Direct Research Journal of Public Health and Environmental Technology

Vol.3 (7), pp. 87-101, December 2018
ISSN 4372-2603
DOI: https://doi.org/10.26765/DRJPHET.2018.2086
Article Number: DRJA1703412086

http://directresearchpublisher.org/journal/drjphet/

Research Paper

Zooplankton Assessment of Usuma Reservoir, in FCT Abuja Nigeria

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Received 12 November 2018; Accepted 26 December, 2018

This paper assessed the zooplankton composition of Usuma reservoir. The occurrence and growth of various species of plankton in the water body are controlled by factors such as abiotic, morphometric factors of water body, sewage discharges and anthropogenic factors. A total of 3.59×10^4 organisms/L was recorded for phytoplankton abundance. For zooplankton, a total of 3.925×10^4 cells/l were counted. Rotifer was observed to have a total abundance of 43%, while copepods contributed a total of 29% of all zooplankton, Cladocera gave 28%. The zooplankton fauna observed are Cladocera with 11 genera, Copepods which is made up of 13 genera, Rotifera with 17 genera. This is an indication that the Usuma reservoir has a total 41 genera constituting its zooplankton composition. The order of dominance of the zooplankton of Usuma reservoir is Rotifer > Copepoda. > Cladocera with Bosmina longirostis being the most dominant (8.9%) of the total zooplankton of Usuma reservoir. The hydrology, water residence time, precipitation, evaporation, and bedrock chemistry were some of the factors identified to influence the variations. Significant positive and negative correlations were observed between the physico-chemical parameters with each other and with the phytoplankton, zooplankton. The reservoir falls into the class II level of pollution which is indicative of Moderate pollution. Canonical correspondence analysis further extracted "organic (DO, BOD), eutrophication (air temperature, water temperature, water current velocity, turbidity, chloride ion, phosphate and nitrate), acidification (manganese, pH, nitrate, BOD and DO) and industrial and anthropogenic" as major influencing factors in the Usuma reservoir. The study showed the reservoir to be eutrophic with moderate water quality, high ecological and pass chemical status, with diverse assemblages of plankton.

Keywords: Physicochemical parameters, plankton, zooplankton and reservoir

INTRODUCTION

The fundamental principle behind biological indicator theory is that organisms provide information about their habitats. A biological indicator (or bio-indicator) is a taxon/taxa selection based on its sensitivity to a particular attribute and then assessed to make inferences about that attribute. In other words, they are a surrogate for directly measuring abiotic features or other biota. Bio-indicators are evaluated through presence/absence, condition, relative abundance, reproductive success, community structure (i.e. composition and diversity), community function (i.e. trophic structure), or any combination thereof (Hellawell, 1986; Landres *et al.*, 1988). Communities (i.e. organisms living and interacting with one another in a specific habitat) are generally regarded as the most appropriate indicators for conservation biology since inferences can be made at the ecosystem level, as opposed to being limited to an individual species or population (Kovacs *et al*. 1992).

Zooplankton includes all major groups of animal members of the drifting planktons found in freshwater. They constitute very important natural fish food (Adebisi, 1989) Zooplankton has been recommended as regional bioindicators of lake eutrophication (Stemberg and Lazorchack, 1994;Attayde and Bozelli, 1998; Straile and Geller, 1998; Pinto-Coelho *et al*., 2005a, b; Burns and Galbraith, 2007), acidification (Pinel-Alloul *et al*., 1990), watershed disturbances by agriculture (Dodson *et al*., 2005, 2007) or logging and wildfire (Patoine *et al*., 2002).

There is an increasing demand by environmental monit oring programs for bio-indicators of water quality (Wanes sa *et al*., 2008). This study will attempt not only to investigate how the trophic state, selected water quality parameters relate with the structure of the zooplankton and phytoplankton communities in the Lower Usuma Dam reservoir but will also try to look at the potential of the zooplankton as a bio-indicator of the main alterations in the water quality of this reservoir and to describe some water quality changes and plankton diversity and abundance in Lower Usuma reservoir as they relate to land use in the FCT.

The specific objectives of this paper are:

(i) Assessment of the species composition, percentage of composition, abundance of the major assemblages of the zooplankton of the reservoir.
(ii) Study of the ecological interactions between the physical, chemical and zooplankton components of the reservoir for management purpose.
(iii) Recommendation for management strategies for effective utilization of the water and sustainable exploitation of its fisheries.

MATERIALS AND METHODS

Sampling stations

Three sampling stations were selected and were conducted fortnightly. They are:

Station 1

This is the Usuma reservoir (main dam) situated along the axis of the inflow (inlet of reservoir); characterized by area of slow moving water receiving an enormous impact of human influence, having an inflow of waste with plastics and other floating materials littering entire water body. It has a depth of about 45 m and a surface area of 8 km and a catchment size of 200 km. It has minimal human activity. It also receives inflow from Gurara inter basin transfer.

Station 2

This is the Ushaffa saddle dam which is about 470 m long and representing an area of moderate flow. It is an area known for enormous fishing and grazing. Other human activities like washing and bathing take place here. It is characterized by a sandy and marshy littoral zone. It has an area of 6 km. The depth is about 25 m. The distance between station 1 and 2 is about 10 km.

Station 3

This is the Usuma outflow representing an area of fast flowing water with rocky substratum. It has a high density of human activities all year round. The anthropogenic activities include farming, bathing, felling and collection of fuel-wood, mining of sand, washing of motorcycles and also serve as grazing ground for animals and herds men. It has an area of 5 km. The depth is about 12 m. It is 4 km from station 1. The station has deforested bank thereby exposing this section of the river to direct sunlight.

Sample collection

Collection of samples was carried out fortnightly in the mornings between the hours of 6.00 am and 10.00 am for a period of one year, from June, 2016 to May, 2017. Samples were collected with plankton net of 90 µm mesh size standard plankton net for zooplankton. Horizontal Zooplankton hauls were made using 90 µm mesh size plankton net at a low speed for about 8 min. Concentrates were fixed with 70% ethanol and transporte d to the laboratory in labeled 250 ml bottles with screw caps (Ibemenuga *et al*., 2013; Iloba and Ruejoma, 2014).

The samples were concentrated to 10 ml by sedimentation method after standing for 48 h for settling. After settling, the supernatant layer was siphoned and the concentrated samples were mixed thoroughly and then 0.1 ml was pipetted carefully into 50 x 9 mm petri dishes and carefully positioned over the chamber for viewing. The zooplankton were identified and counted under a binocular microscope (Olympus CK 40, celestron digital microscope for video recordings and snapshots of isolates and leicher inverted microscope). Organisms were viewed using the x40 and x100 objectives of binocular microscope (Olympus and) and celestron digital microscope. Drawings were made and Zooplankton taxonomic identification was done with reference to appropriate identification key (Jeje and Fernando, 1986;

Olaniyan, 1975; Pennak, 1978; Wetzel, 1977). The various zooplanktons were identified to species and family level where possible. The zooplankton seen with the ocular microscope were identified and counted (Rao and Choubey, 2009; Idowu, 2004; Ibemenuga et al., 2013). Density was expressed as the number of individuals per sample volume (ind/l). The zooplankton community composition was done by calculating the species diversity index (H) (Ogbeibu, 2005). Density of organisms was estimated from the count records of the final concentrate volume in relation to the original volume of water sediment.

$$\text{Cells/ml} = N \times 1000 \text{ ml} \times V$$

Where N=number of cells/unit counted, V= Volume of concentrate viewed.

RESULTS AND DISCUSSION

Zooplankton composition of Usuma reservoir

Overall, 3 groups of zooplankton were seen in the Usuma reservoir. The Observed zooplankton groups in this study were rotiferas, cladocerans and copepods. A total of 28, 31, and 24 species were recorded in Stations 1, 2 and 3 respectively with abundance values of 3.925 $\times 10^4$ cells/m^3.

Table 1 shows the mean density of zooplankton classes in Usuma reservoir. Cladocera and rotifer were observed to be highest in station 1 and 3 while copepod was highest in station 2 (Figure1). *Bosmina longirostis* was the most abundant species with an abundance of 8.9% and *Diaphanosoma* constituting the least abundant with a value of 0.4%. In station 1, CO_2 correlated negatively with Cladocera (r=-0.665) (Figure 2 and Table 3). The classification and composition of the observed zooplankton is given in (Tables 4 and 8).

The zooplankton fauna are *Cladocera* with 11 genera, *Copepods* which is made up of 13 genera, *Rotifera* with 17 genera. This is an indication that the Usuma reservoir has a total 41 genera constituting its zooplankton composition as shown in (Table 2).

In Usuma reservoir, cladoceras constituted 28% of the entire abundance, copepods constituted 29% while rotifer constituted 43%. *Rotifera* constituted the major group in Usuma reservoir.

Rotifera constituted the major group in Usuma reservoir making up 43 % of the entire Zooplankton with a total population of 16.95 $\times 10^4$. This is closely followed by The Copepods constituting the next in distribution with a population of 11.45 × 104 with an abundance of 29% (Table 1). *Cladocera* with 28% and a population of 10.80 $\times 10^4$ constituted the least in abundance.

Station 1 contributed 46.6% of total zooplanktons of Usuma reservoir and a total of 18.3 $\times 10^4$ cells/l (Cladocera making up 28%, Copepod; 22% and Rotifer 50%). Stations 2 made up 39.4% (15.5$\times 10^4$ cells/l.) with Cladocera making up 22%, Copepod; 37% and Rotifer 41%. In Station 3 5.45 $\times 10^3$ cells/l were counted constituted 14% of zooplanktons with Cladocera making up 43.1%, Copepod; 29.4% and Rotifer 27.5% (Table 2).

Species distribution and abundance of zooplankton in all stations

Table 2 shows that station 1 had the highest value of zooplankton 18.3 $\times 10^4$ followed by station 2 (15.5 $\times 10^4$) and then station 3 (5.45$\times 10^3$). The class of Rotifer had the highest abundance of zooplankton making up 50% with a total of 9.15 $\times 10^3$ cells/l. Cladocera had the next highest abundance of zooplankton constituting 28% abundance and a total of 5.1$\times 10^3$ cells/l. the copepods were the least in abundance with a value of 22% and a total of 4.05 $\times 10^3$ cells/l. this is in the order *rotifera > cladocera > copepod* as indicated in (Table 1). Species distribution of zooplankton in station 1 is presented in (Table 2).

In station 2, the total zooplankton abundance is 15.5 $\times 10^4$ cell/l. The most abundant class here is *rotifers* with a count of 6.3 $\times 10^3$ cell/l and constituting 41% of the zooplankton (Tables 1 and 2). The next in ranking was copepods (5.8 $\times 10^3$ cells/l) and making up 37% of the entire population in the station. *Cladocera* had abundance of 3.4 $\times 10^3$ cell/l and with an occurrence of 22% of the distribution (Table 2). Species distribution of zooplankton in station 2 is shown in (Table 2). *Daphnia Daphnia* was the most abundant species with an abundance of 8.4%. *Polyathra and Mytilina ventralis* constituted the least abundant with a value of 0.1%. In station 2, Chloride ion correlated positively with Cladocera (r=0.791) CO_2 correlated positively with Copepods (r=0.717), water temperature correlated positively with rotifer (r=0.622), Chloride ion correlated positively with Cladocera (r=0.791), colour, Nitrate, salinity, TDS, Total Iron and turbidity correlated positively with copepods (r=0.717, 0.801, 0.739, 0.747, 0.737 and 0.739 respectively) (Table 3). The total zooplankton counted in station 3 was 5.45$\times 10^3$ cells/. Cladocera had distribution of 2.35$\times 10^3$cells/l constituting the highest distribution of 43.1% of total zooplankton in this station. Copepod constituted 29.4% with a total distribution of 1.6$\times 10^3$ cells/l. Rotifer constituted the least in distribution with a total of 1.5$\times 10^3$ cells/l and an abundance of 27.5% of zooplankton in this station (Table 2). Species distribution of zooplankton in station 3 is shown (Table 2). In station 3, Air temp, phosphate and Water temperature correlated negatively with copepods, cladocera and

Table 1. zooplankton abundance and distribution of Usuma reservoir.

Zooplankton Group	Species/Genera	Total number of species	Total abundance (%)	Zooplankton class Abundance (%)
CLADOCERA	*Bosmina longirostis*	3500	8.9	28
	Bosmina bosmina	100	0.3	
	Daphnia daphnia	3050	7.8	
	Ceriodaphnia dubia	1050	2.7	
	Simocephalus	1100	2.8	
	Macrothrix	650	1.7	
	Diaphanosoma	150	0.4	
	Eubosmina	200	0.5	
	Alona	600	1.5	
	Ophryoxus gracilis	50	0.1	
	Moina	400	1	
COPEPOD				
	Monocalamus macruru	100	0.3	29
	Skistodiaptomus reighardii	1750	4.5	
	Diaptomus nigerianus	2900	7.4	
	Nauplius larva	950	2.4	
	Mesocyclops edax	1500	3.8	
	Acanthocyclops	750	1.9	
	Macrocyclops	550	1.4	
	Dicyclops	1250	3.2	
	Cryptocyclops bicolor	100	0.3	
	Cyclops s.	100	0.3	
	Eucyclops	700	1.8	
	Thermocyclops	150	0.4	
	Harpaticoida	650	1.7	
ROTIFER				
	Testudinella patina	450	1.1	43
	Brachionus caudata	1200	3.1	
	Brachionus pticotilis	100	0.3	
	Keratella quadratta.	900	2.3	
	Keratella cochlearis.	2150	5.5	
	Philodina	1900	4.8	
	Rotifer vulgaris	1100	2.8	
	Unknown	1150	2.9	
	Lecane	4300	11	
	Asplanchna	2500	6.4	
	Polyathra	250	0.6	
	Euclanis	100	0.3	
	Rotatoria	150	0.4	
	Mytilina ventralis	50	0.1	
	Monostylla	100	0.3	
	Lepadella	50	0.1	
	Conochilus	500	1.3	
TOTAL		39250	100	

copepod (Table 3). In station 3, air temperature correlated positively with copepods (r=0.787), Dissolved Oxygen correlated negatively with Rotifer (r=-0.633) ($p < 0.05$) (Table 3).

Species diversity and richness indices of zooplankton

Table 5 shows the value of species diversity and richness indices of zooplankton in the Reservoir. In station 1, the Shannon–Wienner index and Margalef richness index for zooplankton were 3.06 and 2.94 respectively. In station 2, the values were, 3.01 and 3.21 respectively, while, in station 3, the values were 1.4 and 2.67 respectively. Station 1 is more diverse than station 2 and 3 while station 2 is richer than other stations. The Cj value was 0.21; this indicates that there is 21% similarity of families among the three sample stations. Usuma reservoir water quality class based on degree of pollution is moderately polluted as it falls into the class II Water quality (Table 6). The month of March exhibited the highest diversity and richness (2.83 and 2.66 respectively), while February exhibited the least values of diversity and richness (1.96 and 1.27 respectively) (Figure 5).

In the dry season, 35.5% of the entire zooplankton population was isolated in the dry season (Figure 6). In station 1, the month of April recorded its highest value for

Table 2. Species distribution and abundance of zooplankton in all stations sampled.

Taxa	Species	Station 1	Station 2	Station 3	Abundance (%)
CLADOCERA					
	Bosmina longirostis	2100(11.51)	900(5.8)	500(9.2)	
	Bosmina Bosmina	0	100(0.6)		
	Eubosmina	0	100(0.6)	100(1.8)	
	Alona	0	250(1.6)	350(6.4)	28
	Daphnia daphnia	1150(6.3)	1300(8.4)	600(11)	
	Ceriodaphnia dubia	450(2.47)	350(2.3)	250(4.6)	
	Simocephalus	1000(5.48)	100(0.6)		
	Ophryoxus gracilis	0	0	50(0.9)	
	Macrothrix	300(1.64)	300(1.9)	50(0.9)	
	Moina	0	0	400(7.3)	
	Diaphanosoma	100(0.55)		50(0.9)	
COPEPOD					
	Skistodiaptomus reighardii	750(4.11)	850(5.5)	150(2.8)	
	Monocalamus macruru	0	100(0.6)		
	Diaptomus nigerianus	1100(6.03)	1550(10)	250(4.6)	
	Nauplius larva	100(0.55)	850(5.5)		
	Mesocyclops edax	600(3.29)	550(3.5)	350(6.4)	29
	Acanthocyclops	150(0.82)	600(3.9)		
	Eucyclops	0	150(1)	550(10)	
	Macrocyclops	400(2.19)	150(1)		
	Dicyclops	650(3.56)	550(3.5)	50(0.9)	
	Thermocyclops	0	150(1)		
	Cryptocyclops bicolor	100(0.55)	0		
	Cyclops scutifer.	100(0.55)	0		
	Harpaticoida	100(0.55)	300(1.9)	250(4.6)	
ROTIFER					
	Testudinella patina	450(2.4)	0		
	Brachionus caudata	950(5.20)	200(1.3)	50(0.9)	
	Brachionus pticotilis	0	100(0.6)		
	Keratella quadratta.	900(4.93)	0		
	Keratella c.	750(4.1)	850(5.5)	550(10)	
	Philodina	850(4.66)	950(6.1)	100(1.8)	
	Conochilus	0	300(1.9)	200(3.7)	43
	Rotifer vulgaris	650(3.56)		150(2.8)	
	Tricocerca	1100(6.0)	50(0.3)		
	Lecane	1550(8.49)	2550(16)	200(3.7)	
	Asplanchna	1600(8.77)	800(5.2)	100(1.8)	
	Polyathra	100(0.5)	50(0.3)	100(1.8)	
	Mytilina ventralis	0	50(0.3)		
	Euclanis	100(0.5)	0		
	Rotatoria	150(0.82)	0		
	Monostylla	0	100(0.6)		
	Lepadellapatella	0	0	50(0.9)	
TOTAL		18300	15500	5450	

Values in parenthesis represent percentages relative abundance (%) of zooplankton species in all stations.

rotifer and the lowest value was recorded in the month of February of 2017 (Figure 7). In station 2, the month of November recorded its highest value for rotifer (3.0×10^2 cells/l) and the lowest value (5.0×10^1cells/l) recorded in the month of April of 2017. Rotifers were absent in station 2 in the months of January and March of 2017 (Figure 8). In the wet season, within the period under review, a total of 2.53×10^4 cells/l was counted (Figure 6). In station 1, the month of May 2016 recorded its highest value for rotifer and the lowest value recorded in the month of October of 2017. Rotifers were present throughout the months (Figure 10).

The month of October 2016 recorded the highest value of Copepods (4.50×10^2cells/l). The least values were recorded in the month September 2016.

Cladoceras was recorded in all the months of sampling in this station (Figure 10). In station 2, the month of October 2016 recorded its highest value for rotifer (2.05×10^3 cells/l) and the lowest value (1.5×10^2cells/l) recorded in the month of august of 2016. Rotifers were present throughout the months sampled in the wet season (Figure 11). The month of July 2016 recorded the highest value of Copepods (7.50×10^2cells/l). The least values were recorded in the month October 2016 (1.0×10^2 cells/l)

Table 3. Correlation of environmental variables with zooplankton.

Parameters	Station 1	Pearson's correlation (r)	p (Sig.)	Station 2	Pearson's correlation (r)	p (Sig.)	Station 3	Pearson's correlation (r)	p (Sig.)
Air temp							Copepods	0.787	0.002**
CO_2	Cladocera	-0.665	0.018*	*Copepods*	0.717	0.009**			
DO							Rotifer	-0.633	0.027*
Chloride ion				Cladocera	0.791	0.002**			
Colour				Copepods	0.717	0.009**			
Nitrate				Copepods	0.801	0.002**			
Salinity				Copepods	0.739	0.006**			
Sulphate				Copepods	0.669	0.017*			
TDS				Copepods	0.747	0.005**			
Water temperature				Rotifer	0.622	0.031*			
Total Iron				Copepods	0.737	0.006**			
TURB				Copepods	0.739	0.006**			

* Significant at $p < 0.05$, ** Significant at $p < 0.01$, DO= dissolved Oxygen, TDS= total dissolved solids

Table 4. Classification and composition of zooplankton in Usuma reservoir, Abuja.

Phylum	Class	Order	Family	Genus/Species
Rotifera	*Eurotatoria*	*Ploima*	*Asplanchnidae*	*Asplanchna priodonta*
			Brachionidae	*Brachionus caudate*
				Brachionus pticotilis
				Keratella quadratta
				Keratella cochlearis.
				Philodina
				Rotifer vulgaris
				Rotatoria sp.
			Lecanidae	*Lecane sp.*
			Trichocercidae	*Trichocerca*
			Euchlanidae	*Euclanis*
			Synchaetidae	*Polyathra sp.*
			Colurellidae	*Lepadella ovalis*
		Flosculariacea	*Testudinellidae*	*Testudinella patina*
			Lecanidae *Conochiliidae*	*Monostylla Conochilus*
Arthropoda	*Copepoda*	*Calanoida*		*Skistodiaptomus reighardii*
				Diaptomus nigerianus
				Nauplius larva
		Cyclopoida	*Cyclopidae*	*Monocalamus macruru*
				Acanthocyclops
				Macrocyclops
				Dicyclops
				Cryptocyclops bicolor
				Cyclops s.
				Eucyclops
				Thermocyclops
				Harpaticoida
Arthropoda	*Brachiopoda*	*Cladocera*	*Bosminidae*	*Bosmina longirostis*
				Bosmina bosmina
				Eubosmina
			Daphnidae	*Daphnia daphnia*
				Ceriodaphnia dubia
				Simocephalus vetulus
			Macrothricidae	*Macrothrix*
				Ophryoxus gracilis
			Sididae	*Diaphanosoma*
			Chydoridae	*Alona*
			Moinidae	*Moina*

Table 5. Zooplankton diversity by station.

STATIONS	Total number of species	Total number of Individuals	Shannon Weiner species diversity Index (H')	Margalef species richness Index (D)	Jaccard similarity Index (Cj)
Station 1	28	18300	3.06	2.94	
Station 2	31	15500	3.01	3.21	
Station 3	24	5450	1.4	2.67	
Overall Usuma reservoir		39,250 cells/L	2.49	2.94	0.21

* A Cj value = 1 would indicate complete similarity while a value of 0 would mean complete dissimilarity.
* Thus since the Cj value was 0.21, this study indicate that there is 21% similarity of families among the three sample stations.

Table 6. Interpretation of Shannon wiener index as related to Water quality classes (degree of pollution as follows).

Shannon-Weaver index	Class	Condition
> 3	I	Clean water
1 – 3	II	moderately polluted
<1	III	heavily polluted

Seasonal variation

Table 7. Summary of the Cannonical Correspondence Analysis plot showing the relationships of water physicochemical parameters with plankton fauna in Usuma Reservoir.

Plankton family	Physico-chemical parameter / extent of influence on plankton family	Month of high abundance of plankton family
, Cladocera	Current *, Manganese****, Turbidity****	January
Rotifer	BOD*** Total hardness***	April & May
Cladocera	pH***, Turbidity****	August
Copepod,	CO_2****	October

* Limited influence
** Minimum influence
*** Maximum influence
****Absolute / direct influence

(Figure 11). Cladoceras was recorded in all the months of sampling in this station (Figure 11). In station 3, the month of May 2016 recorded its highest value for rotifer (1.30×10^3 cells/l) and the lowest value (1.0×10^2cells/l) recorded in the month of august of 2016. The month of September 2016 recorded the highest value of Cladoceras (5.0×10^2cells/l). May 2016 recorded the least value. Cladoceras was recorded in all the months of sampling in this station with June, July and October 2016 recording same values (Figure 12). Figures 6-12 show these results.

Canonical correspondence analysis (CCA)

All the classes of zooplankton (*Rotifer, Cladocera and Copepods*) were affected (Figure 13 and Table 7) as indicated by the CCA.

Zooplankton

Zooplankton occupies an intermediate position in aquatic food webs between autotrophs and heterotrophs. The distribution and diversity of zooplankton in aquatic ecosystems depends mainly on the physico-chemical properties of water. Pollution of water bodies by different sources will result in drastic changes in zooplankton potential of the ecosystem. Zooplankters are known to accumulate chemicals by direct absorption from water and through food intake (Raut and Shembekkar, 2015. The distribution of zooplankter in the reservoir is similar to Imoobe and Adeyinka, (2009) who reported 40 species comprising of 16 rotifers, 12 cladocerans, 12 copepods

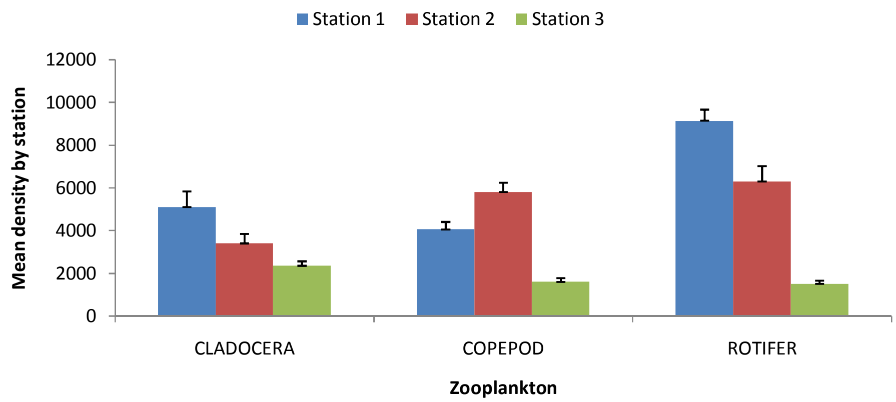

Figure 1. Mean (±SE) station densities of zooplankton species of Usuma reservoir.

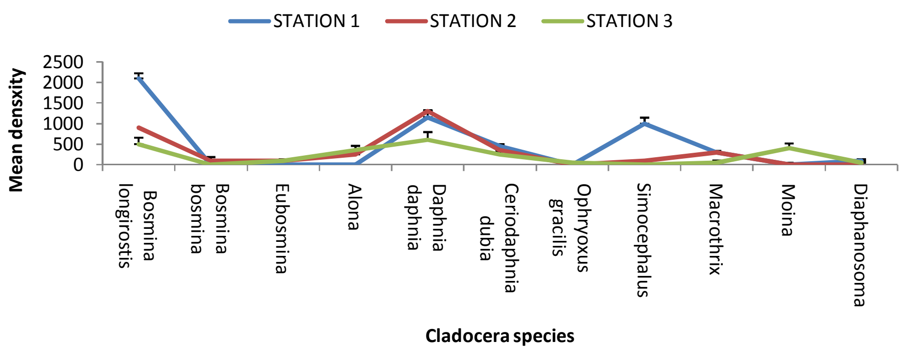

Figure 2. Mean (±SE) station densities of Cladocera of Usuma reservoir.

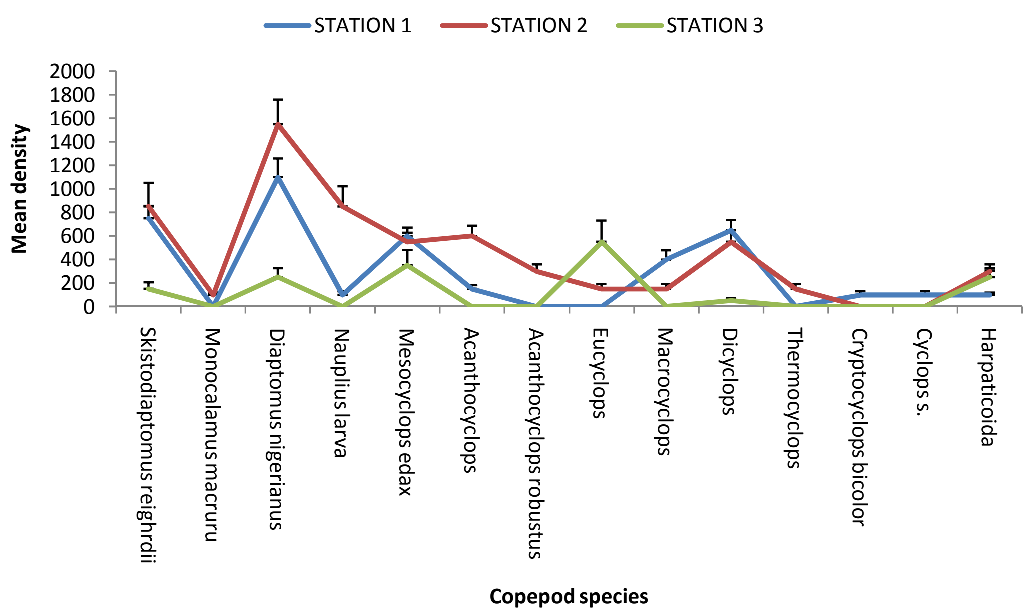

Figure 3. Mean (±SE) station densities of copepods of Usuma reservoir.

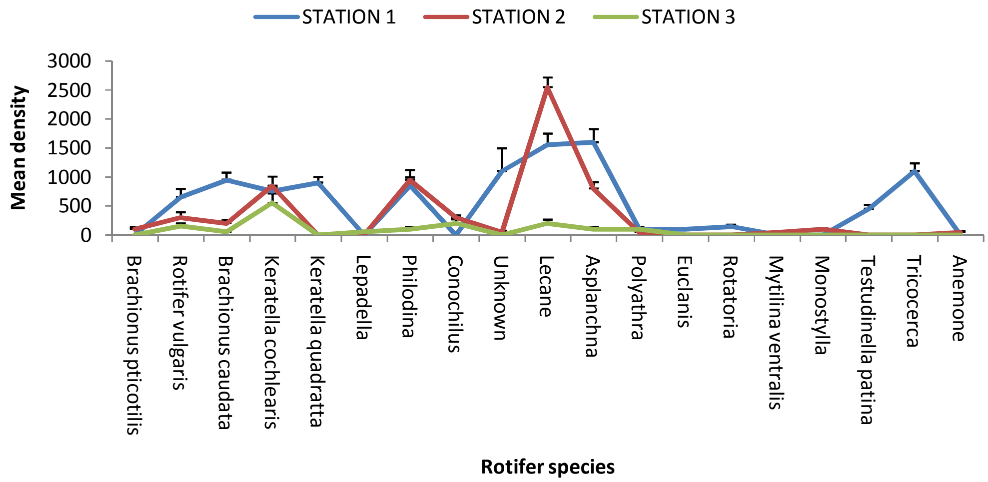

Figure 4. Mean (±SE) station densities of zooplankton species of Usuma reservoir.

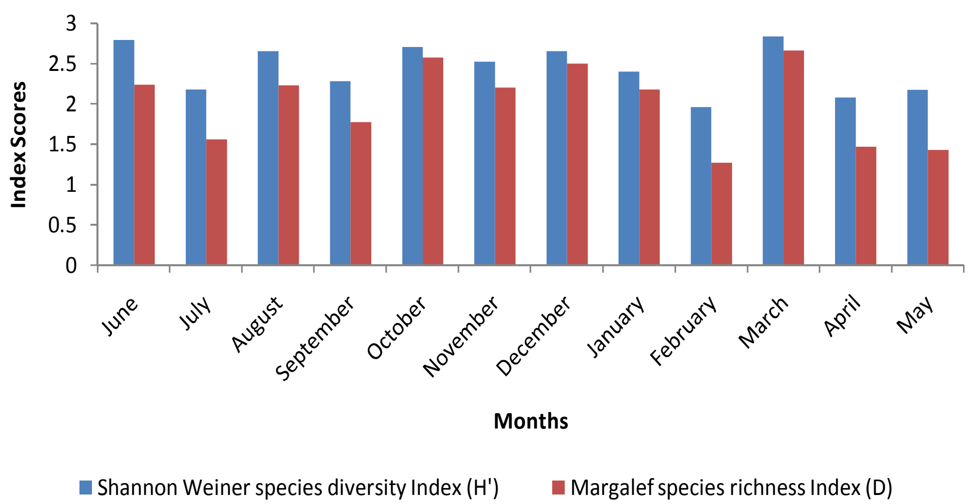

Figure 5. Zooplankton diversity by month.

and 10 calanoids. The variability in the number of zooplankton species observed in this study may be attributed to changes in environmental parameters, hydrological conditions and the seasons of sampling. The order of dominance of the zooplankton conforms to the observation of Rocha *et al.* (1999) where they observed that typical zooplankton assemblages of reservoirs are commonly constituted by Rotifera, Copepoda and Cladocera. Aminu and Saidu, (2001) also observed these three groups in Lake Chad. Raut and Shembekar, (2015) also observed this pattern. Lamai and Kolo, (2003) studied the zooplankton of Dan-Zaria dam and also observed about 40 taxa dominated by the Rotifers (35.38%), Protozoa (27.03%) Cladocerans (25.54%) and the Copepoda (12.05%). *Rotifera* constituted the major group in Usuma reservoir. Similar high dominance of rotiferas was reported by Adeyemi, (2012) in Ajelo stream, Imoobe, (2011) in Okhuo River and Omowaye *et al.* (2011) in Ojofu Lake. The three faunistic groups recorded in this study are characteristics of tropical river systems and is also similar to that of Edward and Ugwumba, 2010 in their study of Egbe reservoir. Iloba and Ruejoma, (2014) in apparent dominance of rotifer also observed this order of abundance (Rotifera > Protozoa > Cladocera > Copepoda) in their study of Ekpan river. Rabiu *et al.* (2014) also observed this order of rotifer dominance in their study of the planktons of Kusalla reservoir. The dominance of rotifer may be due to

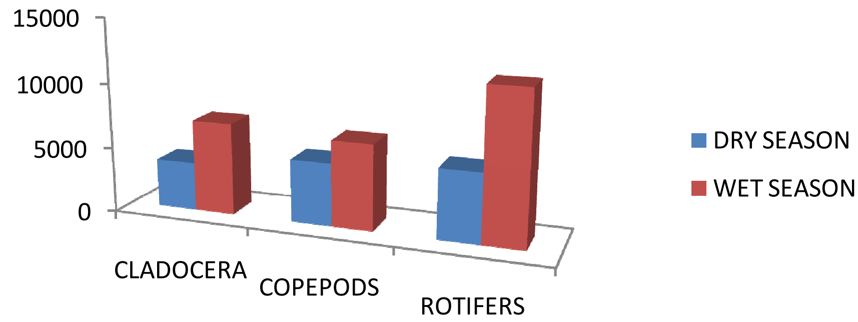

Figure 6. Seasonal variation for zooplankton.

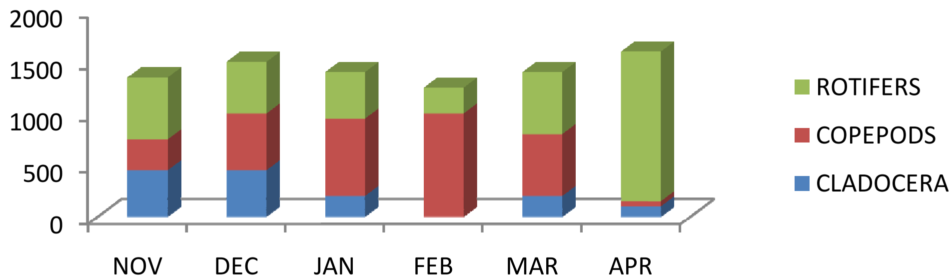

Figure 7. Dry season distribution for station 1.

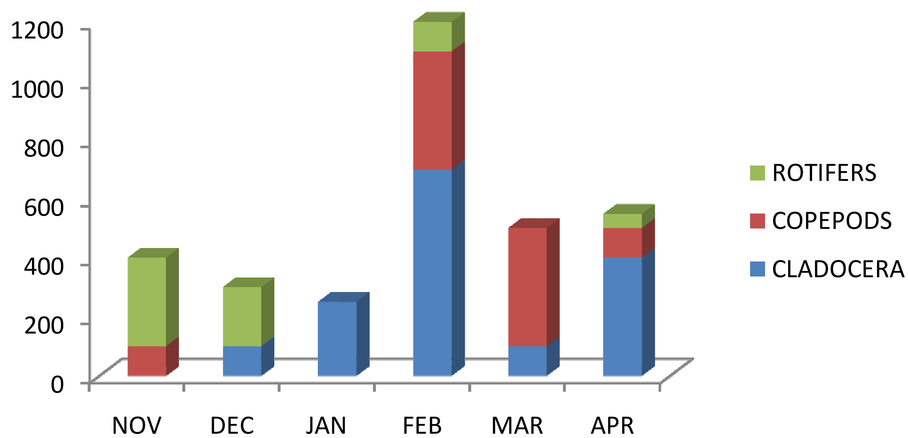

Figure 8. Dry season distribution for station 2.

predation pressure from planktivorous fishes that selectively prey on larger sized zooplankton and then on their reproductive success as well as short developmental rates under favourable conditions in most freshwater systems (Akin-Oriola, 2003; Imoobe and Adeyinka, 2009). Varying number of zooplankton species and populations were reported by different authors in different water bodies in Nigeria.

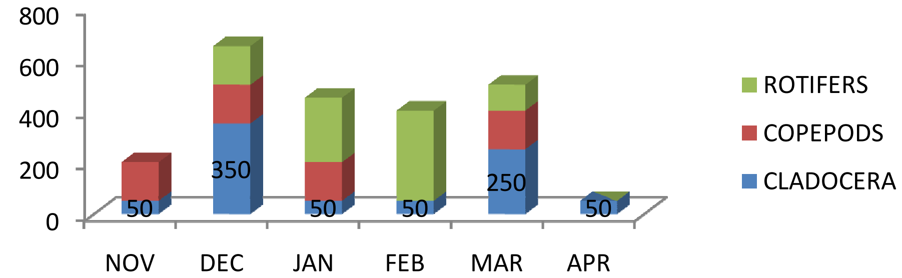

Figure 9. Dry season distribution for station 3.

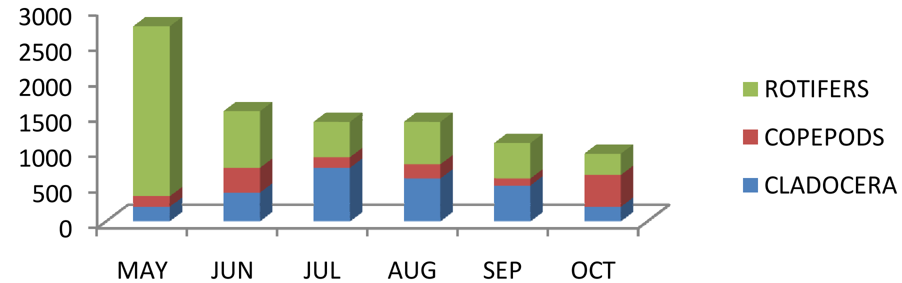

Figure 10. Wet season distribution for station 1.

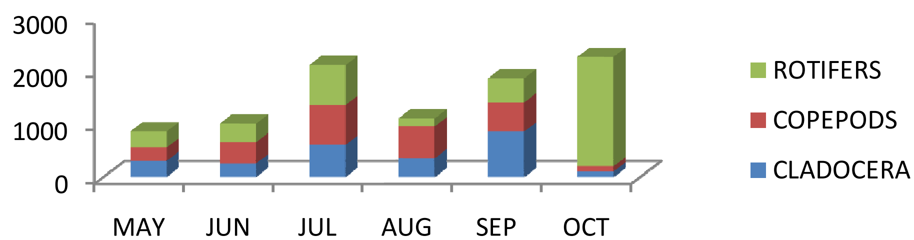

Figure 11. Wet season distribution for station 2.

Matsumura-Tundisi, (1999) observed that reservoirs in which *Branchionus* and *Asplanchna* dominate have high amount of organic matter. The distribution and abundance of the zooplankton was determined by the amount of food (nutrients and phytoplankton) and predation (by zooplankton and fish). This is closely followed by the copepods constitutes the next in distribution with a population of 11.45×10^4 with an abundance of 31% (Table 2). *Cladocera* with 27.6% and a population of 10.80×10^4 constituted the least in abundance. This is similar with the study of Okorafor *et al*. (2013) in Calabar River where cladocerans andcopepods dominated the observed zooplankton taxa. Meanwhile, the dominance of rotiferas in Nigerian aquatic ecosystems has also been documented by some other authors (Aneni and Hassan, 2003; Ogbeibu and Osokpor, 2004). The total number of 10,850 cells/l of cladocera comprising of 12 species (Bosmina l., Bosmina bosmina, Eubosmina, Alona, *Daphnia daphnia,* Ceriodaphnia dubia, Simocephalus, Macrothrix, Diaphanosoma, Moina, Alona, *Ophryoxus gracilis*) were encountered in Usuma reservoir. These are species which are normal inhabitants of natural lakes, ponds, streams, and artificial impoundment in Nigeria and tropical countries (Jeje and

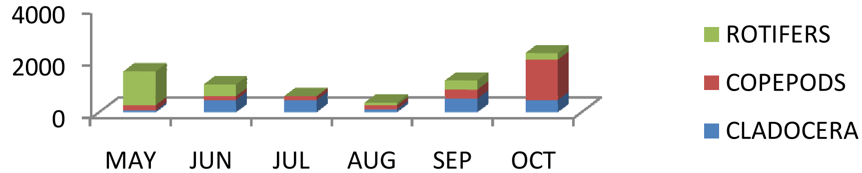

Figure 12. Wet season distribution for station 3.

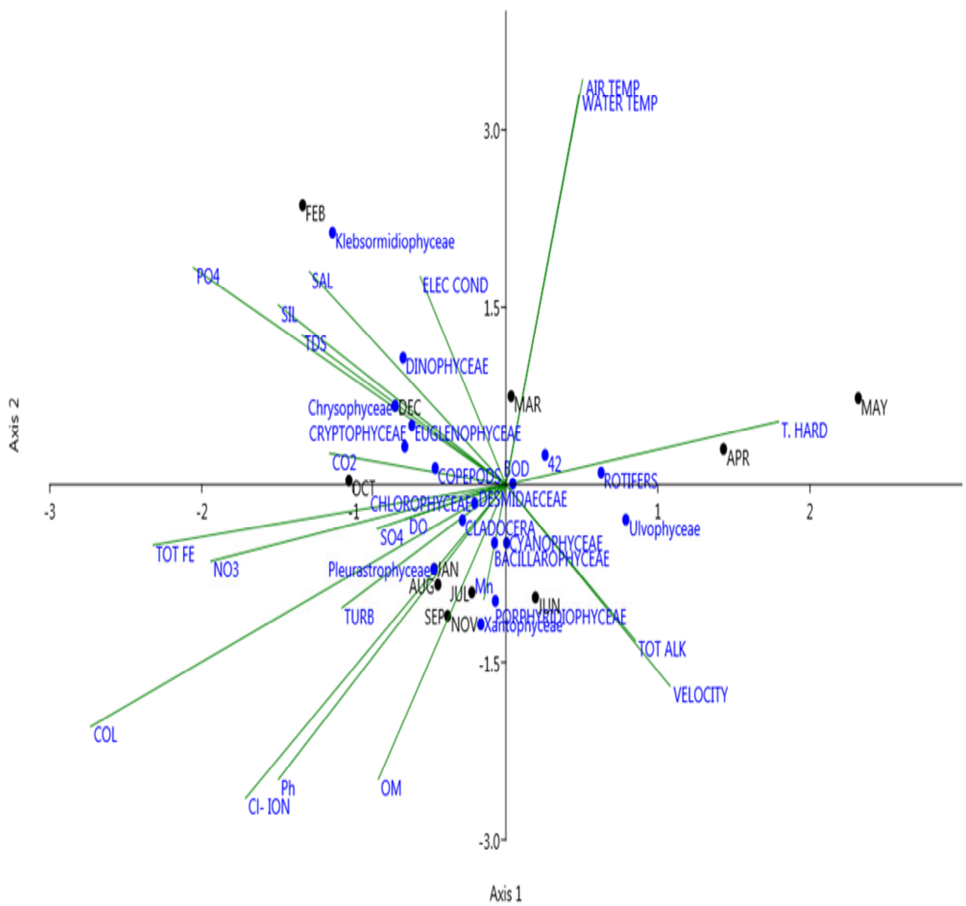

Figure 13. Canonical correspondence analysis between the water quality parameters and plankton families of Usuma reservoir.

Fernado, 1986; Jeje, 1988; Mustapha, 2009; Arimoro, 2010; Kolo *et al*., 2010). *Daphnia* had the highest percentage composition among the cladocera with a population of 3,500 cells/L and a total abundance of 7.8% of the total zooplankton. This may be due to its ability to survive and graze effectively on most phytoplankton and other zooplankton, and this is in consonance with Jeje (1986), Akin-Oriola, (2003) and Mustapha, (2009).

The relatively lower abundance of Cladocerans and Copepods might be as a result of hydrodynamics of the reservoir, such as reservoir water volume and residence time (Mustapha, 2009) and fish predation. The highest population of Cladocerans and Copepods occurred in station 1 and 2 (transitional zone), each having similar values whereas station 3 had the least value for this taxon. The low population of zooplankton in station 3 could be due to the site's high turbidity, which brings low penetration of light energy and high current velocity. This could have caused greater juvenile mortality of the zooplankton and suppressed their growth through food availability. This suppression of crustacean zooplanktons in the station could have been a factor which should encourage rotifer population to dominate according to Mustapha, 2009; but this was not so due to the high current velocity. The dominant phytoplankton species is spirogyra which is an attached algae and usually not palatable to the zooplankter. This is so because of their selective grazing ability on phytoplankton which gives preference to small bodied phytoplankton.

High current velocity and turbidity may have caused the low zooplankton population in station 3 in spite of its high total phytoplankton density.

Seasonal abundance of the zooplankton

According to the studies of Muylaert *et al.* (2003), zooplankton biomass usually reaches their peak during the wet season. This could have been brought about by low predation by fish as phytoplankton abundance in the wet season is less than the dry season. Zooplankton climax in the wet season coincided with lower phytoplankton density since they feed directly on phytoplankton. Temperature, turbidity and pH have a controlling influence on occurrence and distribution of phytoplankton photosynthetic activity which translates to proliferation and by extension zooplankton. The decline in the population of the zooplankton in the dry season may be greatly influenced by the inflow of Gurara interbasin transfer in the dry season, fish predation and low temperature during the harmattan season as was observed in the study (Mustapha, 2009). Achembach and Lampert, (1997), emphasized that factors such as temperature, competition, fish predation and seston food quality can affect zooplankton biomass. There is a succession pattern for zooplankters of Usuma reservoir. Rotifers are dominant in both dry and wet season. This is not totally in agreement with the findings of Okogwu *et al.* (2010) where in the wet season in the lake of Ehoma, cladocera was dominant. This succession was greatly influenced by the inflow of Gurara interbasin transfer in the dry season. As no previous information on the zooplankton of the reservoir is available, this study provides baseline data on the reservoir's zooplankton. The dominance of Rotifers may also be as a result of its preference for warm water (Dumont, 1983) and (Segers, 2003) and availability of food and optimum temperature.

Zooplankton diversity

According to Varadharajan and Soundarapandian, (2013), the diversity of zooplankton species in aquatic ecosystems is linked to its abundance. The high diversity index recorded in station 2 compared to stations 1 and 3 agrees with this finding. Station 1 is more diverse than station 2 and 3 while station 2 is richer that other stations. The Cj value was 0.21; this indicates that there is 21% similarity of families among the three sample stations. This simply means that the fraction of species shared among the stations is 21%

Conclusion

The study revealed that plankton composition and abundance were influenced by changes in water quality as shown by changes in species composition, assemblages and abundance at the various stations. Canonical correspondence analysis further extracted "organic (DO, BOD), eutrophication (air temperature, water temperature, water current velocity, turbidity, chloride ion, phosphate and nitrate), acidification (manganese, pH, nitrate, BOD and DO) and industrial and anthropogenic" as major influencing factors in the Usuma reservoir. The overall results showed that changes in water quality of the river have significant effects on the structure of plankton assemblages. This feature could be used for bio-monitoring of the reservoir's health to ensure the protection of the aquatic biota. Considering the usefulness and importance of this reservoir to the Federal Capital Territory community, the reservoir may be susceptible to imminent pollution problems in the future if deterioration is not abated. The reservoir could be free or level of pollution reduced if proper measures are put in place to discourage the users from polluting the water in order to bring about improved health especially around the river Usuma and its catchments. The water quality class of Usuma reservoir as assessed from the Shannon wiener index compared well with the ranges found in other Nigerian reservoirs and could be classified as moderately polluted under class II of biological index.

Recommendation

Adequate and consistent monitoring of the reservoir and source water should be of utmost priority in order to detect early warning signs and forestall further deleterious deterioration of its health.

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