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Original Article

PHYSICO-CHEMICAL CHARACTERISTICS AND ZOOPLANKTON OF EKPAN RIVER, DELTA STATE, NIGERIA

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ABSTRACT

The physicochemical parameters and zooplankton dynamics of Ekpan River were investigated in two stations from August to November 2011. The physico-chemical parameters of both stations include, pH (6.4 – 7.3), air temperature (25.0 – 28.0°C), water temperature (22.0 – 25.0°C), alkalinity (10.0 – 23.0mg ($CaCO_3$) conductivity (10.2 – 24.0 µs/cm), dissolved oxygen (DO) (1.63-3.27mg/L), biological oxygen demand (BOD) (0.57- 1.5mg/L), phosphate (0.14 – 0.82mg/L) and nitrate (0.001 – 0.054mg/L). The following pairs of parameters; water temperature and dissolved oxygen, alkalinity and BOD, BOD and pH, alkalinity and pH were found to be correlated in Station 1 while correlation was established between alkalinity, pH and BOD only in Station 2. Three factor components accounted for 100% changes in the water quality at the two stations, all indicating anthropogenic influence. However, the overall physico-chemical quality is generally compatible with WHO guideline for domestic use. The zooplankton composition were made up of five taxonomic groups namely, Rotifera constituting 66%, Protozoa 19.1%, Copepod 5.6%, and Cladocera 4.1%. Rotiferas, particularly *Brachionus* species were the most predominant group in the river. Statistical test did not show significant difference in the dominance of zooplankton between the two Stations (P>0.005). Nitrate was the only parameter that did not influence zooplankton composition in any station. No parameter influenced rotifer composition in Station 1. The rotifer abundance at Station 1 did not correlate significantly with any physical or chemical parameters while in Station 2, dissolved oxygen and depth influenced rotifers abundance and composition. For Protozoa, conductivity best described the composition while phosphate and dissolved oxygen influenced Cladocera and Copepod composition, respectively.

KEYWORDS: Factor analysis, Diversity, Physico-chemical parameters, Zooplankton composition.

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INTRODUCTION

Zooplankton are important components of plankton providing not only feeding resource to higher order consumers like macro crustaceans, insects, small fish but to man. Zooplanktons are also considered good indicators of trophic and environmental status of water bodies as a result of their sensitivity. They therefore play an integral role in pollution monitoring in the production of clear water phase due to their filtering activities (Mathivanan *et al*., 2007), regulating algal and microbial productivities, nutrient cycling and as indicators of environmental health status of water as a result of their sensitivity and fast response to a wide range environmental changes. Zooplanktons are thus important in the structuring of dynamics of aquatic environments because of their fundamental role in aquatic food chains (Dijk and ZanTen, 1995). The composition and abundance of zooplankton in any aquatic ecosystem which are crucial in water quality monitoring could be threatened or impacted on due to anthropogenic activities such as domestic (sewage disposal), agricultural (runoff manure and fertilizers) and industrial waste (Kensa, 2011 and Iloba; Ehioghiren, 2014). Several researchers have reported that variations in physical and chemical factors exert profound effects on the number, abundance and distribution of the flora and fauna present in any aquatic system thereby resulting in the changes of the total number of species or organisms present as well as its suitability for both domestic and industrial uses (Nwankwo, 1989; Nwadiaro, 1990; Iloba, 2012).

Ekpan River is an important water body that runs across parts of Delta State. During its course particularly around the study area, it receives huge quantities of sewage both agricultural and industrial runoffs as well as arrays of human impacts from the residents which could impact significantly on the physiochemical characteristics of the River. Thus the health and/or sustainability of the water could be doubtful since these activities cause the water quality to decrease and affect the biotic and abiotic organisms in the water (Perlman, 2005). There is therefore the need for constant monitoring of this important water body to ascertain whether its status, zooplanktons composition and abundance are still within permissible limit, which are of great importance as earlier noted. There have been multiple studies in this water body based on the sediments (heavy metals), water hyacinths and macrobenthic invertebrates (Arimoro *et al.*, 2008; Nduka *et al.*, 2008; Olumokoro and Azubike 2009; Olumokoro *et al.*, 2009).

MATERIALS AND METHODS

Study Area

Ekpan River is a slow flowing river in the Western Niger Delta (Fig.1). It is located in Delta State of Nigeria. It took its source from Utagba- Uno in Ndokwa LGA and flows to Agbarho, Warri through Ekpan from where it flows through the rainforest belt of Forcados and finally discharges into the Atlantic Ocean. The entire length of the River lies between latitude 5°30' N of the equator and longitude 5°44' E. Seventy-five percent of the river is fringed with the mangrove trees consisting of mainly the black Mangrove (*Avicennia germinans*) which blossoms during the raining season. The common aquatic macrophytes are *Pistia stratioles* L., shrubb floating *Salvinia sp.*, *Lemma* sp., and extensive water hyacinths *(Eichhonia crassipes).* The river bank supports rich riparian vegetation, which includes *Rhizophora racemosa* and *Paspalum orbiquilare*. The substratum is mainly muddy with fine silt.

The River is characteristically turbid due to the various anthropogenic activities there such as farming, sand dredging, lumbering, fish farming. It serves as a major drainage channel for the area, receiving domestic and treated industrial waste from Warri Refining and Petrochemical Company as well as other industries around Warri metropolis such as Chevron Nig. Ltd, Niger CAT, Julius Berger, Oando, Delattre Benzons Nig. The river is reverenced and worshipped during festivals such as Ogbu intiation and Ohworo- amen and during such times received rituals from its faithful. Once in 2010, the river experienced oil spill believed to have come from neighbouring industries and companies resulting in the destruction of over 1,850 large fish ponds, killing millions of fishes thereby resulting in joblessness and financial losses to the farmers.

Study Stations

The study area is divided into two stations:

Station1. This is the upstream section of the river and is situated 5 km away from an existing bridge .The catchments are densely populated. This river receives effluents from both the Chevron Nigeria Company and Warri Refinery and Petrochemical Company. The white and red mangroves are characteristic of this station as well as the presence of water hyacinths *(Eichhornia crassipes)* and extensive submerged macrophytes.

The station is used mainly for fish farming purposes, washing, bathing and sand dredging.

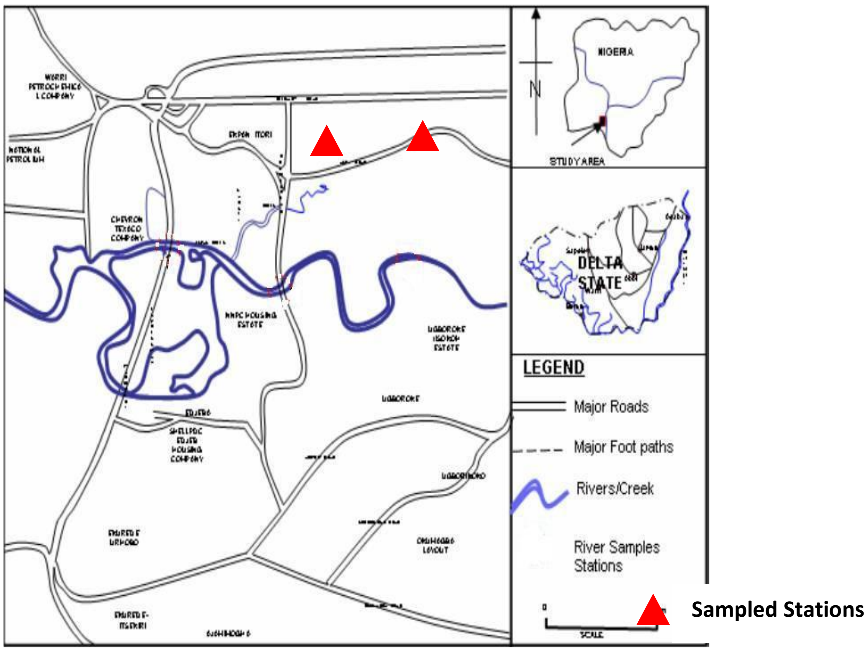

Fig.1. Map of Warri, Delta State showing Ekpan River and the location of the sampled stations (Nduka *et al.,* 2008).

Station 2. This is the downstream section and is located 12 km away from the bridge across the NNPC housing complex. The station has deforested bank thereby exposing this section of the river to direct sunlight. Few palm trees, white and red mangroves as well as submerged macrophytes are present. Anthropogenic activities in this station include fishing, bathing and washing.

Water Sampling

Water samples were collected monthly from the river at the two selected stations (9.0 km apart), between August and November 2011. The sampling stations were visited between 10.0am and 2.00pm on each sampling day. Two litres of water sample were collected and used for the determination of the physico – chemical parameters using standard methods described by APHA (1989). The temperature, conductivity and pH were estimated on the spot using mercury in glass thermometer (0.0 – 110°C), Hanna conductivity meter and pH meter (model H196107), respectively. The rest of the parameters were analyzed in the laboratory. Total alkalinity was determined using the titrimetric method and values recorded in mg $CaCO_3$/L. Dissolved oxygen was determined immediately after collection by the Azide modification method and BOD was determined after 5 days using the same method. Their values were recorded in mg/L. Estimation of phosphate and nitrate were carried out spectrophotometrically following the procedure described in APHA (1989). The values are expressed in mg/L. Depth was read off the graduated rope attached to a Hydrobios sampler and its values were recorded in meters.

Zooplankton Collection

Horizontal Zooplankton hauls were made using 55 μm mesh size plankton net at a low speed for about 10 minutes. No meter was used. The samples were later preserved with 4% formalin. The zooplankton were identified and counted under a binocular microscope (Olympus CK 40) in an ulthmol counting chambers. Pictures of the various zooplankton species were taken using a Canon digital camera (model A 470). The taxonomic identification was made by reference to De-Ridder (1981), Stella (1982), Jeje and Fernando (1986), Onwudinjo, (1990), Korovchinsky (1992) and Dussart and Defaye (1995). The zooplankton density was expressed as the number of individuals per sample volume (ind/l). The zooplankton community structure was studied by calculating the species diversity index (H) (Ogbeibu, 2005)

Statistical Analysis

Factor analysis was applied to physical (air and water temperature and transparency) and chemical (conductivity, pH, alkalinity, dissolved oxygen sulphate, total nitrogen and total phosphorus) and zooplankton abundance assessed over 12 observations. Pearson's correlation coefficient was calculated and used to determine the association between the physico-chemical variables and the zooplankton abundance according to Zar (1984). More so, an independent one-way ANOVA was performed to assess monthly variations in the physico - chemical parameters within and between the stations

RESULTS

The summary of the physico-chemical parameters obtained in Ekpan River from the different stations during the study is shown in Table 1(including the mean and standard error to detect significant differences among the two study Stations. While monthly variations in the physico-chemical parameters are shown in Figs 3 and 4.

The ambient temperature in Station 2 was always higher than in Station 1except in October with equal air temperature value observed. Significant variations were observed in air temperature values within (p = 0.0000) and between (p =0. 0401).

Water temperature values were generally higher in Station 2 than Station 1 except in November where equal values were recorded. The variations in water temperature within the Stations were significant (p = 0.0000) and not significant between the Stations (p = 0.4136)

The depth of the River varied from 1.5 m in Station1 during the dry months (2.15 ± 0.253 (m) to 3.3 m at the peak of the rainy months in August at Station 2 (2.825 ± 0.259 (Table 1). Changes in depth observed at Station 1 (p = 0.0034) and 2 (p = 0.0017) were significantly different.

The results of the mean pH values indicated that Ekpan River was slightly acidic to neutral. Figures 3 and 4 reveal that there were no much variations in the pH of the River. There was no significant difference (p = 0.9219) between stations but within the stations (p<0.01).

Dissolved oxygen values in Ekpan River were relatively low. The Biochemical oxygen demand varied from 0.57 mg/L in September in Station 2 to 1.50mg/l in August in Station 1.

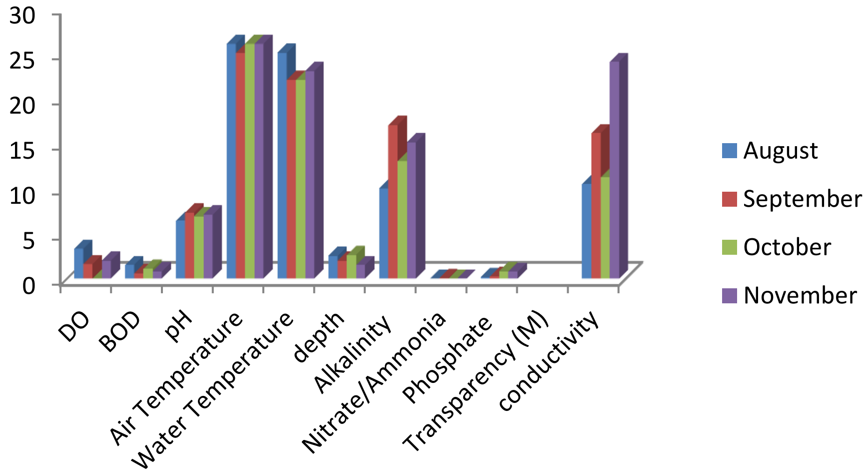

Fig 2 Variations in the physico- chemical parameters of Epkan River in station 1

Table 1: The physico - chemical parameters of Ekpan River at the various stations, range, mean, standard error %) in Parenthesis, F and P values and WHO, SON and NAFDAC Standard

Parameters/ Stations	1	2	Grand mean	Grand S.E	F values	P values	NAFDAC	SON	WHO
Air temperature °C	25.8 (0.25) 25 – 26	27.0(0.41) 26 – 28	26.4	0.34	6.82	0.0401*			
Water temperature °C	22.8 (0.48) 22 – 24	23.8 (0.48) 23 – 25	23.4	0.60	0.77	0.4136			
Transparency m	100%(0.000)	100%(0.000)		0.1796	2.27	0.0000			
Depth m	2.2(0.25) 1.5– 2.6	2.8(0.26) 2.2– 3.3	2.5	0.26	3.47	0.1120			
Conductivity µS/cm	15.5(3.1) 10.50 – 24.00	18.2(1.5) 14.1 – 21.4	16.83	2.46	0.63	0.4585	1000 us/cm-1	1000 us/cm-1)	900us/cm-1
Hydrogen-ion concentration	6.9(0.19) 6.4 – 7.3	6.96(0.15) 6.7 – 7.32	6.9	0.17	0.01	0.9219	6.50-8.5	6.50-8.9	7.0-8.9
Dissolved oxygen mg/L	2.2 (0.38) 1.63 – 3.27	2.5 (0.37) 1.73 – 3.10	2.3	0.38	0.32	0.5912			5
Biochemical oxygen demand	1.01 (0.19) 0.63 – 1.50	0.83 (0.17) 0.57 – 1.33	0.92	0.18	0.42	0.5397			
Alkalinity mg/$CaCO_3$	13.8(1.5) 10.0 – 17.0	17.5 (2.5) 12.0 – 23.0		3.5110	2.43	0.0518*	100mg/l	100mg/l	100mg/L
Phosphate mg/L	0.5(0.17) 0.15 – 0.82	0.39(0.10) 0.14–0.63		0.0192	5.35	0.0005***			50
Nitrate mg/L	0.02(0.01) 0.001 – 0.04	0.02 (0.01) 0.003 – 0.054			6.25	0.0001***	10mg/L	100mg/L	10mg/L

* Significant at $p<0.05$ ** Significant at $p<0.01$

The electrical conductivity values showed significant differences in its concentrations among the seasons and Stations.

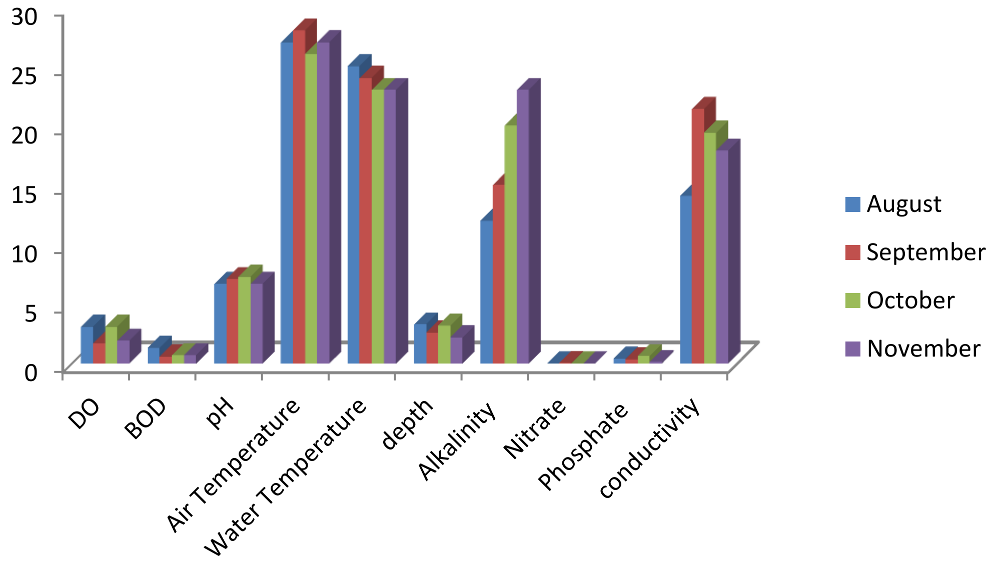

Fig 3: Variations in the physico- chemical parameters of Epkan River in station 2

The total alkalinity values during the period of study were generally low and Nitrate showed the least concentration among the nutrients. Its lowest values were at the peak of the rainy season in August and October at the two Stations. Phosphate had a higher concentration among the nutrients. Phosphate concentration was significantly higher in the rainy season months in station 1 ($P<0.05$).

Factor Analysis

Three principal components each were extracted at both stations as having influence on the water quality of Ekpan River (Table 2). These three principal components (PC) summed up to 100% of the total variance. In station 1, principal component (PC) 1, PC 2 and PC3 accounted for 65.1%. 19.4 % and 15.4% of the total variance respectively and showed strong positive loading of phosphate, conductivity and depth. PC 1 showed weak positive loadings of BOD and weak negative loadings of alkalinity and pH. Principal component (PC 2) revealed high positive loadings of air temperature and phosphate and weak negative loading of nitrate. PC3 shows negative loadings of conductivity, water temperature, and dissolved oxygen.

In station 2, extracted parameters were moderately loaded (Table 2). PC1, PC2, PC3 accounted for 45.4%. 31.7 % and 22.9% of the total variance (100%).PC 1 showed positive loading on conductivity. PC 2 extracted the thermal parameters only; air and water temperature which had weak negative loadings while PC3 showed positive loading on nitrate, phosphate and pH.

Table 2: The Eigen values, variance extracted by the principal component analysis in Ekpan River

Parameters/ Stations	Station 1 components			Station 2 Components		
	1	2	3	1	2	3
Air Temperature	-	0.5235	-	-	-0.4563	-
Water Temperature	-	-	-0.4436	-	-0.4087	-
Depth	-	-	0.5777	0.4118	-	-
Conductivity	-	-	-0.5377	0.3377	-	-
Alkalinity	-0.3906	-	-	-	-	-0.4007
Hydrogen- ion(pH)	-0.3903	-	-	-	-	-0.4403
Dissolved Oxygen	-	-	-0.3475	-0.4288	-	-
BOD	0.3914	-	-	-0.4182	-	-
Nitrate	-	-0.3696	-	-	-	0.4528
Phosphate	-	-0.3696				0.3914
Eigen values %	6.50	1.94	1.54	4.54	3.17	2.29
Proportion (%)	65.10	19.40	15.40	45.40	31.70	22.90
Cumulative %	65.10	84.60	100	45.40	77.10	100

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Association Test

The association test applied to determine the factors that influences the abundance of zooplankton indicated that dissolved oxygen and water temperature had strong positive influence on the abundance of Cladocera while phosphate had a negative association with Protozoa in station 1 (Table 3). In station 2, dissolved oxygen had a high negative influence on Copepoda abundance and a high positive association was found between conductivity and Protozoa abundance, Rotifera with dissolved oxygen and depth and finally between Cladocera abundance and phosphate (Table 3). Slight negative association was revealed between the abundance of Rotifera and Copepoda.

In station 1, highly significant negative correlation was established between BOD and alkalinity (r=-0.9987; p = 0.0187), depth and conductivity (r = -0.9836, P = 0.0164) and pH and BOD (r = - 0.9918, P = 0.0082). In station 2, no significant correlation was established between the parameters (P> 0.05) except the high negative correlation between water temperature and alkalinity.

Table 3: Association Analysis between the physico- chemical parameters and zooplankton groups in Ekpan River.

Parameters/ Stations	Station 1		Station 2	
	r	p	r	p
Water Temperature/ Dissolved Oxygen	- 0.9905	0.0095		
Water Temperature /Alkalinity			- 0.9528	0.0472
Water Temperature/Phosphate			0.6667	0.0353
Depth/ Conductivity	-0.9836	0.0164		
Hydrogen- ion(pH)/ BOD	-0.9918	0.0082		
BOD/Alkalinity	-0.9987	0.0087		
Water Temperature /Cladocerans	0.9898	0.0102		
Water Temperature /protozoa	0.8499	0.0018		
Depth / Rotifer			0.9770	0.0230
Conductivity/ Protozoa			0.9739	0.0261
Dissolved Oxygen /Cladoceran	0.9804	0.0196		
Dissolved Oxygen/Rotifera			0.9527	0.0425
Dissolved Oxygen/Copepods			-0.9988	0.0012
Dissolved Oxygen/Protozoa	0.8035	0.0051		
Phosphate/cladocerans			-0.9799	0.0202
Phosphate/Protozoa	-0.9887	0.0113		
Rotifer/Copepoda			-0.9445	0.0555

Zooplankton Species Composition

A total of fifty eight zooplankton genera were identified in Ekpan River comprising of 27 Rotifera, 9 Cladocera, 7 Copepoda and 14 Protozoan. A list of all species recorded with their abundance and distribution is given in Table 4. The Phylum Rotifera (378 individuals /m^3) was the most abundant constituting 65.6% of the total zooplankton abundance, followed by the Protozoa (19.1%) having 110 organisms/m^3, Copepod (5.6%) with 32 organisms/rn^3 and Cladocera (4.1%) with 24 organisms/m^3.

Table 4: Checklist, Composition, Distribution and abundance of Zooplankton in Ekpan river, August – November 2010.

s/n	Species	Station1				Station 2			
		Aug	Sept	Oct	Nov	Aug	Sept	Oct	Nov
	Rotifera								
1.	*Asplanchna priodonta (Gosse)*	-	-	2	-	1	-	-	-
2.	*Anuraeopsis fissa (Gosse)*	-	1	-	-	-	3	2	-
3.	*Ascomorpha saltans (Bartsch)*	3	-	-	-	-	-	3	-
4.	*Ascomorpha ovalis (Benegengahli, 1892)*	-	3	1	-	-	-	-	-
5.	*Avineta vaga typical (Davis)*	1	-	-	-	-	-	-	1
6.	*Brachionus quadridebtatus*	-	-	-	1	-	-	-	-
7.	*Brachionus calyciflorus*	-	-	-	-	2	-	-	-
8.	*Brachionus angularis (Gosse)*	2	1	2	-	-	-	-	-
9.	*Brachionus urceolaris (O. F. Muller)*	-	1	-	-	-	-	-	1
10.	*Brachionus urceus (linnaeus)*	-	-	-	-	4	-	1	-
11.	*Brachionus fulcatus (Zacharias)*	-	2	-	-	-	-	-	-
12.	*Brachionus variabilis (Hempel)*	-	3	-	-	2	-	2	4
13.	*Brachionus caudatus caudatus (Barrola and Daddy, 1894)*	-	-	1	-	-	3	-	-
14.	*Brachionus plicatilis (Muller)*	1	-	-	4	-	-	-	-
15.	*Brachionus budapestinensis (Daddy, 1885)*	-	-	-	-	3	-	-	4
16.	*Collotheca ambigua (Hudson)*	2	-	-	-	-	-	-	-
17.	*Chromogaster ovalis (Bergendal)*	1	-	-	-	-	-	-	-
18.	*Chromogaster testudo (Lauterborn)*	-	-	1	-	-	-	-	-
19.	*Conochilus hippocrepsis (Schrank)*	2	-	-	-	1	-	-	2
20.	*Enteroplea lacustris (Ehrenberg)*	-	-	-	-	-	1	-	-
21.	*Eosphora trophi (Harring and Myers, 1922)*	-	-	-	3	-	2	-	3
22.	*Eothinia enlongata (Ehrenberg)*	-	-	2	-	-	-	4	-
23.	*Filinia longniseta (Ehrenberg)*	4	2	-	-	2	-	-	2
24.	*Filinia major (Golditz)*	12	3	1	-	4	3	-	6
25.	*Filinia terminalis*	4	1	-	-	-	-	-	-
26.	*Filinia passa (O. F. Muller)*	2	-	-	1	-	-	-	1
27.	*Filinia opoliensis (Zacharias, 1898)*	2	1	-	-	3	-	-	-
28.	*Habrotrocha solida (Donner)*	1	4	-	-	-	-	-	-
29.	*Keratella gracilenta (Ahlstrom)*	2	-	-	-	-	-	-	4
30.	*Keratella valga (Ehrenberg)*	8	7	4	1	-	3	2	-

31.	*Keratella quadrata (Muller)*	-	1	-	3	-	1	-	-
32.	*Keratella tropica tropica (Apstein, 1907)*	6	1	6	-	-	-	7	-
33.	*Keratella cochlearis (Gosse)*	1	-	1	-	3	-	2	-
34.	*Kellicottia longispina (Kellicott)*	-	-	-	2	3	-	-	-
35.	*Lecane ungulate (Gosse. 1883)*	-	2	-	-	-	-	-	-
36.	*Lecane M. quadridentata (Ehrenberg)*	-	-	-	-	-	-	-	2
37.	*Lecane M. bulla (Gosse)*	-	-	-	-	-	7	14	3
38.	*Lepadella apsida (Haring)*	-	2	-	-	4	-	-	-
39.	*Macrotrachela nana (Bryce)*	1	1	-	-	-	-	1	-
40.	*Notholca labis (Gosse)*	-	3	-	-	1	-	2	-
41.	*Philodina erythrophthalma (Ehrenberg)*	-	-	4	1	-	-	-	-
42.	*Pompholyx sulcata (Hudson)*	3	4	-	-	-	-	-	-
43.	*Polyarthra vulgaris*	-	-	-	-	-	1	-	-
44.	*Polyarthra minor*	-	-	-	1	-	3	-	-
45.	*Polyarthra major*	-	-	3	-	-	-	1	-
46.	*Polyarthra trigia (Ehrenberg)*	4	1	-	-	-	8	6	-
47.	*Proales decipiens (Ehrenberg, 1832)*	1	2	1	-	2	-	-	-
48.	*Proales sordid (Gosse)*	2	-	-	-	-	-	-	-
49.	*Ploesoma lenticulare (Herrick)*	-	1	-	-	3	-	-	-
50.	*Rotaria neptunia (Ehrenberg)*	6	1	-	-	-	2	-	-
51.	*Rotaria rotatoria (pallas)*	2	-	-	3	-	-	-	-
52.	*Squatinella sp.*	1	-	-	-	-	-	-	-
53.	*Synchaeta oblong (Ehrenberg)*	-	-	-	-	2	-	-	-
54.	*Trochiscia reticularis*	-	-	-	2	-	-	-	1
55.	*Tetramastix opoliensis (Zach)*	-	-	3	-	1	-	-	-
56.	*Testudinella patina (Hermann)*	-	-	-	-	-	-	1	-
57.	*Testidunella tridentate obtuse (Wu.)*	5	1	-	-	1	-	-	-
58.	*Trichocerca spp.*	-	5	-	-	1	-	-	-
59.	*Trichocerca enlongata (Gosse)*	2	-	1	1	-	-	-	-
60.	*Trichocerca enlongata tchadiensis (Pourriot, 1976)*	3	-	-	-	-	-	3	-
61.	*Trichocerca porcellus*	1	-	-	-	-	-	-	-
62	*Trichocerca lernis (Gosse, 1887)*	1	-	-	-	-	-	-	-
63.	*Trichocerca cylindrical chattoni (Imhof, 1891)*	-	1	1	-	-	-	-	-
64.	*Trichocerca longiseta (Schrank)*	2	-	-	-	4	-	-	-
65.	*Trochosphaera aequatorialsis (Semper, 1892)*	-	-	-	-	6	-	-	-
66.	*Tylotrocha monopus (Jennings)*	-	1	-	-	2	-	-	-
	Cladoceran								
1.	*Bosmina fatalis (Burckhardt)*	-	-	-	-	-	2	-	-
2.	*Bosmina longirostris (O. F. Muller)*	-	-	-	-	1	-	-	1
3.	*Bosminopsis deitersi (Richard)*	-	1	-	-	2	-	-	-
4.	*Sida crystalline (O. F. Muller)*	3	-	-	-	-	-	-	-
5.	*Camptocercus rectirostris (Schoedler)*	3	-	-	-	-	-	-	-
6.	*Alona diaphana (King.)*	-	-	-	3	-	-	-	6
7.	*Leptodora kindti (Focke)*	1	-	-	-	-	-	-	-
8.	*Monospilus dispar (Sars.)*	1	-	-	-	-	-	-	-
9.	*Scapholeberis kingi (Sar.)*	-	-	2	-	-	2	-	-
10.	*Chydorus reticulates (Daday)*	-	-	-	1	-	1	-	-
	Copepoda								
1.	*Mesochra suifunensis*	-	-	-	-	-	-	1	-
2.	*Onychocamptus mohammed (Blanchard et Richard)*	3	-	-	-	-	-	-	1

3.	*Thermodiaptomus galebi (Barrois, 1891)*	-	-	4	3	1	4	-	1
4.	*Ectocyclops phaleratus (Koch)*	-	-	-	-	-	3	-	-
5.	*Rhincalanus nasutus*	-	-	1	-	-	-	-	-
6.	*Eucyclops serrulatus (Fisher)*	-	-		-	-	-	-	6
7.	*Nauplius spp*	-	-	-	2	-	3	-	-
	Protozoan								
1.	*Cocholiopodium bilimbosum (auerbach)*	2	-	-	-	-	2	-	-
2.	*Nebela militaris (Penard)*	-	-	-	1	-1	1	-	4
3.	*Eugleypha tuberculata (Dujardin)*	-	-	-	-	-	1	1	-
4.	*Heleopera sylvatica (Penard)*	-	-	-	-	-	1	1	-
5.	*Pelomyxa palustris (Greeff)*	1	-	-	-	-	2	-	-
6.	*Phryganella hemisphaerica (Penard)*	1	-	-	-	-	2	-	-
7.	*Vorticella monilata (Tamem)*	-	3	-	-	-	-	6	-
8.	*Diffugia oblonga oblonga (Ehremberg)*	-	-	-	-	-	-	-	3
9.	*Diffugia oblonga curvicaulis (Penard)*	-	-	-	3	-	-	-	-
10.	*Diffugia lobostoma (Leidy)*	-	-	-	-	1	-	2	-
11.	*Diffugia constrita (Ehrenberg)*	-	-	1	-	-	-	-	-
12.	*Diffugia globulosa (Dujardin)*	-	-	-	-	-	1	-	-
13.	*Diffugia corona (Walich)*	1	-	-	-	-	4	-	-
14.	*Centropyxis discoids (Penard)*	-	-	3	-	-	3	1	-
15.	*Pelomyxa villosa (Leidy)*	-	2	-	-	-	-	-	-
16.	*Porodon ovum (Ehrenberg. Kahl)*	-	-	-	-	-	-	-	-
17.	*Euglenal caudate (Hubn)*	-	-	-	-	1	4	-	-
18.	*Aspidica dentate (Kahl)*	-	1	-	-	-	-	-	-
19.	*Epistylis breviramosa (Stille)*	-	-	-	-	-	1	-	-
20.	*Vahkampfia limax*	-	-	-	-	-	-	2	-
21.	*Tintinnopsis sinensis (Nie)*	-	-	-	-	-	-	2	2
22.	*Tintinopsis wangi (Nie)*	1	-	-	-	-	-	-	-

Spatial and Temporal distribution

The spatial distribution of the zooplankton species showed that some species were distributed in all stations while some were restricted to certain stations.

The most diverse genus of Phylum Rotifera recorded during this study was *Brachionus*, which had 10 species constituting about 11.8% of the rotifers. The genus *Filinia* had only five species but was the most abundant in number (14.5%). The other genera were Polyarthara *and Lecane* which had 7.5% each, *Trichocerca* 7.0%, *Rotatoria* 3.75% and *Ascomorpha* 2.7 %, were subdominant. Of the ten species of *Brachionus*, 7 species were recorded in station 1 while 6 were found in station 2. *Brachionus calyciflorus, B. ureceus* and *B. budapestnensis* were absent in station 1 while *B quadridentatus, B angularis, B. fulcatus, B. plicalis* were absent in station 2 as shown in Table 2. The result further showed that only three *Lecane* species generated the 7.5% of the total zooplankton composition in the study, two species *were* restricted to station 2 while one; *Lecane ungulate* was restricted to station 1. Four species were recorded for *Polyarthra* and was also subdominant constituting 7.5% of the total Rotifera abundance. These species were not common in the river but recorded three of its species at both stations except *Polyarthra vulgaris*. *Trichocerca* species were well distributed in station 1 while two species: *Trichocerca enlongata* and *T. longiseta* were recorded only once during the entire study. *Keratella was* well represented in the river except for *K. gracilenta* which was counted in only twice.

Rotifers remained the dominant group in the river during the study. The relative abundance of the other zooplanktonic groups was low (Fig. 4).

Protozoa formed the second most abundant zooplankton group in the river. The population was mainly dominated by *Filinia, Brachionus, Keratella, Polyarthra* and *Trichocerca* except in station 2 where *Lecane* species made a significant contribution to the rotifer abundance in September and October. The protozoic group was represented by 22 species which was dominated by *Difflugia*. Besides *Difflugia* (6) and *Tintinnopsis* (2), every other genus was represented by a species. Station 2 recorded more protozoans than station 1. Ten species were restricted to station 2, 6 species were restricted to station 1 while 6 species were represented at both stations.

Cladoceran was the third most abundant and was represented by ten species belonging to nine genera. The genus *Bosmina* recorded the highest number among the cladocerans and was represented by two species which were restricted to station 2 only. Four genera*; Sida, Camptocercus, Leptodora, and Monospilus* were restricted to station 1 while others were recorded at both stations with sparse distribution.

The copepods were represented by seven species belonging to seven genera. Four species *were* represented at both stations except *Ectocyclops phaleratus* and *Eucyclops* recorded in station 2 while only *Rhincalanus* was restricted to station 1

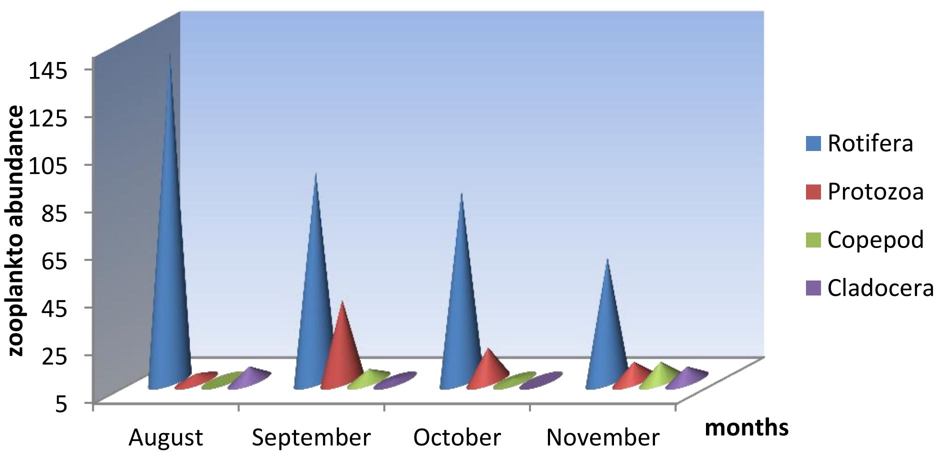
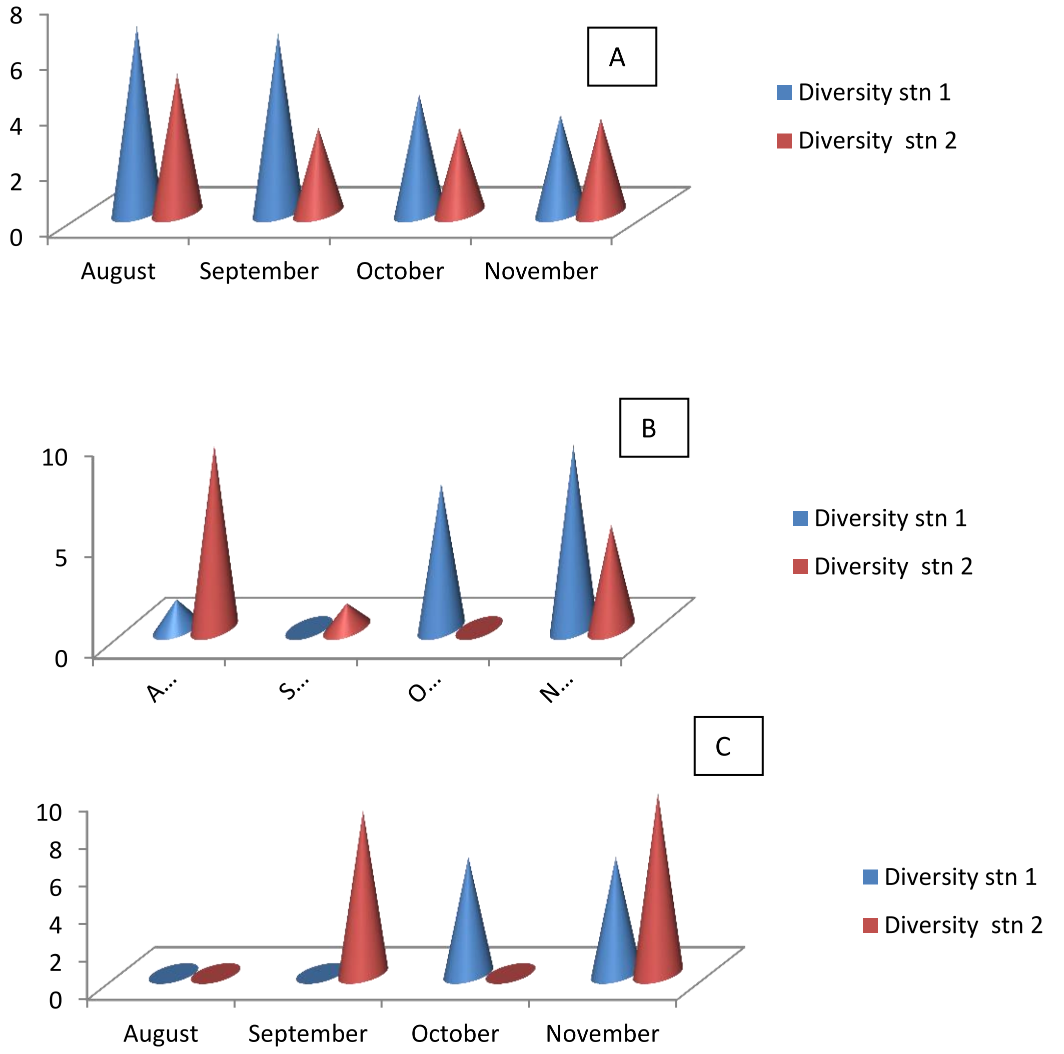


Fig. 4: Monthly fluctuations of Zooplankton in Ekpan River during the period August to November 2011.

The one way anova performed to assess the effects of temporal and spatial variation on the zooplankton density revealed significant effect on the zooplankton density (F= 5.05; P= 0.0119). The high coefficient of variation (CV 147.5%) revealed high variation in the monthly abundance of zooplankton about their mean (51 ind/m^3).

Zooplankton Diversity and Similarity Indices

The zooplankton diversity indices revealed that the rotifers' diversity was higher at station 1 than in station 2 however its diversity decreased from August to November (Fig.2A) while the reverse was observed in the diversity of the other zooplanktonic groups.



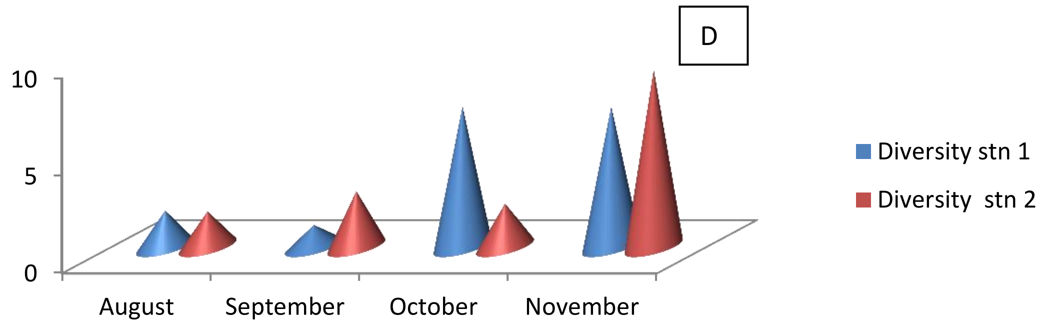


Fig. 5. Comparison of diversity indices (D_{mg}) of (A) rotifer, (B) cladocera, (C) copepod and (D) protozoa in Ekpan River at the various stations.

DISCUSSION

Air temperature was characteristically followed by water temperature. Lower air and water temperature values were recorded during dry season while higher temperature values were recorded during the wet seasons. The low water temperature values recorded during the period of the study was attributed to the rainy season due to the effect of cloud cover, the extensive submerged macrophytes, water hyacinths *(Eichhonia crassipes)* and the white and red mangroves which are characteristic of the study area particularly in station 1. The turbid nature of the River could have contributed to the reduction in temperature due to absorption of heat by the silts. This water temperature range is suitable for the production of plankton (Onwudinjo, 1990, Iloba, 2012).

The temperature values recorded in this river is not similar to those reported in rivers within the same geographical region; Ezekiel *et al.* (2011) on Sombreiro River (27.9°C to 29.2°C), Arimoro *et al.* (2008) on Warri River recorded 26.3 and 30.3°C.

The differences in the water temperature within and between the stations (P>0.05) may significantly favour biological activities of the various life forms in study system because life cycles and population densities of many stream organisms are temperature dependent and alteration of the average stream temperature by a few degrees could alter the flora and fauna of the river (Jackson et al., 1989).

Depth variation occurred at the two stations. Depth reduction observed during the dry season may be attributed to evaporation and reduced runoff while the increase in depth during the rainy season could be due to increased runoff into the river as observed by Iloba (2012).

The pH of Ekpan River during this study was slightly acidic. The pH values reported in Station 1 of the river was high during the dry season, fluctuating from being slightly acidic (6.90) to being almost neutral (7.08) while station 2 remained almost neutral throughout the period of study. This pH range is good for zooplankton growth and culture. Hydrogen ion (pH) values recorded during this period (6.40 to 7.32) reflected low acidic to neural conditions during the rains indicating that the water is well buffered (Olomukoro *et al*., 2009). The low range of pH obtained during the rainy season may probably be due to the nature of materials flowing into the river. The pH values recorded in this study is similar to the records of Olomukoro *et al*. (2009) in the same river. Alkalinity and pH were also found to favour zooplankton growth and abundance in the river as seen from the positive correlation with pH.

The alkalinity range of Ekpan River as recorded in this study is lower than that of the Warri River which in turn is lower than that of other rivers such as those in Benin and Sapele as reported by Egborge and Benka - Coker (1986). The alkalinity values are an indication of low carbonate and bicarbonate ions in the water reflecting the absence of limestone in the water basin. This water alkalinity values compared to that of others is low. Adebisi (1981), recorded 77.9mg/$^{-1}$ $CaCO_3$ in Ogun River; Onwudinjo, (1990), recorded 31.5mgl^{-1} at Ogheye in Benin River while Ogbeibu and Victor (1995), recorded l20 mgl^{-1} at the Okomu forest reserve. Studies by Egborge and Benka - Coker (1986) in Benin River and a section of River Jameison, and Odum (1992) in Ethiope River have shown lower alkalinity values between 2-4 mg/l and 0.93-2.29mg/l, respectively.

The low conductivity of the Ekpan River is attributed to low ionic content and overall chemical composition of the water owing to the discharged of effluent (non dissolution) into the water body, or as a result of nutrient concentration (Fisher *et al*., 1983). The River conductivity was extracted as influencing the zooplankton growth and abundance particularly Protozoa. This also agrees with the findings of Hujare (2005) in Hatkanangale Tahsil, Kolhapur, India.

The dissolved oxygen range during the period of investigation was low. This could be attributed to the decomposition of effluent received from both the Chevron Nigeria Company and Warri Refinery and Petrochemical Company and also the high temperature values observed during the period. This is also evident from the significant negative association between water temperature and dissolved oxygen (Tables 4 and 5). The higher fluctuations of dissolved oxygen during dry season than in the rainy season periods could be attributed to the peak of human activities along the catchment area of Ekpan River during this season. The decomposition of organic matter, metabolic activities of epiphytic organisms could also be responsible for reduced oxygen concentration in the river (Pillai *et al*., 1982; Uka and Chukwuka, 2007).

Biological Oxygen Demand (BOD) values (0.57 to 1.33mg/L) in this study are surprisingly low when compared with the activities in and around the river. High decomposition rate is expected since the River serves as a major drainage channel for the area, receiving both domestic and industrial wastes. However, the lotic nature of the river could have contributed to self purification or recovery of the system (Iloba, 2012).

The relatively high values of Phosphate recorded in this study could be attributed to incoming effluents and human activities such as washing, bathing, fishing and fish farming. The values of phosphate in station 1 were considerably higher than Station 2. This may be due to the biodegradation of organic matter by bacteria. Phosphate concentration was higher than that of nitrate as values recorded for nitrate were negligible for most of the months throughout the study. Nwankwo (1998) observed higher nutrient, conductivity and ionic concentration values in Ekpan River during the rainy season.

The phosphate level fluctuates slightly compared to the nitrate levels. In Station 1 and 2, the nitrate levels show slight change in range. The lower values of nitrates in the upstream Stations could be due to the absorption of the nutrients by floating plants. The absorptive ability of the floating plants to remove nutrients from aquatic environments has been confirmed by Ogunlade (1996). Olomukoro and Azubike (2009) observed in Ekpan River that higher nutrient, conductivity values and ionic concentration levels were recorded in the rainy season.

The use of factor analysis applied to assess the variation in the water quality of Ekpan River showed three latent components identified at each station to be responsible for 100% of the changes in the water quality and biological variables in the river. The factors implicated primarily organic pollution (DO, BOD), eutrophication (air temperature, phosphate and nitrate), and acidification (alkalinity, pH, nitrate, BOD and DO), industrial and anthropogenic factors as the major causes of possible variations in the water quality in Ekpan River. The “organic and acidification” factors could be attributed to point sources from the oil industries around the river system while the nutrient factor could be the various anthropogenic activities in the river such as fish farming, washing, bathing and dredging of sand. The sole extraction of thermal parameters in principal component 2 at station 2 is an indication that thermal influence in the river system is apparently important. This is not surprising since the station has deforested bank thereby exposing this section of the river to direct sunlight. Thus, the two stations are similar to one another in terms of the factors influencing their water variables and natural recovering influence.

The four faunistic groups recorded in this study are characteristics of tropical river systems. The order of abundance (Rotifera > Protozoa > Cladocera > Copepoda) observed in this study does not agree with the order of the general freshwater zooplankton assemblages (Rotifera > Cladocera > Copepoda > Ostracoda except the apparent dominance of rotifers (Wallace and Snell 1991). The preponderance of rotifers and protozoan's in a river system has been reported by Iloba (2012) in River Ethiope. The dominance of rotifers in rivers could be explained by their very brief generation times compared to larger zooplankton (Dijk and Zan-Ten, 1995). The predominance of rotifers over the other zooplankton groups observed in the present study has also been reported earlier in various rivers (Onwudinjo, 1990; Imoobe and Adeyinka 2010; Iloba, 2012,).

The Cladoceran species recorded in this study are cosmopolitan in the tropical region. The dominance of *Bosmina* in Ekpan River agrees with the fact that the species are the most widely and frequently recorded planktonic species of the open water habitat in rivers. The low number of Cladoceran species agrees with studies that Cladocerans appeared disfavoured by riverine conditions (Bass and May, 1996).

The significant positive relationships exhibited by some of the zooplankton densities with dissolved oxygen, water temperature conductivity and phosphate implicated these factors as important factors governing their abundance in the river. This study has implicated temperature as an important variable determining the species abundance of Cladocerans. This is not surprising since thermal factor has been implicated as an important factor influencing the Ekpan River system. This observation has also been reported by Onwudinjo (1990) in Benin River.

The positive significant influence of conductivity on the abundance of protozoa, phosphate and Cladocera could be due to ionic and nutrient enrichment of the river from the surrounding environment. More so, the dominance of *Brachionus*; a nutrient loving rotifer in the river, could also be attributed to this enrichment. The formation of Protozoa as the second most abundant zooplankton group in the river could also be attributed to favourable conditions provided by the water body.

The low levels of conductivity, alkalinity, and nutrient elements in the river are not suggestive of the non influx of these parameters into the river but the intensive natural process of self purification proceeding in the river system. Thus, the low values recorded in these parameters are not suggestive that the river is oligotrophic nature regarding the extent of anthropogenic activities, the companies's around the river and the low biochemical oxygen demand values recorded in this study. Rather, the absorptive ability of the floating plants in the river could have removed these substances from the river as noted by Ogunlade (1996) and Olumukoro *et al.* (2009).

High similarity index revealed between the zooplankton groups at both stations (> 50%) as well as the significant association with one another is an indication that small numbers of species were group recorded in the high zooplankton diversities indices observed in this study signifies a stable community however; fluctuations in their diversities particularly that of Cladoceran and Copepod revealed that the system was unstable in some months (rainy months) which had impact on the abundance of the organism. The instability was more in station 1. This instability could be attributed to a wide variety of disturbances in the river such as nutrient loading, acidification, and sediment inputs from dredging as well as other anthropogenic activities. While the contrast in the physical, chemical and biological characteristics in both stations could be responsible for the variations in the diversity and zooplankton composition and abundance of the different zooplankton groups recorded in this study.

CONCLUSION

The study had revealed that despite the obvious agricultural, urban and industrial developments around the river, the health of the river has not been impaired. However, these activities should be controlled to ensure the protection of the aquatic biota.

The study also revealed that zooplankton composition and abundance were low and is influenced by changes in water quality as shown by changes in species composition, assemblages and abundance at the various stations. Factor analysis further extracted "organic (DO, BOD), eutrophication (air temperature, phosphate and nitrate), acidification (alkalinity, pH, nitrate, BOD and DO) and industrial and anthropogenic" as major influencing factors in the Ekpan River. The overall results showed that changes in water quality of the river have significant effects on the structure of zooplankton assemblages. This feature could be used for bio-monitoring of the river's health to ensure the protection of the aquatic biota. Considering the usefulness of this municipal river to the community, waste water treatment should be applied in order to minimize its influence on the river's water quality.

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