Available online: www.notulaebiologicae.ro
Print ISSN 2067-3205; Electronic 2067-3264
Not Sci Biol, 2018, 10(2):265-274. DOI: 10.25835/nsb10210170
Original Article

Temporal and Spatial Variations in Abundance and Diversity of Zooplankton Fauna of Opa Reservoir, Obafemi Awolowo University, Ile-Ife, Southwest Nigeria

Oluseun Peter BOLAWA[1*], Adebukola Adenike ADEDEJI[1], Yetunde Folasade TAIWO[2]

*[1]Obafemi Awolowo University, Department of Zoology, Ile-Ife, Nigeria; bolawaoluseun@gmail.com (*corresponding author)*
[2]Obafemi Awolowo University, Natural History Museum, Ile-Ife, Nigeria

Abstract

The present study investigated the ecological status of Opa reservoir, Obafemi Awolowo University, Ile Ife, Nigeria, based on the spatial and temporal variations in abundance and distribution of zooplankton. 72 samples were collected monthly with a quantitative net zooplankton from both the surface and bottom levels in three stations established at the dam site (Lacustrine), mid-lake (Transition) and inflow (Riverine) over a period of an annual cycle. A total of fifty-four (54) species were recorded from the reservoir comprising Rotifera (57.41%) > Arthropoda (33.33%) > Protozoa (5.56%) > Ciliophora (1.85%) = Cnidaria (1.85%), in the order of abundance. The least number of species (47) was recorded at the Transition station, while the highest number of species (49) occurred at the Lacustrine zone. Of all the zooplankton recorded, four species had significant spatial variation, while nine displayed seasonal variations during the study period ($p \leq 0.05$). The highest species richness was observed in Transition surface station (4.18), followed by Lacustrine surface station (3.80) and Riverine surface station (3.23). Shannon's index showed that zooplankton species were more diverse during the rainy season than dry season. The highest Trophic State Index (TSI_{CR}) with respect to Rotifer abundance occurred in Transition surface, followed by Riverine surface and the least occurred in Transition bottom portion. The mean TSI_{CR} value obtained was 65.20, indicative of hyper-eutrophic, while the mean TSI_{CL} value with respect to cyclopoida-calanoida obtained was 58.07 also revealing eutrophic status of the study area. Opa reservoir comprises mainly Rotifers and its TSI_{CR} showed the lake as eutrophic, tending towards becoming hyper-eutrophic, which could speed up the aging of the lake.

Keywords: Opa reservoir occurrence; spatial variation; species richness; temporal variation zones; trophic state index

Introduction

Zooplankton are passive drifters, moving with water currents, yet well adapted for their mode of life, hence can withstand diverse levels of environmental changes in physicochemical water quality, thereby useful for measuring the status of their environment (Paterson, 2001; Imoobe, 2011; Akindele and Adeniyi, 2013). Zooplankton also serve to link up the lower trophic level comprising of phytoplankton which are primary producers to the macroinvertebrates and fishes, which occupy a higher trophic level of the ecosystem (Akindele and Adeniyi, 2013). The zooplankton assemblage often influences energy flow through classical food chain, nutrient cycling and community population dynamics within a reservoir ecosystem. This ecological niche has made them key actors in top down grazing effect (trophic cascade) on the bottom up forces which play pivotal roles in bio-manipulation for lake restoration purposes as reported by Carpenter and Kitchell (1993).

Despite this enormous role played by zooplankton in waterbodies, their distribution has been reported to be affected by factors such as the hydrologic regime of the waterbody (Casanova and Henry, 2004), physical and chemical variables (Sarkar and Chaudhary, 1999; Arimoro and Oganah, 2010), drainage density, sinuosity ratio and stream frequency (Akindele and Adeniyi, 2013), hydrological characteristics (Mitsch and Gosselink, 2000). According to Adedeji *et al.* (2011), their occurrence was found to be directly related to the concentration of the nutrient in the waterbody. Plankton is equally susceptible to a wide range of environmental factors such as water physicochemical properties comprising of temperature, light, pH range, oxygen, salinity and toxic contaminants (Paterson, 2001).

Received: 01 Oct 2017. Received in revised form: 18 May 2018. Accepted: 23 May 2018. Published online: 29 Jun 2018.

Adesakin *et al.* (2017) reported direct discharge of untreated municipal/industrial waste, as well as run off from agricultural areas into Opa reservoir, whose effect on the reservoir's physicochemical parameters was significant both temporally and spatially; this could pose a level of risk to the inhabiting aquatic ecosystem. The last record of plankton research carried out on the reservoir, about eighteen years ago (Akinbuwa and Adeniyi, 1991), noted Rotifers only. The present study, therefore, attempts to evaluate the distribution of zooplankton fauna in Opa reservoir through an annual cycle with a view to determine the effects of the recent dredging of the inflowing River Opa and other smaller streams within the catchment basin. The study would also reveal the present ecological and trophic status of the reservoir.

Materials and Methods

Study area

Opa reservoir is sited between latitude 07030'N to 07031'N and longitude 004031'40"E to 004 032'45"E, within the Obafemi Awolowo University community, Ile-Ife, Southwestern Nigeria (Fawole and Arawomo, 2000). The artificial lake was built on the Opa River within the University community in 1978 (Fig. 1) and the project was eventually completed and commissioned in 1979 (Akinbuwa and Adeniyi, 1991). Opa reservoir has a catchment area covering parts of Ife central, Ife East and Atakumosa West Local Government Areas of Osun state, Nigeria. Opa reservoir is one of the African tropical reservoirs, small and shallow, a knowledge of which can be of benefit to the management of the reservoir in meeting its primary need of water supply and secondarily, as a source of fisheries.

Water sampling

Three sampling stations were established as follows: location A for Lacustrine portion, close to the dam wall; location B at the midlake (Transition) and location C for the Riverine portion, towards the inflow of the lake. The coordinates and depths of the three sampling stations as well as their respective depths can be found in Table 1.

Water sampling was done between November 2012 and October 2013 covering a period of one year for the zooplankton analysis. Water was collected with an improvised water sampler of 2.5 L capacity used to take bottom water samples and then 20 L of water were sieved through a plankton net of 50 µm mesh size and then strained into a universal bottle of about 30 ml and preserved with both Lugol solution and few drops of 5% formalin before being taken to the laboratory for analysis. In the laboratory, a plankton chamber of about 1.5 ml capacity was filled with the preserved water sample to be viewed under the microscope using an Omax binocular light compound photo-microscope (Model Number: G013050830). Scaled pictures were taken and measurements of identified plankton were also recorded.

Identification of planktonic species was later done based on standard identification guides and keys prepared by Jeje and Fernando (1986), Fernando (2002).

Estimation of plankton abundance and trophic status

On each of the concentrate taken on the plankton chamber, a count was made so as to estimate the planktonic population abundance with respect to the volume of the sub-sample and to the original volume of water filtered with plankton net. The results were then expressed in organisms per cubic metre of the original water sample (Goswami, 2004):

$$A=\frac{ab}{c}\times 1{,}000$$

where:

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

The above equation was used to estimate the abundance of zooplankton species.

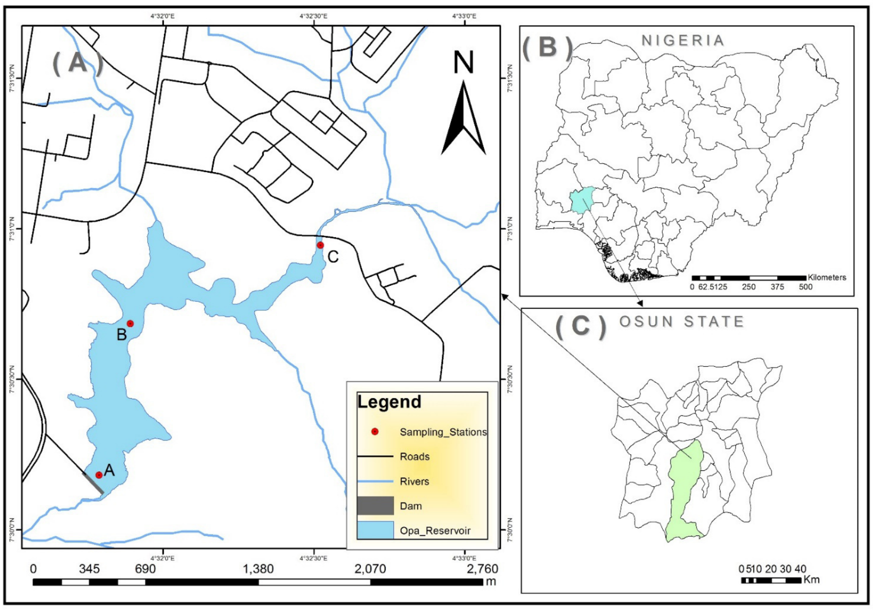

Fig. 1. Map of Opa Reservoir showing the sampling stations

Table 1. Grid location of selected sampling stations

Stations	Longitude	Latitude	Elevation (m)	Depth (m)
Lacustrine (A)	07^{0}30' 13.0" N	004^{0}31' 45.7" E	240 ± 10	6.01
Transition (B)	07^{0}30' 284" N	004^{0}31' 830" E	245 ± 07	4.99
Riverine (C)	07^{0}30' 45.0" N	004^{0}31' 10.5" E	252 ± 08	1.22

In determining trophic status of a water body, few quantitative models have been developed. Duggan *et al.* (2001) developed a potential Rotifer bio-indicator schemes for lake trophic state using TLI (Burns and Rutherford, 1998) and traditional OECD, taken into consideration the following:

i. Indicative species of eutrophic waters
ii. Indicative species of Mesotrophic and Oligotrophic waters
iii. Number and diversity of species
iv. Mean zooplankter weight, mean Cladoceran weight, mean Rotifer weight and mean copepod weight
v. Rotifer abundance
vi. Percentage of Rotifer in total plankton abundance
vii. Ratio of abundance of large Cladocerans to abundance of all Cladocerans
viii. The ratio of Calanoids to Cyclopoids abundance
ix. Ratio of Crustacean abundance to Rotifer abundance (Haberman and Haldna, 2014).

The model proposed by Ejsmont-Karabin (2012) was used to estimate the trophic status of the reservoir:

$TSI_{ROT} = 5.38 \, Ln(N) + 19.28$

where N is the abundance of Rotifers in Ind/L

and $TSI_{CR} = 5.08 \, Ln \, (CY/CA) + 46.6$

where CY is the abundance of Cyclopoida; CA is the abundance of Calanoida in Org/L, according to Ejsmont-Karabin and Karabin (2013).

For the interpretation of the results the following were considered: TSI < 45 = Mesotrophic; TSI (45 – 55) = Meso-eutrophic; TSI (55 – 65) = Eutrophic; TSI > 65 = Hypertrophic lake.

Qualitative analyses and statistical procedures

The reagent bottles and other sampling bottles were washed with detergent and subsequently rinsed severally and thoroughly with tap water and distilled water before use. Other procedures were followed duly. In order to ensure good results were obtained during the course of the sampling, certain necessary precautions were taken into consideration.

Data collected were subjected to various descriptive and inferential analyses such as the means and standard deviations which revealed planktonic species abundance with respect to season and location. Analysis of Variance (ANOVA) was used to compare mean abundance of identified planktonic species while correlation was used to estimate the strength of relationship between various planktonic groups. Moreover, Principal Component Analysis (PCA) was used to reduce all interactions into components that also showed the relationship among recorded plankton species as applicable using SPSS Version 21 software (SPSS, 2012).

Results

A total of fifty-four (54) species of zooplankton were recorded belonging to thirty-five (35) genera, twenty-four (24) families, thirteen (13) orders, ten (10) classes and five (5) phyla of zooplankton, as summarized in Table 2 and Fig. 2. Temporally, nineteen zooplankton (19) species occurred in either of the two seasons, while thirty-nine (39) species were found in both seasons. A total of fifty-one (51) species occurred in the rainy season and forty-four (44) in the dry. Of the species recorded, the season had effect on nineteen species (19), which were recorded either during dry or rainy season only; these include a Protozoan (*Vermamoeba vermiformis*), a Ciliophora (*Favella attingatai),* thirteen members of phylum Rotifera (*Asplanchna* sp. 1, *Asplanchna* sp. 2, *Argonotholca* sp. 2, *Anuraeopsis fissa, Brachionus urceus, Ascormorpha* sp., *Ascormorpha ecaudatus, A. ecaudis, Filinia opoliensis, Polyarthra dolichoptera, Polyarthra remata, Trichocerca cylindrica, Horaella brehmi*) and four species of Arthropoda phylum (*Mesocyclops* sp., *Calanus* sp., *Hesperocorixa obliqua, Hydrozoa actinula*) (Table 3).

Spatially, a total of 37 species were found in the three sampled stations both at the surface and bottom water (Table 3). Species that occurred specific to a station were *Vermamoeba vermiformis* and *Hydrozoan actinula* as recorded from bottom portion of Lacustrine and Riverine stations respectively. Some members of the phylum Rotifera namely *Argonotholca* sp. 2 and *Ascormorpha ecaudatus* were also recorded at the bottom portion of the Riverine station only, while *Asplanchna* sp. 1, *Asplanchna* sp. 2, *Anuraeopsis fissa, Brachionus urceus, Ascormorpha* sp. were also recorded specific to Riverine, but at the surface water (Table 3). The least number of species (47) was recorded from Transition station and the highest (49) occurred at the Lacustrine zone of the reservoir (Table 3).

The highly abundant species include *Asplanchna herrickii, A. priodonta, Keratella crassa, Brachionus falcatus, Ascormorpha ovalis, Trichocerca flagellata, Discorbis* sp., *Copepod nauplii, Copepod larva, Cyclops vicinus, Macrocyclops albidus, Diaphanosoma brachiurum, Acanthocyclops* sp. and *Senecella calanoides.*

Statistically significant seasonal difference were shown by *Trinema* sp., *Hesperocorixa obliqua* and *Favella attingata* ($p \leq 0.05$), while *Asplanchna herrickii, A. priodonta, Brachionus falcatus, Trichocerca flagellata, T. bicristata* and *Chironomid* larvae showed highly significant differences between the two seasons ($p \leq 0.01$) (Table 4). Recorded species that showed statistically significant difference spatially included *Trinema* sp., *Macrocyclops albidus* and *Favella attingata* ($p \leq 0.05$), while *Trichocerca flagellata* had a highly significant difference ($p \leq 0.01$) (Table 5).

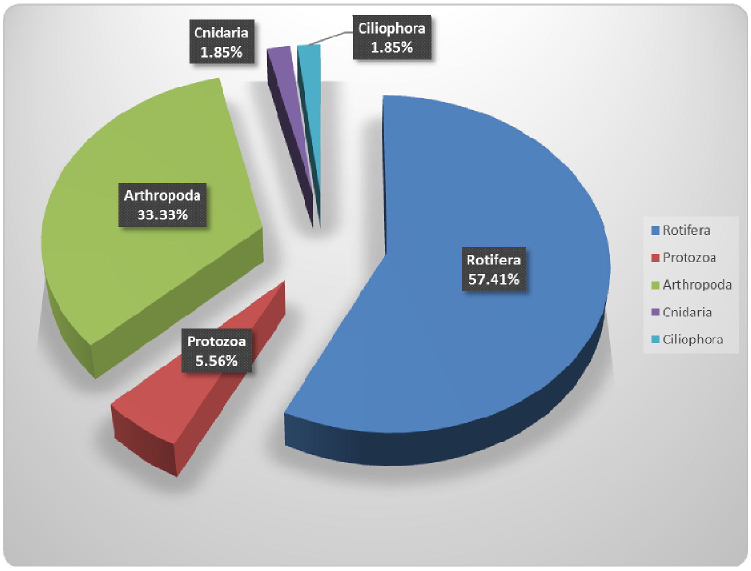

Fig. 2. Taxonomic composition of recorded species of zooplankton taxa

Table 2. Outline classification and taxa composition of the zooplankton fauna

Phylum	Class	Order	Family	Genus	Species	Percentage occurrence (%)
Protozoa	3	3	3	3	3	5.56
Cnidaria	1	1	1	1	1	1.85
Ciliophora	1	1	1	1	1	1.85
Rotifera	1	2	8	12	39	57.41
Arthropoda	4	6	11	18	18	33.33
TOTAL	10	13	24	35	54	100.00

Table 3. Spatial and temporal occurrence of zooplankton and related species

	Temporal		Spatial					
			Lacustrine		Transition		Riverine	
	Dry season	Wet season	surface	bottom	surface	bottom	surface	bottom
Protozoa								
Vermamoeba vermiformis		+		+				
Trinema sp.	+	+	+	+	+	+		+
Discorbis sp.	+	+	+	+	+	+	+	+
Cnidaria								
Hydra vulgaris	+	+			+	+	+	
Ciliophora								
Favella attingata	+		+		+	+		
Rotifera								
Asplanchna sp. *1*	+		+					
Asplanchna sp. *2*		+			+			
A. herrickii	+	+	+	+	+	+	+	+
A. priodonta	+	+	+	+	+	+	+	+
Keratella crassa	+	+	+	+	+		+	+
Keratella tropica	+	+	+	+	+	+	+	+
Keratella lenzi	+	+	+	+	+	+	+	+
Argonotholca foliacea	+	+	+	+	+	+	+	+
Argonotholca sp. *1*	+	+	+					+
Argonotholca sp. *2*		+						+
Anuraeopsis fissa		+					+	
Anuraeopsis sp.	+	+	+		+			
B. falcatus	+	+	+	+	+	+	+	+
B. angularis	+	+	+	+	+	+	+	+
B. calyciflorus	+	+	+	+	+		+	
B. quadridentatus	+	+	+	+	+		+	+
Brachionus urceus		+	+					

Green: present
Blank: absent

The highest species richness was observed in Transition surface station (4.18) followed by Lacustrine surface station (3.80) and Riverine surface station (3.23) (Table 6). These values were higher than the recorded species richness of their corresponding bottom stations. Such a result implies that more species were recorded in the surface portion than the bottom. Shannon index also showed a similar pattern spatially, with the highest value at Transition surface station, thus corroborating the highest number of species and abundance recorded at the Transition station of the reservoir.

Seasonally, Shannon's index showed that the recorded zooplankton species were more diverse during the rainy season than in the dry season. The result was further confirmed by Hill's first diversity index (N1), which revealed that 26 species were abundant in the wet season compared with 14 species in the dry season. Spatially, Hill's diversity indices showed that 26 species (highest value) were abundant at the Transition surface portion, while 13 species (the least value) at the Lacustrine surface (Table 6).

Principal component analysis was used to check the correlation of the planktonic organisms recorded. The result of the analysis revealed twenty-one significant ($p < 0.05$) components with a cumulative variance of 84.92%. Component 1 showed a strong positive correlation for nine (9) species with variance of 10.95%. The strongest loading of 0.929 revealed positive correlation between *Asplanchna* sp. 2 (Sp 2) and *Acanthocyclops vernalis* (Sp 40), while *Keratella lenzi* (SP 7), *Brachionus falcatus* (Sp 13), *Horaella brehmi* (Sp 31), *Trinema* sp. (Sp 33), *Mesocyclops* sp. (Sp 38), and *Scapholebris spinifera* also showed strong positive correlation within Component 1. Component 2 revealed correlation between highest number of species with strong positive loading, 14 different zooplankton species contributing 7.76% of the total variance.

Brachionus urceus (Sp 17) and *Platyias quadricornis* (Sp 18) with strong loadings, and moderate loadings for *Keratella tropica* (Sp 6), *Discorbis* sp. (Sp 34), *Copepod nauplii* (Sp 35), *Limnocalanus macrurus* (Sp 52) and *Chaoborus* sp. (Sp 59) (Table 7). The highest Trophic State Index (TSI_{CR}) with respect to Rotifer abundance was recorded for Transition surface station, followed by Riverine surface and the least occurred in Transition bottom portion. The mean value obtained was 65.20, which

Table 4. Seasonal variation of aquatic microfauna between dry and wet seasons under study

Organisms	Dry season		Wet season		ANOVA	
	Min-Max (Ind/L)	Mean ± SD	Min-Max(Ind/L)	Mean ± SD	F Ratio	p
Trinema sp.	150-1,500	707.14±451.53	150-450	321.43±124.95	6.035*	0.017
Hesperocorixa obliqua	300-2,100	1,087.50±698.55	0	0	5.839*	0.019
Favella attingata	150-750	450.00±244.95	0	0	4.772*	0.033
Asplanchna herrickii	600-27,750	7,366.67±8,293.20	150-14,700	2,034.00±3,207.36	11.380**	0.001
A. priodonta	150-14,250	4,625.00±3,961.45	150-7,650	1,676.79±1,796.45	17.287**	0.000
Brachionus falcatus	150-19,500	5,410.71±5,297.68	150-21,150	2,520.00±4,618.64	10.247**	0.002
Trichocerca flagellata	300-47,400	7,565.63±12,934.07	150-2,100	785.00±585.68	10.321**	0.002
Trichocerca bicristata	1,800-8,850	4,600.00±2,326.48	150-750	325.00±219.37	9.058**	0.004
Chironomid sp. larva	150-1,050	570.00±347.28	0	0	8.758**	0.004

*Significant
**Highly significant

Table 5. Spatial variation of aquatic microfauna between the three sampling stations

	Spatial				
	Lacustrine	Transition	Riverine	ANOVA	
	Mean ± SD	Mean ± SD	Mean ± SD	F-ratio	p
	Protozoa				
Trinema sp.	495.00±373.80	350.00±187.08	1,200.00±0	4.069*	0.022
	Ciliophora				
Favella attingata	700.00±308.22	600.00±150.00	0	3.539*	0.035
	Rotifera				
Trichocerca flagellata	5,589.47±12,330.27	1,488.46±2,269.88	1,360.71±1,110.21	6.506**	0.003
	Arthropoda				
Macrocyclops albidus	150.00±0	0	7,607.14±8,741.18	3.487*	0.037

*Significant **Highly significant

Table 6. Diversity indices for zooplankton at various sampling stations

Diversity Index		Temporal		Spatial					
				Lacustrine		Transition		Riverine	
		Dry season	Wet season	surface	bottom	surface	bottom	surface	bottom
	N	1,064,950	1,234,450	303,150	222,900	666,600	59,100	608,850	264,750
	S	41	51	49	44	57	28	44	41
Richness Index	**R1**	2.88	3.56	3.80	3.49	4.18	2.46	3.23	3.20
Simpson's Index	**λ**	0.12	0.05	0.15	0.08	0.05	0.09	0.13	0.08
Hill's 2nd diversity	**N2**	7.99	20.19	6.87	12.92	18.27	10.80	7.72	11.97
Shannon's index	**H'**	2.58	3.24	2.52	2.93	3.22	2.69	2.69	2.81
Hill's 1st diversity	**N1**	13.23	25.60	12.38	18.65	25.13	14.69	14.72	16.56
Evenness Index	**E4**	0.60	0.79	0.55	0.69	0.73	0.73	0.52	0.72
Evenness Index	**E5**	0.57	0.78	0.52	0.68	0.72	0.72	0.49	0.70

is an indication of hyper-eutrophication process. While comparing the seasons, TSI_{CR} value for rainy season was higher than that of the dry season (Table 8). Moreover, the mean TSI_{CR} value of 58.07 obtained from the ratio of the abundances of Cyclopoida and Calanoida also confirmed the eutrophic status of the reservoir. When comparing the TSI_{CR} values from the Cyclopoida-Calanoida abundance ratio in the different sampling stations, Transition bottom had the highest TSI_{CR}, followed by the Lacustrine surface, while Lacustrine bottom has the lowest TSI_{CR} value (Table 9).

Discussion

Rotifera species were the most abundant zooplankton recorded within the study, which is in agreement with various studies previously carried out on Opa reservoir (Akinbuwa and Adeniyi, 1991, 1996; Ayodele and Adeniyi, 2006; Akindele and Adeniyi, 2013), as well as data on waterbodies in other parts of Nigeria (Ibrahim, 2009; Arimoro and Oganah, 2010; Okogwu, 2010; Imoobe, 2011 and Ekpo, 2013), as well as other waterbodies in the world (Mageed and Konsowa, 2002; Duggan and Duggan, 2011). However, thirty-one (31) species of Rotifera recorded in the present study connote a reduction in the Rotifer composition of the reservoir as compared to sixty-one (61) species reported by Akinbuwa and Adeniyi in 1991. This is an indication of ecological changes that must have affected the reservoir's zooplankton diversity. Akinbuwa and Adeniyi (1991) also reported that the recorded dominance and abundance of Rotifer species in Opa reservoir, during

Table 7. Principal component analysis for the zooplankton species based on their abundance

	Components					
	1	**2**	**3**	**4**	**5**	**6**
Eigen value	**6.35**	**4.5**	**4.334**	**3.688**	**2.997**	**2.826**
Total % variance	**10.948**	**7.758**	**7.473**	**6.359**	**5.168**	**4.872**
Cumulative variance	**10.948**	**18.706**	**26.179**	**32.537**	**37.705**	**42.577**
Asplanchna sp.	0.929***					
Asplanchna herrickii			0.539**	0.560**		
Asplanchna priodonta		0.262*	0.293*			
Keratella tropica		0.515**			0.316*	
Keratella lenzi	0.918***					
Keratella sp.		0.322*				
Argonotholca foliacea	0.513**		0.299*			
Anuraeopsis fissa				0.250*		0.818***
Anuraeopsis sp.	0.898***					
Brachionus falcatus	0.273*		0.661**		0.301*	
Brachionus angularis		0.725***				
Brachionus urceus		0.701***				
Platyias quadricornis					0.292*	
Ascomorpha saltans		0.424*				
Ascomorpha ovalis	0.787***					
Horaella brehmi	0.852***					
Trinema sp.		0.663**				
Polyarthra remata		0.683**				
Trichocerca flagellata			0.787***	0.374*		
Trichocerca cylindrica	0.922***					
Mesocyclops sp			0.324*		0.352*	0.309*
Horaella brehmi	0.929***					
Acanthocyclops vernalis			0.643**	0.366*		
Discorbis sp.					0.277*	
Copepod nauplii		0.443*	0.448*			
Cyclops vicinus					0.284*	
Mesocyclops sp.		0.261*				
Thermocyclops inopinus				0.351*		0.768***
Acanthocyclops vernalis						0.272*
Macrocyclops albidus						0.764***
Limnocalanus macrurus		0.627**			0.265*	
Eudiaptomus gracilis					0.275*	
Hesperocorixa obliqua			0.373*		0.318*	0.344*
Chironomid larva			0.692**			
Chaoburus sp.			0.729**	0.359*		
Diaphanosoma brachiurum				0.289*		
Chaoborus sp.		0.578**		0.277*	0.425*	
Scapholeberis spinifera		0.440*			0.415*	
Moina rostrata		0.326*				
Potamocypris illinoisensis			0.669**	0.337*		

Note: PC loadings < 0.25 are omitted
*Weak loading (0.25 – 0.50)
**Moderate loading (0.50 - 0.75)
***Strong loading (> 0.75) (Yao *et al*., 2014)

their study, was suggesting that the reservoir is unpolluted. However, results from the current study, especially the trophic status indices, showed the eutrophic feature of the reservoir, hence the reduction in the reservoir's Rotifera species diversity.

The current dominance of Rotifers, as compared to other zooplankton species, could also be attributed to their tolerance to a wide range of impact that makes them adaptable to several environmental conditions such as high organic matter or nutrient loading (Arimoro and Oganah, 2010; Clark *et al.*, 2013; Abioye, 2015). Seasonal and spatial variation in zooplankton abundance was also most significant for phylum Rotifera, followed by Protozoa and Ciliophora which could be attributed to their ecological segregation related both to feeding behaviour and susceptibility to contaminants (Olaleye and Adedeji, 2005). Moreover, Rotifers had the highest and the lowest abundance in the Transition zone (the deeper part of the reservoir) at both the surface and bottom portion respectively. The higher abundance at the surface level might be suggestive of their feeding habit as most phytoplankton was found closer to the surface (Egborge, 1994; Burger *et al.*, 2002; Moshood, 2002). Akinbuwa (1992) also linked this Rotifer's abundance at the surface water to effect of light on their vertical distribution.

Arthropods, particularly Copepods and Cladocerans were the second most abundant zooplankton recorded in the hereby study, with 33.33% occurrence from a total of 18 species. This is in contrast with the earlier records on tropical waters, whereas it was reported that Cladocerans are rare, especially the larger zooplankton such as *Daphnia* sp. (Fernando *et al.*, 1987). This report also contradicts Tshevelova and Pomazkova's (1995) report of *Bosmina* sp., as the only Cladoceran representative in Lake Baikal, as well as Coulter's (1991) report of no Cladoceran representative in Lake Tangayika.

Certain Rotifer species characterised with eutrophic communities were recorded. They include *Anuraeopsis fissa*, *Keratella tropica, Filinia* sp., *Brachionus angularis*, *B. calyciflorus, Trichocerca* sp. and *Polyarthra* sp. Generally, Rotifers, brachiopods and copepods are useful indicators of lake trophic status (Duggan *et al.*, 2001; Offem *et al.*, 2011; Ejsmont-Karabin, 2012) and according to Ejsmont-Karabin's Trophic State Index (TSI) values obtained based on the occurrence and abundance of these organisms, Opa reservoir could be classified as eutrophic tending towards hyper-eutrophic. This is in contrast to Ogunfowokan *et al.* (2011) report on the same Opa reservoir, who used Chlorophyll-*a* to classify the lake as mesotrophic. This change must have stemmed from the consistent inflow of nutrients over these years, which could lead to the aging and deterioration of the lake with time.

Table 8. Estimation of Trophic State Index using Rotifer abundance

	Temporal		Spatial					
			Lacustrine		Transition		Riverine	
Organism	Dry season	Wet season	surface	bottom	surface	bottom	surface	bottom
Asplanchna sp. *1*	150	0	150	0	0	0	0	0
Asplanchna sp. 2	0	150	0	0	150	0	0	0
A. herrickii	132,600	50,850	53,550	29,850	24,150	6,900	48,150	20,850
A. priodonta	83,250	46,950	19,650	29,850	19,050	5,100	23,550	33,000
Keratella crassa	17,400	85,500	1,650	20,550	42,450	0	32,250	6,000
Keratella tropica	2,100	91,500	4,500	600	70,650	300	10,800	6,750
Keratella lenzi	13,500	37,950	3,000	5,550	12,900	4,800	22,350	2,850
Argonotholca foliacea	2,700	3,750	1,350	1,050	1,500	1,200	1,050	300
Argonotholca sp. *1*	150	150	150	0	0	0	0	150
Argonotholca sp. 2	0	150	0	0	0	0	0	150
Anuraeopsis fissa	0	150	0	0	0	0	150	0
Anuraeopsis sp.	300	900	300	0	900	0	0	0
Brachionus falcatus	75,750	63,000	13,950	6,300	54,150	11,100	25,500	27,750
B. angularis	8,100	43,050	3,450	4,050	18,750	300	20,850	3,750
B. calyciflorus	3,450	7,950	900	1,200	7,950	0	1,350	0
B. quadridentatus	4,050	11,550	600	2,400	4,800	0	5,550	2,250
Brachionus urceus	0	150	150	0	0	0	0	0
Platyias quadricornis	28,650	16,950	450	1,950	36,450	0	6,600	150
Ascomorpha saltans	300	150	150	0	150	0	150	0
Ascomorpha sp.	150	0	0	150	0	0	0	0
A. ecaudatus	150	0	0	0	0	0	0	150
A. ecaudis	0	300	150	0	150	0	0	0
A. ovalis	32,400	76,800	7,050	19,950	40,350	5,250	21,900	14,700
Filinia opoliensis	0	11,700	6,450	2,700	2,100	0	450	0
Lecane styrax	150	3,550	0	0	1,050	0	2,650	0
Polyarthra dolichoptera	0	12,600	1,200	1,200	5,850	1,200	1,950	1,200
Polyarthra remata	0	4,500	0	300	3,150	0	1,050	0
Trichocerca flagellata	121,050	23,550	85,950	20,250	18,000	1,350	10,950	8,100
Trichocerca cylindrica	0	7,800	450	150	4,050	0	2,700	450
Trichocerca bicristata	27,600	1,950	3,900	2,100	6,600	3,300	4,800	8,850
Horaella brehmi	0	4,950	450	0	3,600	0	0	900
Mean abundance (N)	**17,869.35**	**19,629.03**	**6,759.68**	**4,843.55**	**12,222.58**	**1,316.13**	**7,895.16**	**4,461.29**
TSI_{ROT}	**71.96**	**72.47**	**66.73**	**64.94**	**69.92**	**57.93**	**67.57**	**64.50**

Table 9. Estimation of Trophic State Index using Cyclopoda and Calanoida

Cyclopoida	Lacustrine		Transition		Riverine	
	surface	bottom	surface	bottom	surface	bottom
Copepod nauplii	37,950	8,400	78,300	15,900	21,150	19,050
Copepod larva	9,150	12,000	19,650	150	60,600	14,850
Cyclops vicinus	7,650	1,950	39,000	1,350	14,100	43,800
Mesocyclops sp.	0	0	19,200	0	0	0
Thermocyclops inopinus	300	0	300	300	1,650	0
Acanthocyclops vernalis	150	0	0	0	43,050	10,200
Macrocyclops albidus	12,450	7,500	19,350	0	33,900	22,800
Total abundance	**67,650**	**29,850**	**175,800**	**17,700**	**174,450**	**110,700**
Calanoida						
Limnocalanus macrurus	150	2,700	600	0	7,650	4,950
Senecella calanoides	1,800	600	28,800	300	2,850	15,600
Diaptomus sp	600	2,250	2,400	0	300	0
Eudiaptomus gracilis	300	1,950	750	450	0	150
Calanus sp	300	0	2,100	0	1,350	600
Total abundance (N)	**3,150**	**7,500**	**34,650**	**750**	**12,150**	**21,300**
TSI_{CR}	**62.18**	**53.62**	**54.85**	**62.66**	**60.13**	**54.97**

Acknowledgements

The authors will like to recognise the efforts of the following people and bodies for their immense contribution to the success of this research work: Dr. A.I. Aduwo, Mr. Adesakin Taiwo, Mrs. Helen Abioye, Mrs. Kemi Odeyemi and the entire team in Hydrobiology Laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria.

References

Abioye HY (2015). Planktonic community and primary productivity of Owalla Reservoir, Osun state, Nigeria. M.Sc. Thesis. Department of Zoology, Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria.

Adedeji AA, Aduwo AI, Aluko OA, Awotokun F (2011). Effect of chicken droppings as organic fertilizer on water quality and planktonic production in an artificial culture media. Ife Journal of Science 13(2):239-249.

Adesakin, TA, Adedeji AA, Aduwo AI, Taiwo YF (2017). Effect of discharges from re-channeled rivers and municipal runoff on water quality of Opa reservoir, Ile-Ife, Southwest Nigeria. African Journal of Environmental Science and Technology 11(1):56-70.

Akinbuwa O (1992). A preliminary study of diurnal vertical distribution of Rotifers in Opa Reservoir, Nigeria. Journal of Aquatic Science 7:19-28.

Akinbuwa O, Adeniyi IF (1991). The Rotifera fauna of Opa reservoir, Ile-Ife, Nigeria. Journal of African Zoology 105(5):383-391.

Akinbuwa O and Adeniyi IF (1996). Seasonal variation, distribution and interrelationships of Rotifers in Opa Reservoir, Nigeria. African Journal of Ecology 34:351-363.

Akindele EO, Adeniyi IF (2013). A study of the physicochemical water quality, hydrology and zooplankton fauna of Opa Reservoir. African Journal of Environmental Science and Technology 7(5):192-203.

Arimoro FO, Oganah AO (2010). Zooplankton community responses in a perturbed tropical stream in the Niger Delta, Nigeria. The Open Environmental and Biological Monitoring Journal 3(1):1-11.

Ayodele HA, Adeniyi IF (2006). The zooplankton fauna of six impoundments on the river Osun, Southern Nigeria. The Zoologist 1(4):49-67.

Burger DF, Hogg ID, Green JD (2002). Distribution and abundance of zooplankton in the Waikato River, New Zealand. Hydrobiologia 479(1):31-38.

Burns NM, Rutherford JC (1998). Results of monitoring New Zealand lakes, 1992-1996. NIWA Hamilton Client Report MFE80216, Hamilton, New Zealand. In: https: //doi.org /10.1080 /07438149909354122.

Carpenter SR, Kitchell JF (1993). The trophic cascade in lakes. Cambridge University Press, Cambridge pp 301-335.

Casanova SMC, Henry R (2004). Longitudinal distribution of Copepoda populations in the transition zone of Paranapanema river and Jurumirin reservoir (Sao Paulo, Brazil) and interchange with two lateral lakes. Brazilian Journal of Biology 64(1):11-26.

Clark EO, Aderinola OJ and Adeboyejo OA (2013). Dynamics of Rotifer Populations in a Lagoon Bordered by Heavy Industry in Lagos, Nigeria. American Journal of Research Communication 1(4):172-192.

Coulter GW (1991). Pelagic fish. In: Coulter GW (Ed). Lake Tangayika and its life. Oxford University Press, London pp 111-138.

Duggan IC, Duggan KS (2011). Are botanical gardens a risk for zooplankton invasions? Biological Invasions 13:2997-3003.

Duggan IC, Green JD, Shiel RJ (2001). Distribution of Rotifers in North Island, New Zealand, and their potential use as bioindicators of Lake Trophic State. Hydrobiologia 446-447:155-157.

Egborge ABM (1994). Water pollution in Nigeria: Biodiversity and chemistry of Warri River, Nigeria. Ben Miller Publisher, Warri, Nigeria pp 254.

Ejsmont-Karabin J (2012). The usefulness of zooplankton as lake ecosystem indicators: Rotifer trophic index. Polish Journal of Ecology 60:339-350.

Ejsmont-Karabin J, Karabin A (2013). The suitability of zooplankton as lake ecosystem indicator; Crustacean trophic state index. Polish Journal of Ecology 61(3): 561-573.

Ekpo I (2013). Effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest river in Niger Delta, Nigeria using canonical cluster analysis. The International Journal of Engineering and Science 2(4):13-21.

Fawole OO, Arawomo GAO (2000). Fecundity of *Sarotherodon galilaeus* (Pisces: Cichlidae) in the Opa reservoir, Ile-Ife, Nigeria. Revista de Biología Tropical 48(1):201-204.

Fernando CH (2002). A guide to tropical freshwater zooplankton: identification, ecology and impact on fisheries. Backhuys publishers, Leiden, The Netherlands pp 291.

Fernando CH, Paggi JC, Rajapaksa R (1987). Daphnia in tropical lowlands. Member of Institute of Hydrobiology 45:107-141.

Goswami SC (2004). Zooplankton methodology, collection and identification - a Field Manual. National Institute of Oceanography. Dhargalkar, V.K. Verlecar, X.N. (Eds). Dona Paula, Goa pp 205-300.

Haberman J, Haldna M (2014). Indices of zooplankton community as valuable tools in assessing the trophic state and water quality of eutrophic lakes: long term study of Lake Vortsjarv. Journal of Limnology 73(2):263-273.

Ibrahim S (2009). A survey of zooplankton diversity of Challawa River, Kano and evaluation of some of its physicochemical conditions. Bayero Journal of Applied Sciences 2(1):19-26.

Imoobe TOT (2011). Diversity and seasonal variation of zooplankton in Okhuo River, a tropical forest river in Edo State, Nigeria. Centrepoint Journal 17(1):37-51.

Jeje CY, Fernando CH (1986). A practical guide to the identification of Nigerian zooplankton (Cladocera, Copepoda and Rotifera). Kanji Lake Research Institute, New Bussa, Nigeria, Publication pp 142.

Mageed AA, Konsowa AH (2002). Relationship between phytoplankton, zooplankton and fish culture in a freshwater fish farm. Egyptian Journal of Aquatic Biology and Fisheries 16(2):183-206.

Mitsch WJ, Gosselink RL (2000). Wetlands. 3rd Ed., John Wiley, New York, USA pp 920.

Moshood KM (2002). A pre-impoundment survey of the flora and fauna communities of Oyun Lake in Ilorin, Kwara state, Nigeria. Nigerian Journal of Pure and Applied Sciences 17:1200-1209.

Offem BO, Ayotunde EO, Ikpi GU, Ada FB, Ochang SN (2011). Plankton-based assessment of the trophic state of three tropical lakes. Journal of Environmental Protection 2:304-315.

Ogunfowokan AO, Akanni MS, Ajibola RO, Ayinde FO (2011). Trophic status and physicochemical parameters of three reservoirs in Osun State, Nigeria. Ife Journal of Science 13(1):27-44.

Okogwu OI (2010). Seasonal variations of species composition and abundance of zooplankton in Ehoma Lake, a floodplain lake in Nigeria. Revista De Biología Tropical 58(1):171-182.

Olaleye VF, Adedeji, AA (2005). Water and planktonic quality of a palm oil effluent impacted river in Ondo state, Nigeria. International Journal of Zoological Research 1(1):15-20.

Paterson M (2001). Protocols for measuring biodiversity; zooplankton in freshwaters. www. eman-resecaleman /ecotools/ protocols /freshwater /zooplankton.

Sarkar SK , Chaudhary B (1999). Role of some environmental factors on the fluctuations of plankton in a lentic pond at Calcutta, Limnological Research in India, Daya Publishing House pp 108-130.

SPSS (Statistical Package for Social Sciences) (2012). Statistical Package for the Social Sciences Base 21 for Windows. Chicago, IL: SPSS

Tshevelova NG, Pomazkova I (1995). The Order Cladocera. In: O. Timoshkin (ed.). Guide and Key to Pelagic Animals of Baikal. Nauka, Novosibirisk pp 431-474.

Yao H, Qian X, Gao H, Wang Y, Xia B (2014). Seasonal and Spatial variations in Heavy Metals in Two typical Chinese Rivers: Concentrations, Environmental Risks and Possible sources. International Journal on Environmental Resource and Public Health 11:11860-11878.