THE COMPOSITION, ABUNDANCE AND DISTRIBUTION OF ZOOPLANKTON OF RIVER NIGER AT ONITSHA STRETCH, NIGERIA

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ABSTRACT

The zooplankton assemblage of River Niger at Onitsha stretch was investigated at five sampling stations from January 2008 to December 2009. Some physical and chemical parameters were studied. Among these are: transparency, total alkalinity, conductivity, total dissolved solid (TDS), total suspended solid (TSS), total solid (TS), water level, nitrate, lead, iron and calcium varied significantly (p<0.01). Air and water temperature were significantly different (p<0.05) across the five stations. A total of 26 species of cladocera, 8 species of copepoda and 23 species of rotifera were encountered. The general diversity using Shannon Wiener and Margalef's indices for zooplankton showed higher diversity in decreasing order of stations 2 > 4 > 3 > 5 >1. Similarity indices using Jaccard's Bray Curtis and Euclidean distance indices showed that stations 1 and 5 and stations 2 and 4 respectively are more similar to each other, while station 3 is closer to 1 and 5 than it is to 2 and 4. The effect of adverse human activities and perturbations affect the composition and distribution of zooplankton at this study stretch.

Keywords: Composition, Abundance, Distribution, Zooplankton, Onitsha, River Niger

INTRODUCTION

The pivotal role of zooplankton in aquatic food web and their grazing activities in phytoplankton populations have been recognized. They function as intermediaries between fish and lower trophic levels. Their importance as food to juvenile and adult fish is well known (Ogbeibu, 2001). Zooplankton generally occupy a central role in the aquatic food web as many of them feed largely on algae and bacteria and in turn fall prey to numerous invertebrates and fish predators. This factor coupled with their high sensitivity to environmental factors, has drawn the attention of several biologists focusing on zooplankton occurrence, composition, distribution and significant role in pollution studies (Ogbeibu and Obanor, 2002). Zooplanktons of several Nigerian rivers have been reported: Holden and Green (1960) in River Sokoto; Egborge and Sagay (1979) in in some Ibadan water bodies; Ogbeibu and Victor (1989) in the Ikpoba River, Edo State. The taxonomy of the African zooplankton of Chad, Niger and Senegal is different from that found in the Sahara and in the equatorial Africa. Many species are shared by the Nile and Lake Chad (Dumont, 1981). He showed that the plankton communities of the desert and semi desert belt are very different from those of the Sahel belt and the latter again, differs strongly from those of the equatorial rainforest belt. The rotifers of numerous coastal rivers of Nigeria have been studied (Chigbu, 1987; Egborge and Chigbu, 1988). Jeje and Fernando (1986) studied biotopes in different parts of Nigeria. The ratio of planktonic-littoral-cladoceran species has been used to reconstruct past changes in lake level (Siitonen *et al.,* 2011). Other indicators as geochemical and geomorphologic techniques are employed in environmental study, but the two groups of crustaceans (Cladocera and Anostraca) have been known to contribute information in tracking down environmental shifts on short-times scale (Ramdani *et al.,* 2001). Published records of cladocera of inland water bodies of Nigeria based on net samples indicated the presence of at least 100 species (Robinson and Robinson, 1971; Bidwell and Clarke, 1977; Jeje and Fernando, 1986) with the exception of Warri Rivers, creeks, ponds and pools in the coastal region of western Nigeria (Jeje and Fernando, 1986). Robinson and Robison (1971) provided a checklist of rotifers from Lake Chad, while Bidwell and Clarke (1977) recorded the fauna of Lake Kainji. Victor and Matthews (1989) studied some aspects of the ecology of five cyclopoid copepods in a water pond in Nigeria. Zooplankton make up an invaluable source of protein, amino acids, lipids, fatty acids, minerals and enzymes and are therefore, inexpensive ingredient to replace fishmeal for cultured fish (Kibria *et al.,* 1997). An advantage of zooplankton as fish food is that they contain lower amounts of environmental toxins than organism higher up the food chain (Suontama, 2004). The major groups of zooplankton have species adapted to pelagic, littoral and benthic environments. Rotifers fascinate zoologist and amateur microscopists because of their incessant movement and fantastic variety of shapes. They vary from worm-like attachment types to rotund forms that float near the surface, but all are bilaterally symmetrical. They are abundant in ponds and other fresh water and can be recognized by crown of cilia at the anterior end, which serves as the chief organ of locomotion and a means to bring food to the mouth (Egborge and Chigbu, 1988). The efforts of hydrologists to preserve a healthy aquatic environment are strengthened through monitoring of the physico-chemical condition of the water. These parameters when not monitored cause a subtle but extensive damage and distortion at the primary, secondary and tertiary production in the aquatic ecosystem. Pollutants from domestic and industrial wastes, heavy metals, organic wastes among many others into the aquatics ecosystem constitute public hazards (Arimoro and Osakwe, 2006). WHO (2003) however, noted the need to protect the water bodies from deterioration, chronic or intermittent health hazards and loss of aesthetics and recreational values. Based on the aforementioned background this study accessed the composition, abundance and distribution of zooplankton of River Niger at Onitsha stretch, Nigeria.

MATERIALS AND METHODS

Study Area: The section of River Niger under study flows through the heavily commercialized/industrialized city of Onitsha in Onitsha South Local Government Area of Anambra State, Nigeria (Figure 1).

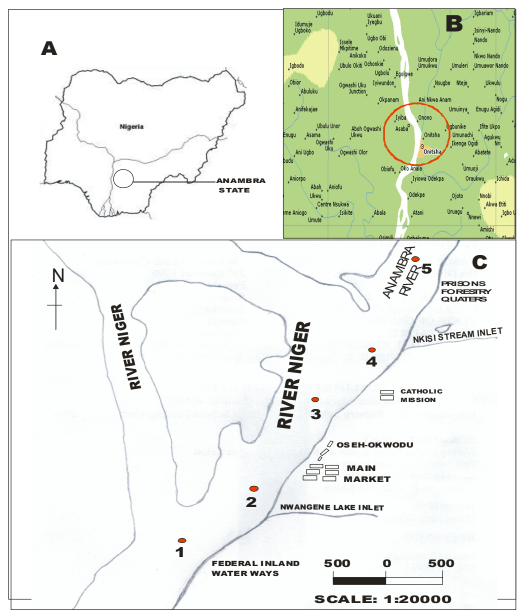

Figure 1: Map of the study area: A- Nigeria showing Anambra State, B –The major towns and cities around Onitsha, C – Sampling stations along River Niger (Arazu *et al.,* 2015)

Geologically, the reach of the Niger River under study is made up of more resistant rocks of the basement complex. The floor is made up of alluvial sediments which include gravels, silts and light clays and loamy. The major soils are hydromorphic and alluvial sediments (Odunuga *et al.,* 2003). The vegetation is mainly riparian forest and woody grassland. Human activities along the river and its littoral areas include fishing, farming, sand mining etc. Five sampling stations had been established along this stretch considering their peculiar ecological settings, vegetation and human activities (Arazu *et al.,* 2015).

Station 1: (N009.06 E006.44) is the downstream station. It is accessed through the gate of the former National Inland Water Ways Complex, closely beneath the Niger Bridge. The outermost part is located about 30 m from the margin. Greater portion of the littoral part of the station is fairly grown with rooted aquatic macrophtes like *Salvinia* sp.*, Lemna* and *Ceratopteris cornuta*. Not many activities go on except few artisanal fishing and few early morning swimmers (Arazu *et al.,* 2015).

Station 2: (N006.07 E006.45) is the tributary of Nwangene Lake inlet into the River Niger. The lake is separated from the river by the road leading from main market in Onitsha to Fegge. It used to be a part of the Niger-Benue River Complex, prior to its isolation largely as a result of human activities. It is located about 15 m from the margin. Around the confluence of this lake tributary and River Niger samplings were done. Four mighty pipes lead water below the Sokoto road bridge into River Niger. The substratum consists mainly of sand and light clay, to loamy in some areas. Other common sights are people defeacating, bathing, launderings and disposals of large quantities of wastes from abattoirs, utensil washings by peasant hoteliers, and motorbike washings in fifties, by bike drivers. All these are mainly in the morning hours. There are no true aquatic macrophytes except vegetation like *Spirogyra* sp. and *Commelina* that were submerged during heavy rains. Also boats offloading sand scooped from the other side of the river, berth there in large numbers (Arazu *et al.,* 2015).

Station 3: (N006.08 E006.45) is the Oseh-Okwodu market station. It is a boat landing site located about 20 m from the margin grossly littered with various food items, especially green vegetables in very large quantities for sell to whole sellers. The bottom is an entangled mesh of roots and stems of macrophytes like *Nymphaea lotus* and *Commelina* sp. The muddy substratum has a mixture of vegetables and other decaying organic matter. It is also a heavy dumping site of wastes from market environs and domestic discharges from the catchments residential area. The semi-dry banks are flooded with insects of varied types. Defeacation by humans, foraging pigs are common sights here (Arazu *et al.,* 2015).

Station 4: (N006.09 E006.46) is the Nkisi stream inlet which channels erosion water run-offs from several places into the river located about 15 m from the margin. It has sparse aquatic macrophytes as *Commelina* sp. and *Spirogyra* sp. overlying both sides of the channel entering the river. The descending land space bears a large stationery cow house with heaps of dungs flowing into the channel. The station is close to the Marine Police Station and the Onitsha Prisons. It is also a navigable boat landing site. It has a substratum with little percentage of coarse sand, fine sand and silt (Arazu *et al.,* 2015).

Station 5: (N006.10 E006.46) is the upstream station. The station is directly behind Onitsha Prisons quarters located about 27 m from the margin. There is no accessibility by foot other than boat. Artisanal fishing is the major activity. Apart from the sparsely rooted macrophytes, the bottom has entangled mesh of roots and stems of macrophytes as *Nympheae lotus, Ceratophyllum submersun* and *Spirogyra* sp. The station is partially shaded (Arazu *et al.,* 2015).

Sampling Technique

Physical and chemical conditions: The water level was determined at specific points in the study stations using a meter rule. Air and water temperatures were measured *in-situ* with mercury in glass thermometer, while a 20 cm diameter Secchi disc was used to measure water transparency. pH and conductivity were measured using HACH digital meter. Dissolved oxygen (DO) and Biochemical oxygen demand

(BOD) were estimated using Winkler's method (Boyd, 1981). The BOD was carried out after 5 days incubation in the dark at 28 ^{0}C. Alkalinity, phosphate-phosphorous, nitrate-nitrogen and calcium were determined titrimetically following the methods in APHA (2005). Other heavy metals: chromium, copper, zinc, lead and cadmium were determined by Atomic Absorption Spectrophotometer. These metals were determined by preparing standard solutions of known metal concentrations.

The metal concentrations in the water samples were read against their standard using spectrophotometer set at the normal wavelengths and the readings recorded (APHA, 2005).

Zooplankton: The zooplankton samplings were collected quantitatively using 55 µm Hydrobios plankton net. 100 liters of water sample from the particular station was filtered through the net. The resultant filtrates were upturned into a 250 ml plastic container and preserved in 4 % buffered formaldehyde. In the laboratory, a broad sorting of each zooplankton sample was carried out. The random sorting from the condensed 25 ml of the zooplankton concentrate was carried out. 1 ml of sample was put into the hydrobios counting chamber. Serial dilution was made with samples of very high zooplankton density and numbers per ml of concentrated sample computed. Identification and enumeration were carried out using x20 and x40 objectives of an Olympus binocular microscope according to the methods of Jeje and Fernando (1986). These organisms were mounted on a clean glass slide in 100 % glycerin or polyvinyl lactophenol initially treated with lignin pink. The counting was done using a hydrobios counting chamber. Density was expressed as number of organism per m^3 using the formula: Density = N x 100 / Initial volume of water filtered. Where N = number of organism per sample (Ogbeibu and Obanor, 2002).

Data Analysis: The species dominance (D), Shannon diversity index (H), Margalef's index (d) and equitability (J) were calculated using Ogbeibu (2005). The single factor analysis of variance (ANOVA) and Duncan Multiple Range (DMR) test were used to test for significant difference among stations (Ogbeibu, 2005). SPSS 16.0 package and PAST 1.97 were adopted. The principal components (PCA) were determined using communalities extraction method, while the screen plot graph was plotted for components with Eigen values of less than 1.

RESULTS

The water quality parameters that were evaluat ed are summarized in Table 1. Transparency was significantly higher ($p<0.001$) at station 5 than at the other stations. Total alkalinity and conductivity were higher in stations 2 and 3, 1 and 4, respectively than in station 5. TDS, TSS and TS were significantly higher at stations 2, 3, 4 than in stations 1 and 5. Water level showed highest significance at station 1 against what obtained at the other four stations. Lead was significant at station 1 against what obtained at the four stations. Lead was significantly higher in station 2 than other stations. Iron was significantly higher in stations 3 and 4, respectively than stations 1, 2 and 3. Calcium was significantly higher in stations 2 and 3 than in 1, 4 and 5. Air and water temperatures were significantly different ($p<0.05$) across the five stations, while CO_2 was significantly higher at station 1 than others. pH in stations 2 and 5 is significantly higher than it is in 1, 3 and 5. DO is higher in stations 5 and 2 than others. BOD was highest in stations 1 and 4 than the other three stations. Phosphate was significantly lowest at stations 1 and 4 than the other three stations. Magnesium was higher in stations 2 and 4 compared to 1, 3 and 5. Zinc was lower in station 1 than in the other four stations. Copper and cadmium were significantly lower in stations 1 and 5, respectively than in the other three stations. Chromium and sulphate were significantly lower in station 1 than the other four stations and sodium lowest in station 5. Table 2 indicated that the phylum arthropoda recorded 5 families of cladocera, 4 of copepoda and 9 of rotifera, respectively. 26 species, 8 species and 23 species were respectively encountered from these 3 groups. Stations 3 and 5 recorded 1120 and 990 individuals, respectively of cladocera with station 2 recording 740 individuals. Copepoda was similarly highest in station 5(1180 individuals); station 4 (820 individuals); station 1 (820 individuals); station 3 (740 individuals) and station 2 (720 individuals) in decreasing order (Figure 2). The highest abundance of rotifera was noted in station 1 (1420); station 5(1280); station 3 (1,040) respectively.

Ceriodaphnia cornuta (Daphnidae) was fairy recorded in stations 1, 2, 4 and 5, but absent in station 3. The taxon, *lecane luna* was relatively and uniformly abundant across the 5 stations (Table 2). Similarly, the representatives Cyclopidae *(Mesocyclops leuckarti)* and Diaptomidae (*T. processifer*) were densely distributed across the 5 stations with lowest densities in stations 3 and 4, respectively. *Lepadella ovalis* (Collurellidae) was also heavily abundant in all the stations but entirely absent in station 2. The diversity indices dominance (D), equitability (J), Shannon diversity (H), Margalef's index (d) calculated for the five stations are presented in Table 2. Dominance was highest in station 1, followed by station 3, 5, 4 and 2 in decreasing order of magnitude. At station 1 (Figure 3), August and January 2008 recorded the highest number of Cladocera while moderately higher number were recorded in August and September 2009. The lower trends were noticeably in February, March, April, July, September, October, November and December of 2008.

Table 1: Physico-chemical characteristics of River Niger at Onitsha urban-stretch (January 2008 – December 2009) (Arazu *et al.,* 2015)

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5
Air Temperature (^{O}C)	30.92 ± 2.93^{a}	29.3 ± 2.07^{a}	30.58 ± 2.81^{a}	30.5 ± 2.41^{a}	30.75 ± 4.04^{a}
BOD (mg/l)	5.32 ± 1.45^{a}	5.10 ± 1.24^{a}	4.40 ± 1.28^{b}	4.30 ± 1.85^{b}	3.69 ± 1.11^{c}
Cadmium (mg/l)	0.05 ± 0.16^{b}	0.51 ± 0.52^{a}	0.08 ± 0.08^{b}	0.42 ± 0.45^{a}	0.07 ± 0.06^{b}
Calcium (mg/l)	1.39 ± 0.48^{b}	2.08 ± 0.76^{a}	2.03 ± 0.73^{a}	1.18 ± 0.41^{b}	1.15 ± 0.38^{b}
Chromium (mg/l)	0.12 ± 0.15^{b}	0.19 ± 0.25^{c}	0.06 ± 0.03^{a}	0.12 ± 0.19^{b}	0.10 ± 0.19^{b}
CO_2(mg/l)	2.99 ± 0.59^{a}	3.08 ± 0.35^{a}	2.85 ± 0.51^{a}	2.84 ± 0.35^{a}	2.55 ± 0.28^{b}
Conductivity (µS/cm	113.40 ± 15.60^{b}	128.4 ± 35.8^{c}	121.70 ± 39.40^{c}	106.70 ± 26.70^{b}	96.4 ± 10.66^{a}
Copper (mg/l)	0.52 ± 0.15^{b}	1.27 ± 1.62^{a}	0.65 ± 0.19^{b}	0.55 ± 0.23^{b}	0.34 ± 0.21^{b}
DO (mg/l)	7.14 ± 1.61^{a}	6.82 ± 2.00^{a}	6.09 ± 1.78^{b}	5.63 ± 1.19^{b}	7.48 ± 2.32^{a}
Lead (mg/l)	0.83 ± 0.39^{b}	1.01 ± 0.40^{a}	0.69 ± 0.26^{c}	0.86 ± 0.35^{b}	0.61 ± 0.36^{c}
Magnesium (mg/l)	3.56 ± 1.39	4.72 ± 1.99	3.97 ± 2.19	3.08 ± 1.67	3.83 ± 2.56
Nitrate (mg/l)	1.73 ± 1.40	1.92 ± 1.42	1.65 ± 1.63	1.60 ± 1.42	1.61 ± 1.57
pH	6.36 ± 0.59	7.32 ± 0.66	6.69 ± 0.73	6.82 ± 0.93	7.18 ± 1.13
Phosphate (mg/l)	0.36± 0.16^{a}	0.34 ± 0.09^{a}	0.41 ± 0.13^{a}	0.38 ± 0.17^{a}	0.27 ± 0.05^{b}
Potassium (mg/l)	0.63 ± 0.14^{b}	0.89 ± 0.21^{a}	0.83 ± 0.09^{a}	0.52 ± 0.14^{c}	0.51 ± 0.09^{c}
Sodium (mg/l)	0.89 ± 0.21^{a}	1.21 ± 0.26^{b}	1.21 ± 0.22^{b}	3.25 ± 12.1^{c}	0.76 ± 0.09^{a}
Sulphate (mg/l)	0.36 ± 0.06^{a}	0.39 ± 0.19^{a}	0.26C ± 0.06	0.32B ± 0.05	0.33B ± 0.05
TDS (mg/l)	137.9 ± 42.80^{c}	222.80 ± 96.50^{b}	192.50 ± 87.00^{b}	251.20 ± 123.00^{a}	126.90 ± 54.40^{c}
Total Alkalinity (mg/l)	33.15 ± 9.01^{b}	39.75 ± 10.90^{a}	35.17 ± 10.30^{a}	33.20 ± 9.02^{b}	29.03 ± 6.31^{c}
Total Solid (mg/l)	206.9 ± 52.60^{b}	338.40 ± 152.00^{a}	245.80 ± 101.00^{b}	368.00 ± 177.80^{a}	189.20 ± 62.60^{b}
Transparency (m)	98.88 ± 35.00^{b}	81.33 ± 26.07^{c}	96.80 ± 29.50^{b}	79.71 ± 31.80^{c}	101.20 ± 24.70^{a}
TSS (mg/l)	68.42 ± 11.2^{b}	115.7 ± 61.20^{a}	62.88 ± 8.50^{b}	117.50 ± 60.50^{a}	60.17 ± 9.09^{b}
Water current (m/s)	25.88 ± 7.21	22.69 ± 7.45	23.86 ± 7.82	26.28 ± 10.30	22.61 ± 5.65
Water level (m)	7.31 ± 1.52^{a}	3.37 ± 1.07^{c}	4.48 ± 1.76^{b}	4.89 ± 1.52^{b}	4.39 ± 1.67^{b}
Water Temperature (^{O}C)	28.71 ± 2.63	28.92 ± 2.98	29.04 ± 3.30	30.33 ± 3.81	28.92 ± 4.04
Zinc (mg/l)	2.29 ± 1.50^{c}	4.01 ± 1.89^{a}	4.58 ± 2.23^{a}	3.26 ± 2.27^{b}	1.63 ± 2.22^{d}

Similar letters on a row indicate means that are not significantly different from each other at $p<0.001$

The months of October and November had also low density of Cladocera which later increased slightly in December 2009. However no Cladocera were observed in June 2008 and January, February and March 2009. Similarly, copepods showed its highest densities in May 2008 and May/June 2009 respectively.

Table 2: Distribution, abundance and frequency of occurrence of zooplankton at the five study stations of River Niger at Onitsha urban-stretch

Phylum: Arthropoda	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**
Class: Crustacea					
Order: Cladocera					
Kurzia longirostris		30			100
***Pleuroxus* sp.**	90	20	70	60	
Chydorus barriosi	-	-	-	40	-
Chydorus eurynotus	-	-	-	50	-
Chydorus pubescens	-	-	220	-	90
Chydorus parvus	-	-	-	50	-
Alonella excise	90	70	70	-	-
Alona diaphana	-	-	-	70	-
Alona eximia	-	90	-	-	-
Alona davidi	-	-	-	150	-
Dunhevedia crassa	-	30	-	70	-
Dunhevedia serrata	-	-	40	-	-
Dadaya macrops	80	-	40	-	50
Ceriodaphnia cornuta	60	50	-	50	30
Simocephalus	50	80	-	-	80
Bosimina longirostris	100	130	60	120	40
Pseudosida bidentata	-	30	80	50	30
Diaphanosoma excisum	120	-	90	-	-
Diaphanosoma sarsi	-	-	-	-	90
Guarnella raphaelis	-	-	130	40	30
Echinisa triseralis	130	80	-	50	160
Echinisa capensis capensis	-	-	90	30	
Llyocryptus verrcosus	-	30	50	20	70
Macrothrix spinosa	60	30	120	-	-
Moina micrura	-	70	60	70	40
Moina daphnia	110	-	-	-	180
Order: Copepoda	-	-	-	-	-
Tropodiaptomus processifer	180	60	90	70	100
Tropodiaptomus incognitus	90	-	80	60	100
Thermocyclops neglectus	80	50	40	150	230
Paracyclops fimbriatus	-	50	70	80	150
Ectocyclops phaleratus	110	120	160	110	100
Microcyclops varicans	120	160	120	110	120
Mesocyclops leuckarti	130	120	80	120	140
***Ergasiloides* sp**	110	160	100	110	240
Order: Rotifera	-	-	-	-	-
Lecane (1) luna	70	60	50	60	80
Lecane (m) lumeris	-	-	20	-	-
Monostyla hamata	120	70	20	-	-
Euchianus dilate	-	65	40	70	50
Mytilina ventralis	90	85	-	60	60
Colurella undiminuta	-	70	40	-	110
Lepadella ovalis	490	-	320	220	220
Trichocerca cylindrical	-	-	-	110	-
***Trichocerca* sp**	170	-	30	-	210
Proales decipiens	-	-	30	-	-
Epiphanis Macrorus	-	90	-	40	30
Notholca squamula	100	110	30	20	-
***Kellicottia* sp**	80	-	30	-	70
Brachionus diversi formis	60	-	-	-	-
Brachionus variabilis	-	130	-	-	150
Brachionus forficula	-	-	150	140	-

Table 2 continues

	Station 1	Station 2	Station 3	Station 4	Station 5
Keratella quadrata	50	20	60	110	50
Anuraeopsis fissa	-	80	40	-	-
Filinia longiseta	70	70	110	50	120
Synchaeta longipensis	80	90	40	-	80
***Testudinella* sp**	-	-	30	-	-
Dissotrocha aculeata	40	-	-	30	50
Rotaria neptunia	-	85	-	-	-
Taxa S	29	36	38	37	34
Individuals	3130	2400	1960	2650	3390
Dominance (D)	0.04925	0.02939	0.0377	0.03461	0.03572
Shannon Diversity Index (H)	3.242	3.598	3.488	3.503	3.469
Margalef's Index (d)	3.569	4.911	4.845	4.696	4.496
Equitability (J)	0.9533	0.973	0.9454	0.9631	0.9535
Cladocera	790	740	1120	920	990
Copepoda	820	720	740	820	1180
Rotifera	1420	940	1040	910	1280

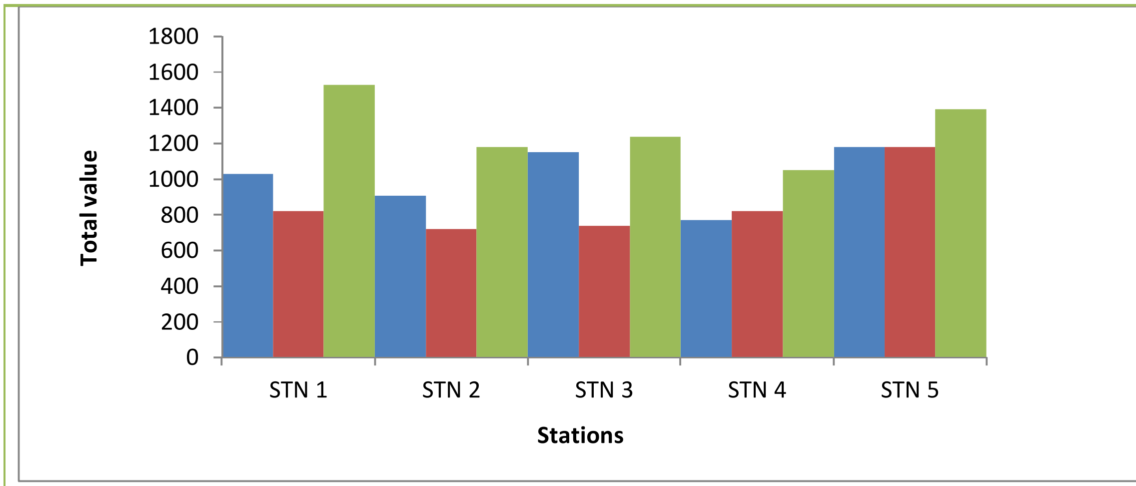

Figure 2: Spatial variation in density of zooplankton across the 5 stations (overall abundance)

Whereas low densities were recorded in January, March, April to December 2008 and March to April, July to December 2009, respectively. The months of February and December 2008 had no record of copepod. The months of May, June and October 2008 showed the highest densities of rotifer in this station. However, low densities were observed across the 2 years in January, February, March, August, September, November and December, while much lower densities were typified in April and July 2008; June and July 2008 and October 2009. No records of rotifers occurred in August and September 2009. At station 2 (Figure 4), the highest points of Cladocera were in June and September 2008.

Whereas, the trend was uniformly low across the other months of 2008 and 2009, respectively, with the exception of March 2008 that had no record of Cladocera. In the same vein, copepods had its highest density in June 2008. A low but uniform pattern was observed across the rest of the months in 2008 and 2009. Except for October 2008 where there were no records of copepod, January/July 2008 and February/July 2009, respectively had highest densities of Cladocera. A decreasing pattern was noticeable between January to April, July to October 2008, February to April and July to September 2009 respectively. Notably January 2008 had no records of rotifer, whereas, April, June, September and October 2008 had lowest densities of rotifers.

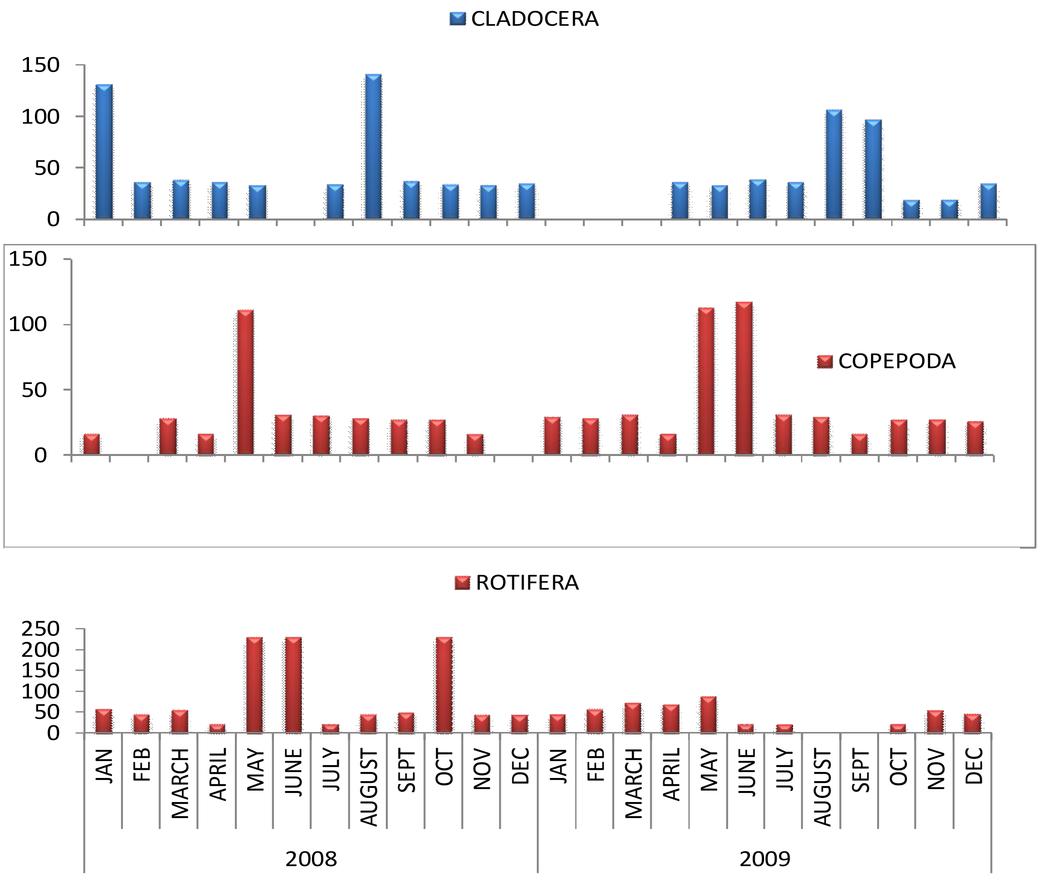

Figure 3: Monthly variation in zooplankton densities (station 1) of River Niger at Onitsha stretch, Nigeria

At station 3 (Figure 5), February and September 2008 recorded the highest densities of Cladocera, with a fluctuating low patterns throughout the other months of the two years were observed. No records were made in February/March 2009. Also, the months of February, June and July 2008, and February, May and June 2009 recorded significantly high densities of copepods. While a closely high but fluctuating pattern prevailed across the other months of the two years with the exception of March/April 2008 that had no representation. The rotifers showed its highest densities in February, May, June, August and September 2008. While a low and fluctuating uniform was observed across other months in the 2 years. There was no observation of rotifers in September / October 2009.

At station 4 (Figure 6), the highest density of Cladocera were observed in January and August 2009. Slightly high densities were also noted across the other months in the 2 years; no records were made in March 2009. The month of May showed the highest density of copepod in 2008 and 2009, respectively. Although, in year 2009, the density of copepods was slight and evenly distributed, but was either low in density or not represented at all in some months of year 2008. In Rotifera, the highest density was typified in August and November, 2008, while an increased fluctuating pattern was recorded over the rest of the months in the two years of study.

At station 5 (Figure 7), the cladocerans were similarly highest in the months of May and July, 2008. It showed a uniform and slightly increased density pattern across the other months of the 2 years. However, there was complete absence of Cladocera in March, July and September of 2009.

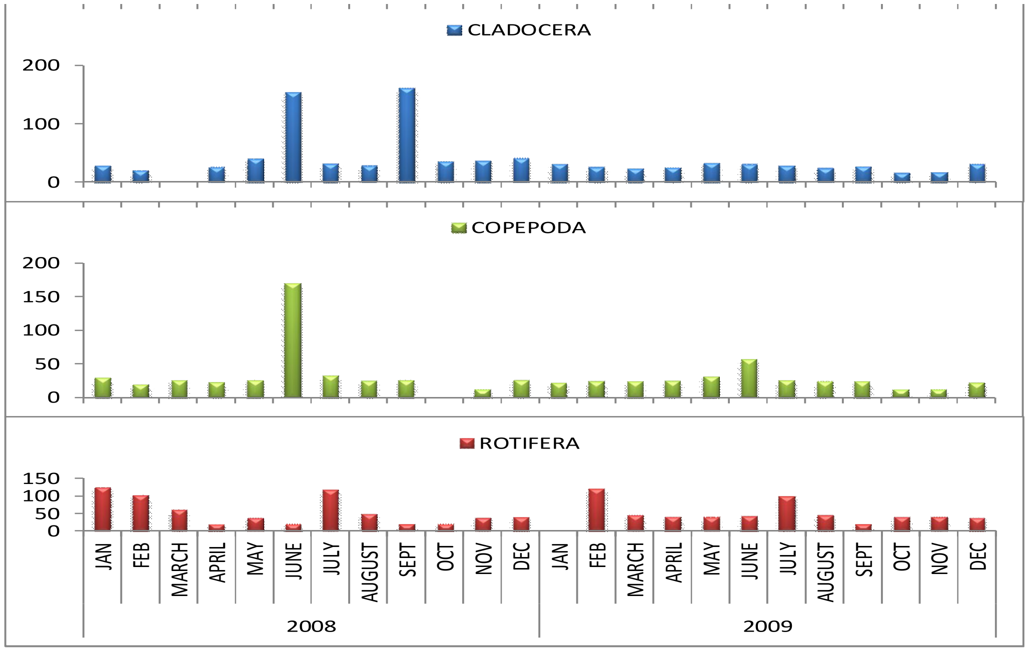

Figure 4: Monthly variation in zooplankton density (station 2) of River Niger at Onitsha stretch, Nigeria

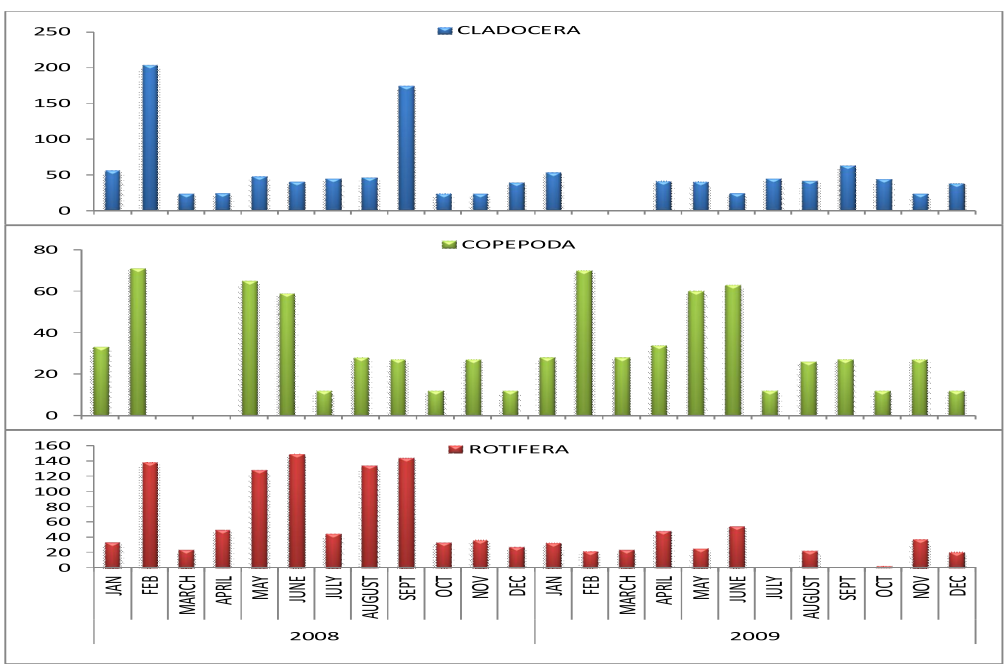

Figure 5: Monthly variation in zooplankton density (station 3) of River Niger at Onitsha stretch, Nigeria

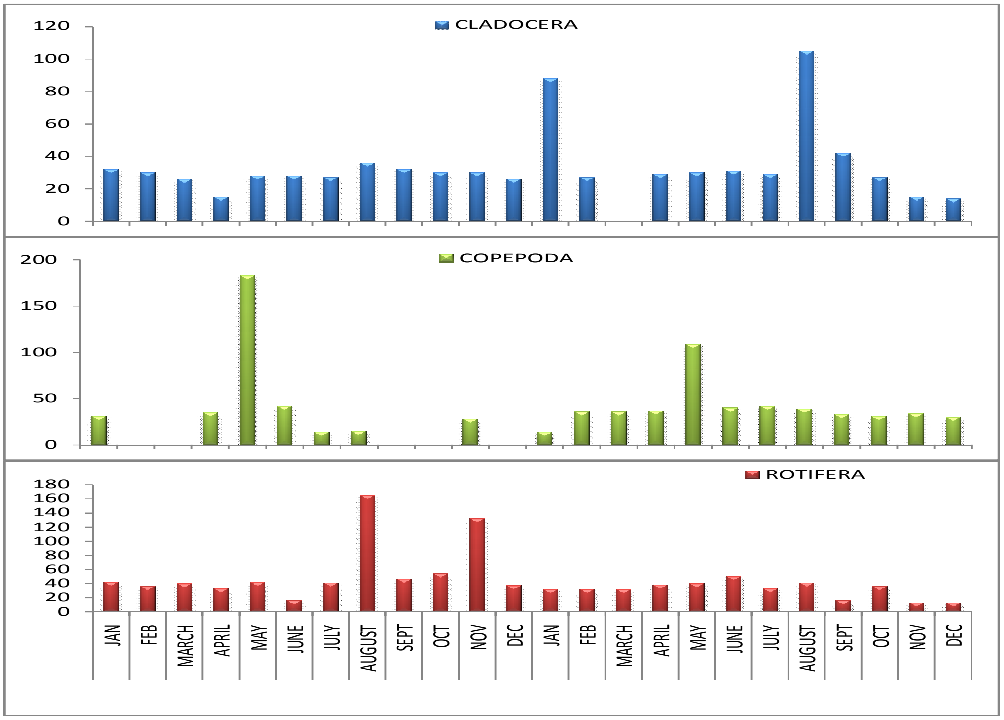

Figure 6: Monthly variation in zooplankton density (station 4) of River Niger at Onitsha stretch, Nigeria

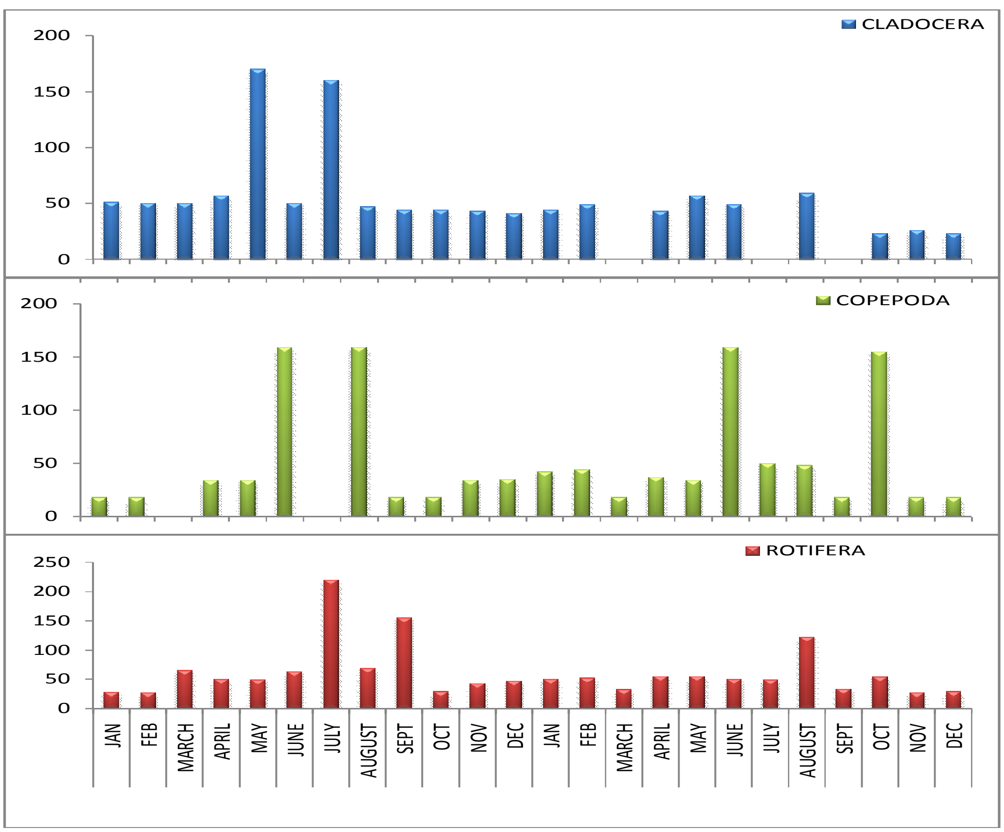

Figure 7: Monthly variation in zooplankton density (station 5) of River Niger at Onitsha stretch, Nigeria

Copepod had highest occurrences in June and August 2008 and June and October 2009. With exception of March and July 2008, the other months had slightly increased but fluctuating pattern of occurrence across the 2 years, while rotifer depicted had decreasing pattern in July and September 2008 and August 2009. All the other months across the whole months of the two years were slightly and uniformly represented.

Diversity indices (H) were highest in decreasing order of magnitude: Stations 2 → 4 → 3 → 5 → 1, respectively. Margalef's species richness index (d) was highest in station 2 and lowest in station 1.

In the same vein, station 3 was higher in species richness than station 4 which was higher than that of station 5. The equitability index (J) was highest in station 2 → station 4 → stations 5 → station 1 → station 3, in decreasing order of magnitude.

DISCUSSION

The physical and chemical characteristics of rivers and streams have been intensively studied in the recent years because of the large and diverse number of stations/sizes that can be examined at a relatively low cost with simple equipment. These physico-chemical parameters have considerable bearings on the life of lotic organism (Hynes, 1970) in eliciting different responses on several species (Holden, 1960; Boyd, 1981). Hence, good water quality and healthy aquatic ecosystems are important in maintenance of fish and other biota (Arimoro and Osakwe, 2006). The present study agreed with other authorities that higher values of dissolved oxygen were obtained in the dry than wet season. It is also higher in non-organically polluted area. This becomes more pronounced when the amount of inherent organic wastes/matters exceed the thresholds of oxygen needed for decomposition. Hence, stations 1 and 5 showed higher values of BOD and this is in line with the fact that they were less organically polluted. Conductivity is a measure of total ionic composition of water (overall richness) favourable to fish. It helps in maintaining the pH by buffering the effect as determined by the levels of magnesium, calcium and sodium in the water. This latter relationship is observed at stations 2 (with highest conductivity and calcium respectively). The highest conductivity in this station favoured its zooplankton and benthos richness as indicated by the Margalef's index of species-richness. Hence if the present conductivity potential of station 2 is controlled from perturbations, then it can have more fishes coming for food at its banks. The present study similarly agreed with report of Walsh *et al.* (2008) that conductivity value is higher in dry than wet season. Alkalinity is a measure of weak acid and weak salts in water. Alkalinity was higher in wet season in the present study is in contrary to the report of Walsh *et al.* (2008), that there was higher concentration of salt due to evaporation, decomposition and mineralization of litters during dry season. Therefore, it could be attributable to the perturbations militating against the afore-mentioned processes (Baijot *et al.,* 1997).

Nitrate and phosphate are indicators of organic pollution. Both nutrients were higher in stations 2 and 3 than in other stations with submerged macrophyte (stations 1, 4 and 5). Decomposition of raw human sewage washed into the water in stations 2 and 3, vegetables and agro decomposition in station 3, and water run-offs from overlying cow dung deposit in station 4, all contributed to the different concentrations of nitrate and phosphate. Total dissolved solids (TDS), total suspended solids (TSS) and total solid (TS) were low in stations 1 and 5 but high in stations 2, 3 and 4. These three parameters were higher in wet than in dry season due to the large array of human activities in stations 2, 3 and 4. These activities include domestic waste deposits by the riverside, industrial effluents and run-offs into the river from the catchments stretch. The TSS in particular was variable between stations and determines the transparency of a water body (Booth, 2005). The range of TDS in the present study of 60 to 471 agreed with the finding of Omoigberale and Ogbeibu (2005) in Osse River (42.5 – 456) whereas, the TSS of the present study (40 – 260) was higher than that of Osse Rivers (14.66 – 210). The flow velocity was higher in wet season while station 1 (close to the Niger Bridge) and station 4 (influenced by the inlet of Nkisi stream) had higher flow rates. Fluctuations in water level are usually associated with rainfall frequency. The highest water level was at station 1 while the observed low water levels at stations 2 and 3 encouraged more human activities. Transparency is literally translated means water clarity, which is an important property of water related to productivity. This physical property is strongly affected by the materials suspended and dissolved in water. And the present study with highest transparency at the less perturbed stations 1 and 5 agreed with the study of Castro and Huber (2008) that transparency is higher in dry season due to absence of surface run-offs. Photosynthetic activities had pronounced effect on water transparency in the present study. Kosten *et al.* (2009) observed a positive feedback between photosynthesis, submerged vegetation and water clarity and opined that this forms the backbone of the alternative state theory in shallow lakes. CO_2 had direct influence on pH. Free CO_2 in water is acidic (carbonic acid), while carbonates and bicarbonates are alkaline. However increased pH favours fish production but within a narrow range (6.5 - 9.0) (YEC, 2014). The value of free CO_2 was lowest in station 5 with equally the highest pH value.

However, Onitsha stretch of the River Niger with a range of phosphate of 0.18 to 0.90 and nitrate of 0.10 to 5.46 is comparatively fair given the EPA limits of phosphate (<5 mg/l) and nitrate (10 mg/l) respectively (EPA, 2016). Other authors that have reported similar ranges of phosphate and nitrates in their studies include Holden and Green (1960) for River Sokoto, Egborge (1971) for River Osun and Ogbeibu and Victor (1995) for water bodies in Okomu Forest Reserve. The high phosphate levels in stations 1, 3 and 4 of the present work study agreed with Hynes (1970) that soaps and detergents used in bathing and other laundry activities are important sources of phosphate. Sodium, potassium and calcium as cations were higher in wet season as observed in the present study may be attributed to dilution and $CaCO_3$ dissolution (Guo *et al.,* 2007). However, sodium is usually higher than potassium due to its retention by living organisms. The values of sodium in the present work can be best described as incidental at station 3. Potassium levels at the Onitsha stretch of River Niger was quite low compared to Osse River (Omoigberale and Ogbeibu, 2005) and Sokoto River (Holden and Green, 1960). Chromium, copper, zinc, lead and cadmium are also known to have densities five times greater than water (Tchounwou *et al.*, 2012). Chromium and copper were higher in stations 3 and 4 and exceeded EPA (2016) permissible limit for surface water. Similarly zinc and cadmium were extremely high in the Onitsha stretch of River Niger and exceeded EPA (2016) permissible limit for surface water. The high level of lead at station 1 with less perturbation could be attributed to rusted abandoned metallic body ships and machineries formerly used by the Federal Inland Water Ways, whose base is by the station.

The general preference of zooplankton to nutrient rich environments (Jeje and Fernando, 1986) was also demonstrated in the present study at less perturbed stations 1 and 5. The higher density of copepods in station 5 of this study where perturbation was low is line with the study of Onwudinjo and Egborge (1994) that recorded high abundance of rotifers in Benin River during rainy season. High densities of cladocerans and rotifer were recorded from May to September respectively throughout the two years study period. The record of *Ceriodaphnia cornuta* and *Bosmina longirostris* in this study is not uncommon as they are ubiquitous and could be traced to its link with Benue River (Khan and Ejike, 1984). However, the total absence and reduction of both species respectively at station 3 may be due to effects of human perturbations. Previous studies that had documented the distribution and abundance of rotifers in Nigerian waters includes Egborge and Chigbu (1988), Onwudinjo and Egborge (1994) and Ogbeibu and Edutie (2002). *Brachionus species* were moderately abundant in perturbed stations 2, 3 and 4. *Filinia longiseta* and *Synchaeta longipensis* absent in station 4 were fairly distributed across the other stations, while *Rotaria neptunia* could only be found in station 2. *Lepadella ovalis* was heavily abundant at stations 1, 3, 4 and 5 but absent in station 2. Similarly, *Trichocera* sp. was moderately abundant at the less perturbed station 1 and 5 but incidental in station 3. Members of the family Brachionidae are cosmopolitan (Segers, 1993; Ogbeibu *et al*. 2001) and had high densities in the less perturbed stations 1 and 5 due to the decomposing submerged macrophyte. These agreed with previous reports of higher abundance of organisms abound in lentic than lotic water bodies (Nwoko, 1991). The higher level of cladocerans in perturbed stations 3 and 4 agreed with Ramdani *et al.* (2001) that planktonic cladocerans can be used in tracking down environmental shifts on short time scale. There is a consistent recurring pattern in the density of copepod, between May/June in both years. A sharp increase in density between May/June in both years followed by a sharp decrease in the rest of the year. According to Wetzel and Likens (1979), copepod's population drops at unfavorable conditions. This is typical in perturbed stations 2, 3 and 4 due to run-off from upland following the heavy rain. Also the dominance of cyclopid copepods in the present study agreed with Green (1962) for copepods of River Sokoto and Imoobe and Ogbeibu (1996) for copepods of Jamieson River, Nigeria. Copepods in the present study were more abundant in turbid than transparent waters, was in line with the report of Imoobe and Ogbeibu (1996). A fairly stable habitat as in station 5 agreed with Bishop (1993) for a small Malaysian River. Habitat stability often produce high species distribution and abundant of taxa (Eriksson *et al.,* 2006).

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