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ZOOPLANKTON PERIODICITY AND ENVIRONMENTAL VARIABLES IN SHIRORO LAKE, NIGERIA

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ABSTRACT:
Zooplankton dynamics and periodicity in a water body provide useful information on the ecological status of the water body and may serve as bio-monitors of ecosystem health. In this study, we investigated the monthly variation of zooplankton community structure and the environmental variables of Shiroro Lake in north central, Nigeria between January 2013 and December 2015 using standard methods with the aim of ascertaining the ecological status and ecosystem health of this lake. Results obtained indicated that most of the physicochemical parameters examined showed variations within the months as affected by the rainfall regime. Temperature fluctuated between 20.8 and 27.4^oC, pH (7.19 – 8.04), transparency (17.8 – 23.73cm), dissolved oxygen, DO (3.34 – 8.04 mg/l), BOD (2.34-3.33mg/l), total hardness (25.57 – 36.43mg/l), alkalinity (13.45 – 15.72 mg/l), phosphate (0.22 – 0.32 mg/l), magnesium (0.26 - 0.35mg/l), nitrate (0.29 – 0.61mg/l) and total dissolved solids (90.5 – 154.5mg/l). Diversity was rather low with only 19 genera recovered from the water body consisting of 5 Rotifers, 6 Cladocera and 8 Copepods. Generally, abundance was significantly higher in the dry season (November – April) as compared with the wet season period (May – October). Although, the cladocerans (*Moina* and *Diaphanosum*) had significantly higher abundance values, *Keratella* (Rotifer), and *Ceriodaphnia* (Cladocera) were the dominant taxa occurring in all the months. Furthermore, the zooplankton population fluctuated well with the temporal changes in environmental variables with DO and nutrients (phosphate and nitrate) accounting for most of the variations observed by Canonical Correspondence Analysis (CCA). The Shiroro Lake is a stressed water body owing to the numerous human activities occurring there. Care should therefore be taken to protect and preserve the fauna species by ameliorating the effects of the pollution.

Keywords: Zooplankton, *Keratella*, *Moina*, Physicochemical parameters, Shiroro Lake, Nigeria, Hydroelectric.

INTRODUCTION

Zooplankton are important members of the biotic community in most food chains in an aquatic ecosystem. Most are microscopic, have short life cycle, play very important role in nutrient cycling, serve as food to the nekton and exhibit quick response to changes in their environment (Park and Shin 2007). It is these attributes that enable them provide useful information on the ecological status of the water body, thus serving as bioindicators of ecosystem health (Arimoro and Oganah 2010). It has been shown that changes in water quality of any water body have significant effects on the structure of zooplankton assemblages (Idowu et al. 2004; Umerfaruq and Solanki, (2015); Ahmedabad et al. 2017; Arimoro et al. 2018a). Therefore, the wellbeing of every ecological setting depends largely on the balance of the interactions existing between the living and the non living components of the ecosystem.

Shiroro Lake is one of the important inland resources of Nigeria, constructed mainly for the generation of electrical power (Adie *et al*., 2012), improve fishing (Oyero, 2001), tourism and recreational activities (Osu *et al.,* 2014). Most often the anthropogenic activities around lake catchments tend to mar the qualities of the water bodies (Liyanage and Yamada, 2017). Shiroro Lake is not an exception as severe implications of human activities are abounded around the catchment arising from several boating activities in the lake and buying and selling activities around the catchment with high human population (Arimoro 2018b).

Shiroro Lake have received only little attention from researchers over the years in spite of its importance as one of water bodies housing a major hydropower generating plant in the country. Earlier works include those of Ovie and Adeniji (1994) who monitored the zooplankton and environmental characteristics of the lake at the extremes of its hydrological cycle. Kolo (1999), on the other hand, studied the physicochemical parameters of the lake while Auta *et al*. (2016) and Arimoro et al. (2018), examined the seasonal variations in the environmental variables and chironomid diversity of the lake respectively. There is therefore, the urgent need to monitor and report on the status of the zooplankton fauna and environmental characteristics of the lake in recent times as the area has witnessed and still experiencing alarming increase in human activities that could alter its quality. In addition, a five-year continuous cycle is recommended for the proper monitoring of a lake water quality and its biota (WHO, 1992; World Meteorological Organization, 2013). Therefore, this study conducted after two decades of available work on zooplankton of the lake will not only reveal the present status of the lake but would be useful in strengthening the policy for its protection and conservation.

MATERIALS AND METHODS

Study area

Shiroro Lake is located in Shiroro Local Government, in Niger State, Nigeria with a coordinates of 9^{o}59'7"N and 6^{o}54'58" east (Figure 1). It has a tropical wet and dry climate where rainfall is seasonal occurring between April and October, and sometimes extending to November with highest mean monthly rainfall in August/September. The dry season lasts from October to April, sometimes with temperatures as high as 29˚C (Garba & Muhammed, 2011). The vegetation of the study area falls within the Guinea Savannah region with fairly scattered trees and luxuriant grassland and some common economic trees found in the area.

Surface water sampling

Water samples for determination of dissolved oxygen (DO), biological oxygen demand (BOD), hardness, alkalinity, nitrate, phosphates, magnesium and total dissolved solids were collected and analysed according to the techniques described by APHA (2010). Dissolved oxygen, electrical conductivity, total dissolved solids and pH were measured *in situ* using a HANNA HI 9828 multi-probe meter manufactured by HANNA instruments.

Zooplankton samples collection

Zooplankton were sampled monthly from January 2015 to December 2015. Samples were collected from three sites in the lake namely, Site 1, which is close to the landing site where boats conveying villagers drop off their goods (coordinates of 9˚53'33.029"N and longitude 6˚49'55.234E); Site 2, about half a kilometre from the shore (coordinates of XXXXXXXXX) and Site 3, close to the power plant (coordinates of 9°56'27.85''N and longitude 6°50'6.00E). A zooplankton net of 40 cm diameter, 63 mm and 20 mm mesh size was used in collecting zooplankton samples were collected according to the techniques described by (Edmondson and Winberg 1971). Samples were collected, labeled and preserved in 4% formalin and analyzed as described by Ramachandra, *et al.* (2006). In the laboratory, one millilitre of the sample was taken into a dropper and added drop wise on a glass slide for identification using Olympus microscope model number CKX41. Plankton encountered were enumerated and grouped according to different taxa using keys provided by Altaff, (2004) and Haney, *et al*. (2013).

Data analysis

The mean monthly and standard deviation in physicochemical parameters of were compared using one way ANOVA. Before conducting ANOVA, Shapiro–Wilk and Levene's tests were utilized to test for the assumptions of normality and homogeneity of variance. Whenever it was found that these assumptions were not adhered to, data were log (x + 1)-transformed, except for pH. Data were actually analyzed by repeated measure ANOVA using sampling month as a sub factor. For data that were significant using ANOVAs ($P < 0.05$), were followed by post hoc {Tukey Honest (HSD)} tests to identify differences between month means. Canonical correspondence analysis (CCA) was employed in the evaluation of the relationships between zooplankton data and environmental variables using PAST statistical package (Hammer et al. 2001) after the variables were log transformed {log (x + 1)} to prevent to prevent extreme values (outlier) from unduly influencing the ordination. The species-environment correlation coefficients explained clearly how the individual environmental variables affected the community composition. The significance of the canonical axes extracted was assed using the Monte Carlo permutation test with 199 permutations. Students T-Test was conducted to determine seasonal relationship between parameters recorded using the SPSS version 16.0. The taxa richness (Margalef), diversity (Shannon and Simpson dominance), evenness indices were calculated using PAST statistical package (Hammer et al. 2001).

Results

Monthly variation in environmental variables of the lake water

The values of the physical and the chemical properties of the lake are presented in Table 1. The result shows that no significant difference was observed in Secchi transparency, nitrate and total dissolved solids. The range of temperature was (21.65±1.74^{O}C) in January to (20.80±2.04 ^{O}C) in February which was within the FEPA (1991) allowable standards. The range of pH was from 7.19±0.52 in February to (8.04 ±0.66) in June. The Secchi transparency value ranged from (17.8±4.48cm) in July to (23.73±0.88cm) in January. The range of the electrical conductivity was from 96.56±8.44 in April to 172.98±4.24 in the month of July. The Dissolved Oxygen ranged from 3.34±0.47 in the month of January to 8.04±0.63mg/l in July, while the range of alkalinity was from 13.75±0.65mg/l in the month of January to 15.72±2.5mg/l in the month of march. The highest nitrate level value was recorded in August (0.61±0.56mg/l) whereas the lowest value was in the month of November (0.29±0.08mg/l). the BOD values recorded ranged from 2.090.21 to 0.21 in the month of May to 3.33±0.19mg/l in the month of August
The values of phosphate ranged from 0.22±0.07mg/l in September to 0.32±0.04mg/l in November. The observed values of magnesium varied 0.24±0.02mg/l in the month of November to 0.33±0.03mg/l in December. The TDS values recorded ranged from 90.50±0.59mg/l in the month of March to (154.50±1.18mg/l) in the month of May.

The DO value in the month of June and July, falls below the FEPA 1991 standard value allowed for surface Water.

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Table 1: Monthly Values of Physico-chemical Parameters in Shiroro Lake from January to December 2017

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	FEPA, (1991)	NESREA 2010
Temperature (^{0}C)	21.65 ±1.74^{a}	20.80 ±2.04^{a}	24.54 ±2.03^{b}	27.39 ±1.15^{d}	26.93 ±1.37^{cd}	27.20 ±1.39^{d}	27.80 ±0.82^{d}	26.90 2±1.48^{c}	26.53 ±0.79^{c}	27.30 ±0.40^{d}	25.28 ±0.69^{bc}	24.24 ±0.85^{b}	15.00 - 35.00	-
Ph	7.66 ±0.35^{abc}	7.19 ±0.52^{b}	7.16 ±0.68^{ab}	7.40 ±0.12^{b}	7.54 ±0.80^{b}	8.04 ±0.66^{c}	7.65 ±0.44^{abc}	7.71 ±0.32^{bc}	7.55 ±0.30^{abc}	6.95 ±0.34^{a}	7.85 ±0.46^{bc}	7.21 ±0.52^{b}	6.50 – 9.20	6.5-8.5
Transparency (cm)	23.73 ±0.88^{a}	23.13 ±0.72^{a}	21.90 ±2.29^{a}	19.26 ±3.03^{a}	22.89 ±6.11^{a}	21.91 ±4.18^{a}	17.8 ±4.48^{a}	18.67 ±4.27^{a}	21.07 ±3.86^{a}	21.72 ±2.22^{a}	19.55 ±2.86^{a}	23.00 ±1.77^{a}	5.00 - 15.00	-
Electrical Conductivity µS/cm	141.20 ±7.44^{d}	135.66 ±1.95^{cd}	105.96 ±14.34^{bc}	96.56 ±8.44^{a}	119.96 ±7.53^{bc}	110.26 ±11.19^{b}	172.58 ±4.24^{e}	142.30 ±7.09^{d}	159.96 ±1.89^{e}	148.24 ±8.83^{de}	143.60 ±9.99^{d}	131.26 ±3.95^{c}	10.0 - 200.0	-
Dissolved Oxygen (m g/l)	8.04 ±0.63^{f}	7.48 ±0.76^{e}	5.79 ±0.99^{cd}	5.40 ±0.80^{c}	5.69 ±0.92^{cd}	4.14 ±1.64^{bc}	3.34 ±0.47^{a}	3.87 ±0.38^{b}	5.16 ±1.47^{c}	6.54 ±1.10^{d}	6.94 ±0.69^{d}	7.46 ±0.69^{e}	5.00	6.9
Biological Oxygen Demand (mg/l)	2.34 ±0.19^{ab}	2.99 ±0.21^{ab}	2.51 ±1.02^{a}	2.58 ±0.35^{ab}	3.08 ±0.47^{ab}	3.15 ±0.51^{ab}	2.68 ±0.38^{ab}	3.33 ±0.19^{b}	3.05 ±0.19^{ab}	3.04 ±0.28^{ab}	2.45 ±0.26^{ab}	3.28 ±0.15^{b}	3.0	3.0
Total Hardness (mg/l)	36.43 ±4.82^{ab}	31.22 ±1.89^{ab}	27.80 ±0.82^{ab}	29.77 ±1.42^{a}	25.57 ±4.36^{ab}	28.47 ±6.59^{ab}	26.65 ±4.39^{a}	28.72 ±4.87^{ab}	33.40 ±1.51^{b}	33.42 ±6.51^{ab}	33.45 ±5.48^{ab}	33.50 ±2.77^{ab}	500.00	-
Alkalinity (mg/l)	13.75 ±0.65^{a}	15.53 ±2.97^{a}	15.72. ±2.5^{a}	15.65 ±3.35^{a}	13.18 ±0.78^{a}	14.08 ±2.07^{a}	14.13 ±0.78^{a}	15.22 ±2.70^{a}	15.20 ±2.99^{a}	13.45 ±0.63^{a}	13.65 ±0.5^{a}	14.15 ±0.97^{a}	20.00 - 300.0	
Nitrate (mg/l)	0.44 ±0.22^{a}	0.38 ±0.19^{a}	0.34 ±0.34^{a}	0.34 ±0.2^{a}	0.51 ±0.37^{a}	0.39 ±0.17^{a}	0.35 ±0.19^{a}	0.61 ±0.56^{a}	0.51 ±0.39^{a}	0.44 ±0.15^{a}	0.29 ±0.08^{a}	0.31 ±0.20^{a}	10.00	9.1
Phosphate (mg/l)	0.32 ±0.05^{ab}	0.29 ±0.07^{ab}	0.26 ±0.02^{ab}	0.28 ±0.04^{ab}	0.25 ±0.03^{ab}	0.27 ±0.04^{ab}	0.27 ±0.05^{ab}	0.28 ±0.03^{ab}	0.22 ±0.07^{a}	0.27 ±0.04^{ab}	0.32 ±0.04^{b}	0.28 ±0.09^{ab}	0.50 - 5.00	3.5
Magnesium (mg/l)	0.26 ±0.02^{ab}	0.29 ±0.04^{b}	0.27 ±0.04^{ab}	0.32 ±0.02^{bc}	0.27 .±0.02^{ab}	0.29 ±0.04^{b}	0.35 ±0.03^{c}	0.29 ±0.02^{b}	0.29 ±0.05^{b}	0.30 ±0.06^{bc}	0.24 ±0.02^{a}	0.33 ±0.02^{bc}	50.00 - 150.00	40.0
Total Dissolved Solids (mg/l)	122.50±0 .26^{a}	102.50± 0.49^{a}	90.50±0. 59^{a}	125.50± 0.99^{a}	154.50± 1.18^{a}	122.00± 0.72^{a}	145.50± 1.25^{a}	139.50± 0.81^{a}	137.50± 0.89^{a}	119.50 ±0.36^{a}	141.00 ±0.40^{a}	132.00 ±0.99^{a}	1500.00	0.25

Notes: values are means ± standard deviation. Values followed by the same letters along the row are not significantly different at (p<0.05) using Tukey Honest test for comparison of means.

Seasonal variation in the environmental variables of the lake water

The seasonal variation in the physicochemical characteristics of the lake, indicated that temperature, pH, electrical conductivity, biological oxygen demand, nitrate, magnesium and total dissolved solids had significantly higher values in the wet season as compared to the dry season using student t-test for comparison (Table 2).

Zooplankton population dynamics and periodicity in the lake

The temporal variation in the population of zooplankton in Shiroro Lake is depicted in Table 3. A total number of 19 genera were encountered in the study made up of 5 rotifers, 6 Cladocerans and 8 copepods. *Leptodiaptomus* sp. had the highest number of individuals collected in January (208.5±0.00 individuals/ml), while *Ptygura* with a mean value had the least. 7genera were not recorded in the months. The genus *Leptodiaptomus coloradensi* was recorded in all the months and have the highest abundance, this was followed by Daphnia pulcaria, while least observed were *Bosminia longistris, Eubosmaina tubicen* and T*ropocyclops prasinus*.

Table 2. Independent student t-test comparing seasonal variation between the physico-chemical properties of Shiroro Lake.

	DRY SEASON	WET SEASON
Temp ^{O}C	24.75±2.93^{a}	26.34±1.33^{b}
pH	7.49±0.33^{a}	7.49±0.34^{a}
Transp (cm)	22.13±1.58^{a}	20.30±1.97^{a}
Conductivity µC/cm	1183±17.42^{a}	1467±14.58^{a}
DO, mg/l	6.09±1.43^{a}	5.55±1.69^{a}
BOD mg/l	2.78±0.34^{a}	2.97±0.34^{a}
Hardness mg/l	29.88±3.73^{a}	31.52±3.04^{a}
Alkalinity mg/l	14.65±1.11^{a}	14.30±0.76^{a}
Nitrate mg/l	0.4±0.06^{a}	0.42±0.13^{a}
Phosphate mg/l	0.28±0.02^{a}	0.27±0.03^{a}
Magnesium mg/l	0.28±0.02^{a}	0.30±0.03^{a}
TDS mg/l	1196±21.93^{a}	1358±9.14^{a}

Note: Values are means ±standard deviation. Values with the same superscript along the row are not significant (P>0.05) using Tukeyy Honest test for comparison of the means.

Table 3: Temporal Distribution of Zooplankton in Shiroro Lake, 2013/2014.

GENUS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Asplanchna	5.5±3.13	16.50±4.77	8.0±30.05	1.50±0.86	3.0±1.73	0.0±0.00	1.0±0.52	3.50±1.60	0.0±0.00	10.0±0.57	6.50±2.25	9.0±0.00
Anuraeopsis	12.0±0.00	2.0±0.00	4.0±0.00	0.0±0.00	2.0±0.00	0.00±0.00	0.0±0.00	0.0±0.00	0.0±0.00	26.0±0.00	2.0±0.00	7.0±0.00
Brachionus	2.50±0.00	1.50±0.00	0.50±0.00	0.00±0.0	0.00±0.0	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	1.50±0.00
Keratella;	21.00 ±0.00	0.50±0.00	7.0±0.00	1.50±0.00	1.50±0.00	0.0±0.00	0.50±0.00	9.0±0.00	00. ±0.00	7.0±0.00	7.0±0.00	14.50±0.00
Ptygura;	1.50±0.00	1.00±0.00	12.0±0.00	0.0±0.00	0.0±0.00	4.0±0.00	0.0±0.00	2.0±0.00	0.0±0.00	0.50±0.00	3.0±0.00	10.0±0.00
Limnocalanus	0.0±0.00	0.0±0.00	2.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	13.0±0.00	2.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00
Leptodiaptomus	208.5±0.00	64.5±0.00	84.5±0.00	52.0±0.00	64.0±0.00	25.0±0.00	128.0±0.00	40.0±0.00	215.0±0.00	8.0±0.00	210.0±0.00	208.0±0.00
Skistodiaptomus	40.5±0.00	8.0±0.00	0.0±0.00	1.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	10.5±0.00	2.5±0.00	0.0±0.00	23.0±0.00
Bosmania	0.0±0.00	4.0±0.00	1.0±0.00	0.0±0.00	31.5±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.5±0.00	0.0±0.00	0.0±0.00
Eubosmina	0.0±0.00	0.0±0.00	1.0±0.00	4.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	1.0±0.00	5.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00
Ceriodaphnia	84.0±0.00	39.5±0.00	45.5±0.00	23.5±0.00	41.0±0.00	0.0±0.00	0.0±0.00	22. ±0.00	4.5±0.00	18.5±0.00	28.5±0.00	75.0±0.00
Daphnia	84.0±0.00	62.0±0.00	58.5±0.00	46.5±0.00	72.5±0.00	0.0±0.00	0.0±0.00	76.0±0.00	9.5±0.00	19.0±0.00	28.5±0.00	75.0±0.00
Moina	32.0±0.00	3.0±0.00	11.5±0.00	15.5±0.00	16.0±0.00	14.0±0.00	8.5±0.00	2.0±0.00	35.0±0.00	22.5±0.00	43.0±0.00	13.5±0.00
Diaphanasoma	11.5±0.00	22.0±0.00	2.0±0.00	24.5±0.00	2.0±0.00	16.5±0.00	7.5±0.00	14.0±0.00	38.0±0.00	18.0±0.00	164.5±0.00	90.5±0.00
Cyclops	74.5±0.00	36.0±0.00	0.0±0.00	16.0±0.00	45.0±0.00	17.0±0.00	52.5±0.00	62.0±0.00	37.5±0.00	30.0±0.00	42.0±0.00	72.5±0.00
Diacyclop	0.0±0.00	9.0±0.00	8.0±0.0	17.0±0.00	29.0±0.00	0.0±0.00	13.5±0.00	17.5±0.00	4.0±0.00	5.0±0.00	0.0±0.00	28.5±0.00
Eucyclops	0.0±0.00	51.5±0.00	8.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	23.05±0.00	30.5±0.00	27.0±0.00	6.5±0.00	44.5±0.00	71.0±0.00
Tropocyclops	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00	3.0±0.00	0.0±0.00	0.0±0.00	5.5±0.00	6.5±0.00	0.0±0.00	0.0±0.00
Anthocyclops	0.0±0.00	0.5±0.00	1.0±.000	4.0±0.00	0.0±0.00	0.0±0.00	8.5±0.00	0.5±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00

Values are means ±standard deviation.

Table: 4. Mean, seasonal variation and correlation between wet and dry season of Zooplankton diversity of Shiroro Lake 2013/2015.

GENUS	Dry Season	Wet Season	Mean Value	Taxa_S	Simpson dominance index	Shannon wiener diversity	Evenness	Taxa richness (Margalef index)
Rotifer								
Asplanchna	8.1±5.51[a]	2.91±3.77[a]	5.38±4.72	10	0.8524	2.066	0.7889	2.16
Anuraeopsis	5.0±4.69[a]	4.66±10.48[a]	4.58±7.33	7	0.7035	1.501	0.6408	1.497
Brachionus	1.20±0.97[a]	0[b]	0.5±0.82	4	0.6944	1.265	0.8858	1.674
Keratella;	8.90±8.75[a]	3.0±3.96[a]	5.79±6.33	10	0.8169	1.883	0.6576	2.122
Ptygura;	4.9±5.64[a]	1.0±1.63[b]	2.83±3.88	8	0.7608	1.664	0.6598	1.985
Cladocera								
Bosmania	1.0±1.7[a]	5.33±12.82[b]	3.08±8.64	4	0.2626	0.5333	0.4261	0.8308
Eubosmina	1.0±1.7[a]	1.0±2.0[a]	0.92±1.65	4	0.6446	1.162	0.7993	1.251
Ceriodaphnia	53.5±25.26[a]	14.33±16.09[a]	31.83±25.89	10	0.8615	2.109	0.8238	1.514
Daphnia	65.2±14.61[a]	29.5±35.38[b]	44.29±30.09	10	0.8782	2.172	0.8779	1.434
Moina	15.1±10.58[a]	16.33±11.47[a]	18.04±12.21	12	0.8785	2.251	0.791	2.046
Diaphanasoma	30.1±34.93[a]	16.0±12.33[b]	34.25±45.36	12	0.7705	1.851	0.5304	1.828
Copepods								
Leptodiaptomus	123.5±78.23[a]	80±78.22[a]	108.96±77.12	12	0.8749	2.218	0.7659	1.533
Skistodiaptomus	14.5±17.19[a]	2.16±4.20[b]	7.13±12.05	6	0.6784	1.342	0.6376	1.124
Limnocalanus	0.4±0.89[a]	2.5±5.21[a]	1.42±3.57	3	0.3875	0.7087	0.6771	0.7059
Cyclopoda	39.8±33.3[a]	40.67±16.11[a]	40.42±21.87	11	0.8923	2.301	0.9077	1.617
Diacyclop	12.5±10.78[a]	11.5±10.74[a]	10.96±9.89	9	0.8487	2.016	0.8341	1.64
Eucyclops	26.1±32.98[a]	14.5±13.92[b]	21.84±22.82	8	0.8257	1.871	0.812	1.257
Tropocyclops	0[a]	2.5±2.97[b]	1.25±2.29	3	0.6378	1.052	0.9546	0.7385
Anthocyclops	1.1±1.67[a]	1.5±3.44[a]	1.21±2.45	5	0.5731	1.085	0.5919	1.496

Note: values are means ± standard deviation. Values followed by the same super script letters along the column are not significant.

Generally, the dry season was observed to favour more organisms. More than half of the rotifers were recorded in the dry season. Significance difference was only observed among the *Brachionus* and *Ptygura*. The number of taxa recorded among the cladocerans and the copepods were equally distributed within the seasons. Significant difference was observed among the Bosmania and the Diaphanasoma in the Cladocerans. In the copepods, the taxa recorded were also equally distributed among the season, with significance difference observed in Skistodiaptomus, Eucyclops and Tropocyclops.

Taxa Richness, Diversity, Evenness and Dominance Indices:

The diversity indices show that, the margalefs diversity was generally low with Asplanchna, having the highest while (2.16) followed by keratella, Moina, Diaphanosum. Cyclopos and Tropocyclops were the most evenly distibuted. The most dominant species were Kereatella, Ceriodaphnia, Daphnia, Moina, Leptodiaptomus, Cyclops Diacyclops and Eucylops.
The Canonical correspondence analysis (CCA) ordination plots (Figure 2) have shown a good relationship between the months, physico-chemical parameters and the zooplankton genus. DO and the nitrate were strongly negatively correlated. DO is negatively correlated with transparency whereas nitrate is positively correlated with transparency.

Asplanchnidae were most commonly associated with DO in a positive way, while Bosmanidae are mostly related to nitrate in a positive way. Where Bosmanidae and nitrate where negatively correlated with the rotifer Anureopsis. The local environmental conditions accounted for 31.06% of the variation of the abundance of the zooplankton in axis 1. The parameters in axis 2 were mostly affected by parameters that are sensible to environmental factors like nitrate, Total Dissolved solids, Electrical Conductivity, Alkalinity, Magnesium, Phosphate Temperature.

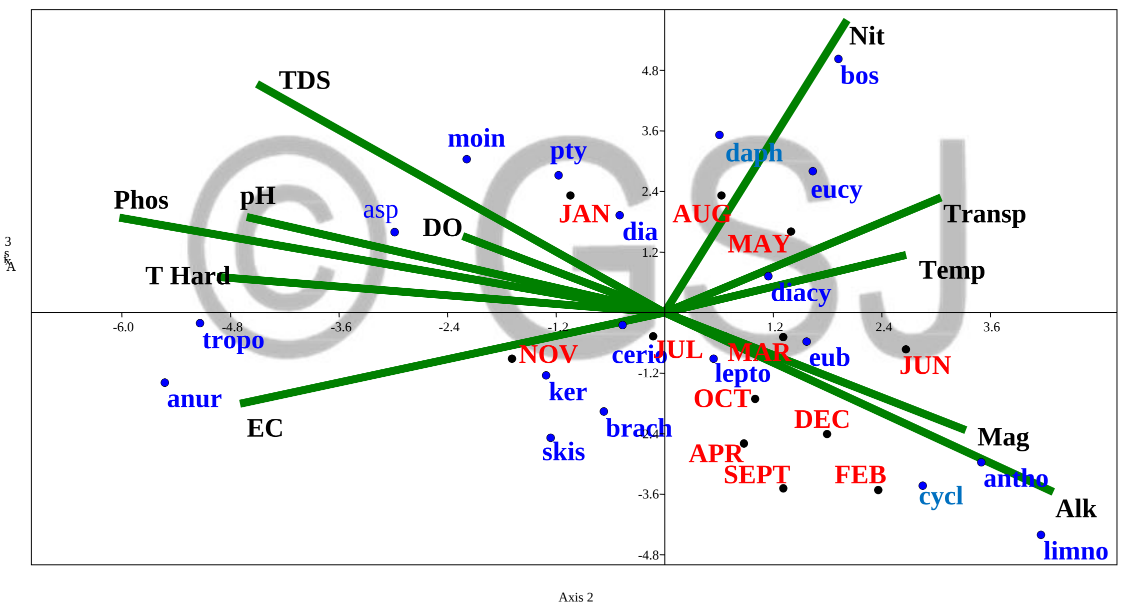

Fig. 1: Canonical correspondence analysis plot of physico-chemical parameters and zooplankton genus of Shiroro Lake in 2013/2015.

Key: Asplanchna, Asp; Anuraepsis, Anur; Brachionus, Brach; Kearatella, Ker; Ptygura, Pty; Limnocalanus, Limno; Skistodiaptomu, Skis; Bosmania, Bos; Eubosmania, Bos; Ceriodaphnia, Cerio; Daphnia, Daph; Moina, Moin; Diacyclops, Diacy; Eucyclops; Eucy; Tropocyclops, Tropo; Anthocyclops, Antho.

Discussion

The low temperature value recorded in the lake within the months of January and February was possibly as a result of the effect of the north east trade winds (Oluleye and Jimoh, 2018) (the could be due to increased insolation and high evaporation, and this is a characteristics of African lakes, (Nikki, *et al*, 2014, Ashaolu and Iroye, 2018). Lower numbers of zooplankton recorded in the wet season could be due to a dilution of the water or run off from tributaries is washing away a large number of the zooplankton, (Lukasz, 2019). The lake water could be described as transparent and it is clearer in the dry season compared to the wet season, this could be due to reduced turbid materials from run-offs into the lake, Yi *et al.* (2018).

So also the concentration of dissolved oxygen is exhibiting the same characteristics with that of transparency. Zooplankton encountered in this study have wide distribution as compared with those in other reports from rivers, stream and lakes in Nigeria, (Jeje 1989). The rotifers being smaller and compared to other zooplankton, could easily be flushed out of the lake or killed by the influx if run-off into the lake, thus reducing their numbers in the wet season or because of higher values of total dissolved solids, nitrates and biological oxygen demand in the wet season which could signify pollution in lake water.

The crustacean zooplankton were mostly dominated by the copepods which have more genus that were dominated by wet seasons tolerant types with leptodiaptomus having the highest number of individuals. This is in agreement with the report of Arimoro and Ogana (2010) who observed similar increase in the number of the organisms in the wet season in Orogodo River, southern Nigeria.

The increased level of electrical conductivity in the wet season is an indication of increased level decomposition of organic matter that is brought in to the lake and result into decreased level of DO in the wet season which metamorphose into increased number of the zooplankton in the wet season (12 genus) compared to the dry season(7 genus). This wet season increase could result from increased inflow of various materials into the lake, whose decomposition results into the seasonal variation. In this study it was observed that the rotifers were tolerant to the dry season while the copepods were more tolerant the wet seasons.

From this report it was observed that the genus Diacyclops, Bosmania, Eucyclops, Daphnia, Diacyclops were sensitive to nitrate, temperature and transparency all of whom were abundant the in the wet season from the canonical correspondent analysis plot.

Conclusion

This research shows that the zooplankton responds to the variation of the physico-chemical parameters which lead to their having different diversities at different seasons. It was observed that the copepods, Leptodiaptomus have the largest numbers of individuals and is influenced by the seasons and is most abundant in the wet season. Cyclops, Anthocyclops and Limnocalanus were influenced by Magnesium, and Alkalinity was all common in the wet season. Among the rotifers Brachionus was most even, but Asplanchna and Keratella were the most dominant, while in the Cladocera, Ceriodaphnia and Daphia and the Moina were the most dominant with Ceriodaphnia and Daphia more even. In the Copepods, the Leptodiaptomus, Cylops, Diacyclops and the Eucyclops were the most dominant while the Cyclops, Diacyclops, Eucyclops and Tropocyclops have most even distribution. These types of researches could be used to monitor aquatic ecosystems so as to understand and know the effects of each of these parameters.

References

Adie DB, Ismail A, Muhammad MM, Aliyu UB. 2012. Analysis of the Water Resources Potential and Useful Life of the Shiroro Dam, Nigeria. Niger. j. of Basic and appl. Sci. 20(4):341-348.

Altaff, K. (2004). *A manual of Zooplankton.* University grants commission, New Delhi, 1-145.

APHA, 2010. *Standard methods for the examination of water and waste water 17th Edition.*Am. Public Health Assoc. Inc. Washington D.C., 68 - 70.

Arimoro FO, Oganah OA. 2010. Zooplankton Community Responses in a Perturbed Tropical Stream in the Niger Delta, Nigeria. Open Environ. Biol. Monit. J. **3**: 1-11.

Arimoro F.O,Olisa H.E., Keke, U.N; Ayanwale A.V., Chukwuemeka V.I. (2018a). Exploring spatio-temporal patterns of plankton diversity and community structure as correlates of water quality in a tropical stream *Acta Ecologica Sinica*, 38(3): 216-223

Arimoro F.O, Auta Y.I, Odume O.N., Keke, U.N; Mohammed A.Z. (2018b). Mouthpart deformities in Chironomidae (Diptera) as bioindicators of heavy metals pollution in Shiroro Lake, Niger State, Nigeria *Ecotoxicology and Environmental Safety* 149:96-100

Ashaolu ED, Iroye KA. 2018. Rainfall and potential evapotranspiration patterns and their effects on climatic water balance in the Western Lithoral Hydrological Zone of Nigeria. Ruhuna J. of Sci.9(**2**): 92-116 .

Edmondson W.T., Winberg G.G. (1971). A Manual on Methods for the Assessment of Secondary Productivity in Freshwaters. IBP Handbook No. 17, Blackwell Scientific Publications, Oxford.

Federal Environmental Protection Agency (FEPA), 1991. Guidelines and Standards for Environmental Pollution in Nigeria.

Garba I K, Mohammed A E. (2011). The Socio-Economic Impact of Shiroro Hydroelectric Dam on the Displaced and Resettled Inhabitants of Zumba Community, Niger State, Nigeria. J. of Sci. Techno. Math. and Educ. 8(1).

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: paleontological statistics software package for education and data analysis. Palaeontol. Electron. 4(1): (9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm Accessed 10 December, 2019).

Haney, J.F. *et al*. "An-Image-based Key to the Zooplankton of North America" version 5.0 released 2013. University of New Hampshire Center for Freshwater Biology <cfb.unh.edu> 8 Mar 2004

Idowu RT, Inyang NM, Eyo JE. 2004. The physico-chemical parameters of an African arid zone man-made lake. Anim. Res. Int. 1(2):11 –119.

Ireneusz Z, Aleksandra Z. 2017. Analysis of factors affecting the ecological status of the large water bodies on the basis of monitoring and integrated 3D models. *E3S Web of Conferences* 19, 02009

Jeje CY. 1989. The Cladoceran fauna of Nigeria: A checklist, review of literature and distribution. Rev. of hydrobiol. Trop. 22(1): 3-11(198.9)

Kolo RJ. 1999. The assessment of physico-chemical parameters of Shiroro Lake and its major tributaries. In: 13th Annual Conference of the Fisheries Society of Nigeria 3-8 November 1996, New Bussa, Nigeria. 260-268.

Liyanage CP, Yamada K. 2017. Impact of Population Growth on the Water Quality of Natural Water Bodies. Sust. 9: 1405

Lukasz S, Robert C, Monica KG, Magdalena S, Anabela R, Joao SC, Carlos AT. (2019). The Impact of Land Use Transformations on Zooplankton Communities in a Small Mountain River (The Corgo River, Northern Portugal). Int. J. of environ. Res. and public health. 16(10): 20

Nikki V, Steve WL, Georgia D. 2014. Seasonal influence of insolation on fine-resolved air temperature Variation and snowmelt. J. of Appl. Meteorol. Clim. 53: 232- 332.

Oluleye A, Jimoh OR. 2018. Influence of atmospheric circulation patterns on dust transport during Harmattan Period in West Africa. Pollut. 4(1):9-27.

Osu UU, Mohammed MD, Yelwa SA, Mohammed SS, Mahmud A, Ismaila N.I. 2014. Promoting Sustainable use of Rivers for Tourism and Recreation in Nigeria. The Journal of Research in National Development 12(2).

Ovie SI, Adeniji HA. 1994. Zooplankton and environmental characteristics of Shiroro Lake at the extremes of its hydrological cycle. Hydrobiol. 286(3):175-182.

Oyero JO. 2001. A preliminary investigation into the post harvest losses of fish in Shiroro Lake area. *In:* 14th Annual Conference of the Fisheries Society of Nigeria 19-23 January 1998, Ibadan. Nigeria 213-216.

Park KS, Shin HW. 2007. Studies on phyto-and-zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem. J. of Environ. Biol. 28:415-422.

Ramachandra TV, Rishiram R, Karthick B. 2006. Zooplanton as bioindicators: hydro-biological investigation in selected Bangalore lakes. The ministry of science and technology, Government of India. 1-240.

Umerfaruq QM, Solanki HA. 2015. Physico-chemical Parameters of Water in Bibi Lake, Ahmedabad, Gujarat, India. J. of Pollut. Eff. and Control 3(1): 1-5.

World Health Organization. 1992. Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition. Printed in Great Britain at the University Press, Cambridge. 609

World Meteorological Organization, 2013. Planning of water quality monitoring systems. Technical Report Series No. 3. 7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland. 128

Yi W, Rong D, Yongfeng X, Jiangang H, Pingping L. (2018). Statistical Assessment of water quality issues in hongze lake, china, related to the operation of a water diversion project. Sust. 10, 1885.