean, and 0.88 mg L^{-1} in Site A as its least mean. The parameters observed in the wet season showed that the highest mean pH of 8.20 was recorded in Site The least mean pH of 8.18 was recorded in Site B, the highest mean Temperature of 27.73 ^{0}C recorded was in Site B, while the least 27.51 ^{0}C was in Site A. As for the Electrical conductivity, the highest mean of 344.85 mg L^{-1} was recorded in Site C and the least mean of 341.51 mg L^{-1} was recorded in Site B., Total Dissolved Solute (TDS) had its highest mean of 178.79 mg L^{-1} in Site A and the least 168.33 mg L^{-1} in Site C, the Total Suspended Solute (TSS) recorded its highest mean 0.18 mg L^{-1} in Site B while Site A had the least mean 0.16 mg L^{-1}, as for Dissolved Oxygen (D.O) the highest mean 4.58 mg L^{-1} was recorded in Site B and the least mean 4.31 mg L^{-1} was recorded in Site C. Biological Oxygen Demand (BOD) had its highest mean 2.94 mg L^{-1} in Site B and its least mean 2.61 mg L^{-1} in Site C. Then, the Chemical Oxygen Demand (COD) had 3.36 mg L^{-1} as its highest mean in Site B 3.18 mg L^{-1} as its lowest mean in Site C. Finally, Ammonia recorded 0.33 mg L^{-1} in Site A as its highest mean, and 0.31 mg L^{-1} in Site C as its least mean (Table 1). The composition and distribution of the planktons by classes in Lake Geriyo showed that for phytoplanktons composition, Site C had the highest with 1039 (21.84%) during the wet season, while, Site C during the dry season period recorded the lowest with 532 (11.18%). The distributions are displayed in Table 4.41. The distribution and composition of zooplankton by classes showed that site B recorded the highest composition with 718 (20.97%) during the wet season period. While site C recorded the least during the dry season period with 352 (10.28%). This is displayed in Table 2. The Principle Component Analysis (PCA) of phytoplankton in the dry season period showed that Ulvophyceae, Zygnematophyceae, and Chlorophyceae are positively correlated to TDS, Conductivity, and temperature. Bacillariophyceae, Cyanophyceae, Euglenophyceae, Fragilariophyceae, Rhodophyceae, and Dinophyceae are positively correlated to COD, pH, BOD, DO, and TSS. While Bacillariophyceae and Chlorophyceae are negatively correlated to ammonia (Figure 1). The PCA analysis of zooplankton in the dry season period showed that; Insects, Ostracoda, Branchiopoda, Copepoda, Monogonta, Bdelloidea, and Malacostraca are positively correlated to BOD, DO, and TSS. But negatively correlated to Ammonia, T.D.S, Conductivity, and Temperature (Figure 2). The analysis of phytoplankton in the wet season period showed that Zygnematophyceae, Ulvophyceae, and Chlorophyceae are positively correlated to Ammonia, pH, and TDS. Rhodophyceae and Dinophyceae are positively correlated to DO, Temperature, COD, BOD, Conductivity, and TSS. While, Euglenophyceae, Cyanophyceae, Bacillariophyceae, and Bacillariophyceae are negatively correlated to DO, Temperature, COD, BOD, Conductivity, and TSS (Figure 3). The PCA analysis of zooplankton in the wet season period showed that Insect, Bdelloidea, and Monogonta are positively correlated to TSS, Conductivity, BOD, COD, Temperature, and DO but negatively correlated to TDS, Ammonia, and pH (Figure 4).

Table 1: Physicochemical Parameters across Sites in Both Seasons

Physicochemical Parameters	**Site A**	**Site B**	**Site C**
pH	7.39±0.77	7.51±0.77	7.38±0.77
Temperature (^{0}C)	20.63±9.50	20.28±9.32	20.23±9.08
Electrical Conductivity (µS cm^{-1})	315.71±109.10	323.72±120.23	383.33±253.50
Total Dissolved Solute (mg L^{-1})	158.24±56.35	160.00±60.55	192.38±128.45
Total Suspended Solute (mg L^{-1})	0.11±0.06	0.09±0.06	0.08±0.04
Dissolved Oxygen (mg L^{-1})	3.28±0.37	3.46±0.64	2.71±0.65
Biological Oxygen Demand (mg L^{-1})	1.68±0.38	1.76±0.40	1.56±0.46
Chemical Oxygen Demand (mg L^{-1})	2.39±0.72	2.50±0.72	2.42±1.06
Ammonia (mg L^{-1})	0.88±0.31	0.96±0.42	0.97±0.41
Wet season			
pH	8.20±0.32	8.18±0.34	8.18±0.39
Temperature (^{0}C)	27.51±0.58	27.73±0.97	27.61±1.26
Electrical Conductivity (µS cm^{-1})	342.12±151.15	341.51±156.90	344.85±156.49
Total Dissolved Solute (mg L^{-1})	178.79±87.17	169.39±80.98	168.33±77.87
Total Suspended Solute (mg L^{-1})	0.16±0.08	0.18±0.10	0.17±0.07
Dissolved Oxygen (mg L^{-1})	4.46±1.78	4.58±2.25	4.31±2.15
Biological Oxygen Demand (mg L^{-1})	2.61±1.07	2.94±1.42	2.77±1.44
Chemical Oxygen Demand (mg L^{-1})	3.20±1.04	3.36±1.44	3.18±1.41
Ammonia (mg L^{-1})	0.33±0.10	0.32±0.10	0.31±0.10

Table 2: Phytoplankton Composition by Class in Lake Geriyo

Sites	Chlo	Zygn	Ulvo	Eugl	Rho	Baci	Dino	Fra	Cyn	Total (%)
Dry season										
Site A	93	87	79	45	22	121	14	29	160	650 (13.67)
Site B	84	60	77	45	29	92	16	40	156	599 (12.59)
Site C	93	89	87	23	22	61	14	19	124	532 (11.18)
Wet season										
Site A	163	130	117	52	31	158	28	73	227	979 (20.58)
Site B	146	129	108	58	41	140	42	66	227	957 (20.12)
Site C	143	125	104	62	29	194	35	84	259	1039 (21.84)
Total	722	620	572	285	174	766	149	311	1153	4756 (100.00)

Keys: Chlo = Chlorophyceae;Zygn = Zygnematophyceae; Ulvo = Ulvophyceae; Eugl = Euglenophyceae; Rho = Rhodophyceae; Baci = Bacillariophyceae; Dino = Dinophyceae; Fra = Fragilariophyceae; Cyn = Cyanophyceae

Table 3: Zooplankton Composition by Class in Lake Geriyo

Sites	Cope	Mono	Bdell	Insec	Bran	Mal	Ostra	Total (%)
Dry season								
Site A	81	158	18	25	194	16	20	512 (14.95)
Site B	80	142	15	26	195	11	22	491 (14.34)
Site C	69	104	12	24	123	11	9	352 (10.28)
Wet season								
Site A	91	193	20	32	251	26	22	635 (18.55)
Site B	104	252	29	40	249	18	26	718 (20.97)
Site C	138	189	29	41	252	36	31	716 (20.91)
Total	563	1038	123	188	1264	118	130	3424 (100.00)

Keys: Cope = Copepoda; Mono = Monogonta; Bdell = Bdelloidea; Insec = Insect; Bran = Branchiopoda; Mal = Malacostraca; Ostra = Ostracoda

The Principal Components Analysis (PCA) seeks to establish combinations of variables that can describe the main trends for a particular matrix observed during the study. This statistical method is designed to transform the original data set into new, unrelated to each other indicators, called Principal Components (PC) that are linear combinations of the original variables (Shrestha and Kazama, 2007; Wu *et al.*, 2014). The PCA is a useful tool that makes it possible to identify relationships between species and to describe their seasonal changes (Garate-Lizarraga and Beltrones, 1998). According to Kocer and Sen, (2014), PCA is a suitable instrument for the determination of the effect of Temperature, pH, Suspended Solids, NO^{3-}, N, and Si on the abundance and distribution of plankton. Other studies on the seasonal and spatial changes in plankton established a similar relationship between the concentration of TDS, Temperature, Conductivity pH, and the dynamics of the communities (Lira *et al.*, 2011). The present study showed a slight difference from the report of Yusuf, (2020), who recorded that four Phytoplankton classes; Bacillariophyta, Chlorophyta Cyanophyta, and Desmidiaceae showed a positive close relation with; Dissolved Oxygen (D.O), pH, Transparency and Electrical Conductivity, while they were negatively associated with; water temperature, nitrate-nitrogen, and phosphate-phosphorus, while, Euglenophyta was closely associated with; water temperature, nitrate-nitrogen, and phosphate-phosphorus.

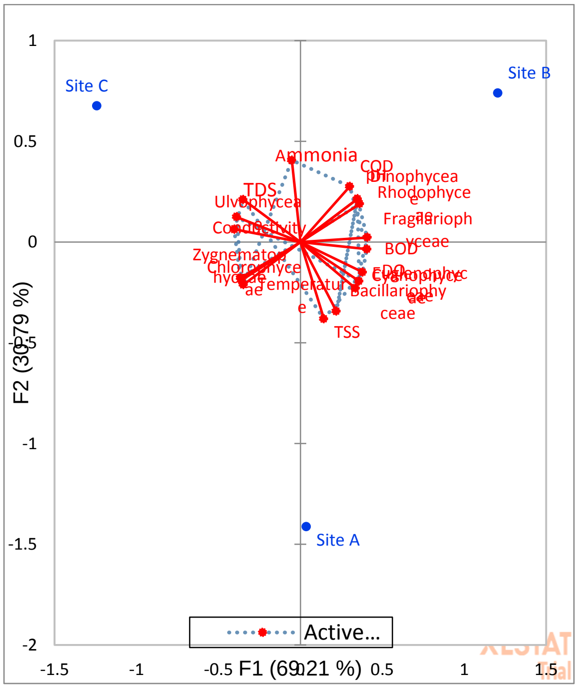

Fig. 1: Biplot of phytoplankton and environmental parameters during the dry season in Lake Geriyo

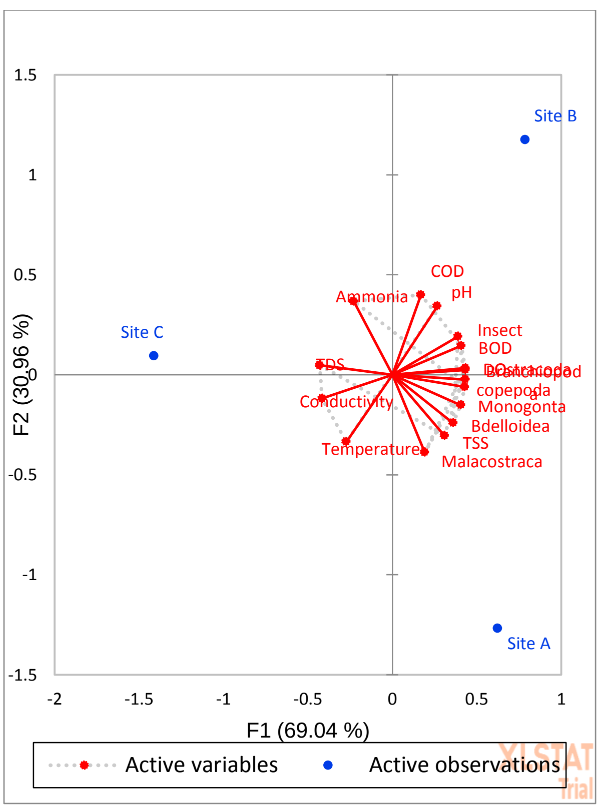

Fig. 2: Biplot of zooplankton and environmental parameters during the dry season in Lake Geriyo

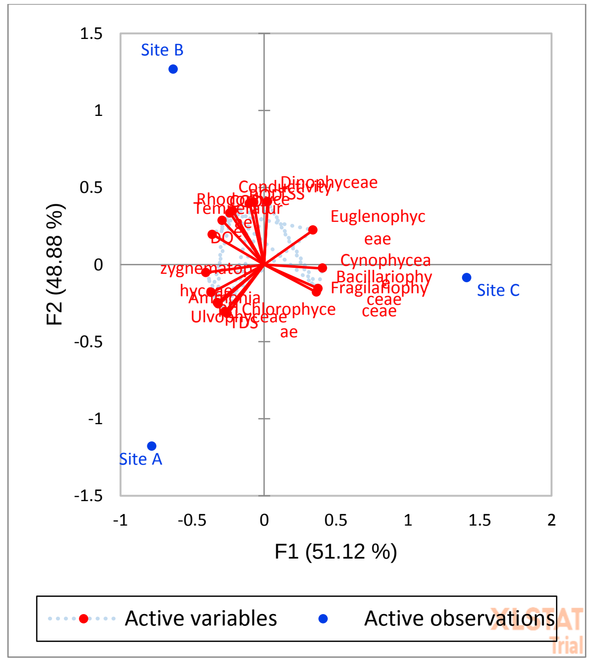

Fig. 3: Biplot of phytoplankton and environmental parameters during the wet season in Lake Geriyo

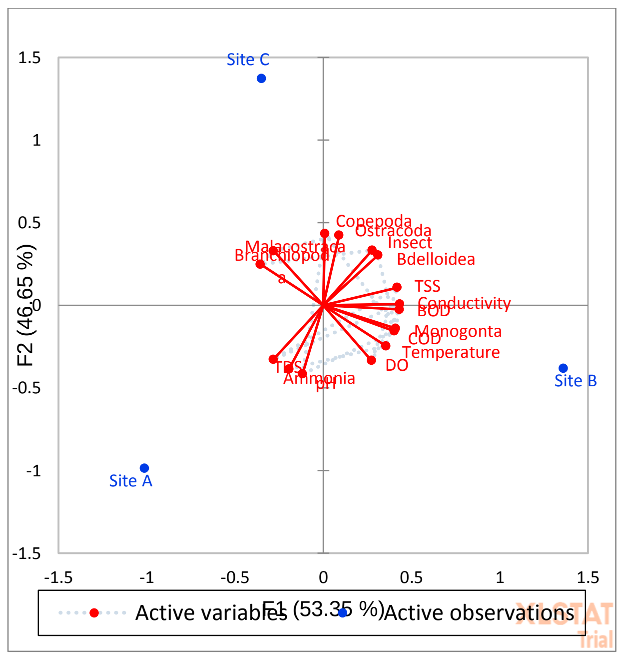

Fig. 4: Biplot of zooplankton and environmental parameters during the dry season in Lake Geriyo

These differences might be due to the wide range of environmental parameters like pH, D.O, Biochemical Oxygen Demand (BOD), conductivity, and TDS, recorded in Nasarawa reservoir, Katsina State when compared with what was recorded in Lake Geriyo. The observed significant positive correlation between D.O, pH, and the abundance of some phytoplankton by Kostadin *et al.* (2017), is in line with the present study. This may be due to the fact that oxygen is produced during photosynthesis, therefore an increase in phytoplankton abundance comes with a resultant increase in Dissolved Oxygen concentration, and this assertion is in line with the report of Tanimu *et al.* (2011).

The present study established that the parameters with the highest level of significance influencing the spatial and temporal distribution of the phytoplankton include pH and Conductivity. It is similar to the statement of Ognjanova-Rumenova *et al.* (2013), who also established that temperature, pH, and D.O were the most important environmental factors that determined the distribution of diatoms with the greatest significance were determined to be the Conductivity, Similar dependencies were observed in previous studies on the microbial community dynamics in the water column as reported by Iliev, (2014).

The present study shows that the river is eutrophic which is confirmed by the three indices i.e. Cyanophyceae, Chlorophyceae population, and compounds present, which may be due to domestic sewage, municipal waste, and effluents of organic and inorganic waste from irrigation farmland and mechanic workshops entering the lake, this is in line with the report of Jafari and Alavi**, (**2010), who reported that water temperature is an important abiotic factor affecting the biotic parameters of aquatic ecosystems, such as species composition and physiological activity of microbial communities, this was also confirmed by Zmyslowska *et al.* (2001) and Zmyslowska and Golas, (2003).

The occurrence, abundance, and diversity of phytoplankton in the present study are influenced by ambient physicochemical conditions like B.O.D, pH, and DO, this was slightly different from the report of Fonge *et al.* (2015), who reported that the occurrence, abundance, and diversity of phytoplankton are influenced phosphorus concentrations, which is also consistent with previous findings of Fonge *et al.* (2012). The environmental parameter that favored the composition and abundance of zooplankton in the present study was slightly different from the record of Emmanuel and Godwin, (2014), who reported Secchi depth (water transparency), D.O, and water temperature favored the composition and abundance of zooplankton as indicated by their significant direct relationships, while the concentrations of Total Solids (TS) and Total Suspended Solid (TSS) could be considered limiting owing to the inverse relationships they showed with species composition and abundance. These relationships could also explain the spatial trend in species composition and abundance of zooplankton in the two water bodies (Lake Geriyo and Aiba Reservoir)

The pH value of water in all the areas during the study period was mostly found to be within the suitable range of 6.5 to 9.0 (Department of Fisheries [DoF], 2005) for fish growth. The pH showed a positive correlation in the growth of plankton this is in line with Chisty, (2002), who reported that pH value, is very important for plankton growth. pH of around 7 seems to be best for the distribution of plankton in the present study, this is in the range of Marathi *et al.* (2007), who reported pH ranged from 5 to 8.5 is best for plankton growth, a similar finding was reported by Emmanuel and Godwin, (2014), who recorded a direct relationship between pH and species diversity, this similarity could because the recorded pH values fell within the WHO recommendation (6.0–8.5) for aquatic life as supported by Chapman and Kimstach, (1996). This underscores the fact that neither an acidic medium nor an extremely alkaline medium is favorable for aquatic life. Moreover, D.O. is indispensable for the metabolism of all aquatic organisms that possess aerobic respiratory biochemistry (Wetzel, 1983). Though there were significant differences in the D.O. among the studied areas, the D.O. in all the water bodies was suitable for supporting optimal fish growth (DoF, 1998).

*Conclusion:*There are both positive and negative correlations between the environmental (Physico-chemical) parameters and the distribution of plankton in the lake. The occurrence, abundance, and diversity of plankton are influenced by ambient physicochemical conditions like B.O.D, pH, and D.O.

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