Zooplankton Community Responses in a Perturbed Tropical Stream in the Niger Delta, Nigeria

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Abstract: The effect of abattoir wastes and other anthropogenic activities on the distribution and abundance of zooplankton and environmental variables were investigated in Orogodo River, southern Nigeria. Samples of zooplankton were collected for a period of six months from three stations, representing upstream of the river course, effluent discharge point and downstream of the river course. A combined total of 79 species of zooplankton were encountered in the study. Station 1 recorded the highest number (78 species), station 2 with 22 taxa and station 3 with 72 representative taxa, showing recovery in terms of diversity and abundance of zooplankton. Rotifers of the order Bdelloidea dominated all the stations and were relatively high in station 2 indicating their tolerance to a wide range of impact. Generally, the cladocerans were abundant at all stations. However, *Moina micrura,* and *Thermocylops neglectus* were the only members of this group recorded in station 2. The low fauna diversity experienced in station 2 throughout the period of sampling showed strong evidence of impact arising from the abattoir waste discharge and heavy human activities at that station. Local environmental conditions (i.e. Temperature, flow velocity, depth, dissolved oxygen, alkalinity and conductivity) accounted for 69% of variation in zooplankton assemblages using canonical correspondence analysis (CCA). Seasonal trends in zooplankton community composition were also related to changes in environmental characteristics of the river. Our results indicate that the changing water quality status of the Orogodo River affected the zooplankton diversity and abundance and such measure could be used as a biomonitoring tool to determine the ecological health of the river.

Keywords: Zooplankton, Orogodo river, organic pollution, environmental variables, Nigeria.

INTRODUCTION

River pollution is becoming a critical issue of water management in Nigeria, especially in urban and semi urban cities. Many rivers in urban and semi urban areas of Nigeria have been used for disposals of both solid wastes and waste waters, usually untreated, and are thus adversely polluted. This high pollution status threatens and, in many cases, has already altered the ecological balance of most rivers in Nigeria [1-3]. Zooplankters offer several advantages as indicators of environmental quality in both lakes and rivers: as a group, they have worldwide distribution and the species composition and community structure are sensitive to changes in environmental conditions, nutrient enrichment [4-6] and different levels of pollution [7-9]. Zooplankton play an important ecological role in lakes and rivers, feeding on non-living organic matter, phytoplankton and bacteria, and in turn being eaten by secondary consumers such as fish [10]. The physico- chemical parameters of an aquatic ecosystem are very important in assessing the composition of any aquatic biota and also their sensitivity to pollution [5, 10, 11]. Therefore, a major interest in zooplankton investigation is to understand environmental factors that influence their diversity [12]. Certain knowledge of the responses of zooplankton to changes in water quality could therefore constitute an important tool to be used by water managers in Nigeria to continually and rapidly assess the health of the water bodies. Some researchers in the tropics [13, 14] have reported higher densities of zooplankton in the rainy season, with copepod forming the dominant group, followed by cladocerans, rotifers and ostracods [15] had earlier suggested that since most of these factors are influenced by rainfall, rainfall regime is therefore considered a dominant factor affecting zooplankton dynamics in tropical waters. Orogodo River is one of the numerous freshwater bodies that abound in the Niger Delta area of southern Nigeria. It is a typical municipal stream flowing through Agbor town with a population of over 100,000 people. The stream at the middle reaches is subjected to organic pollution load arising from the effluent discharged from the abattoir comprising of stomach and intestinal contents of slaughtered animals, ashes of burnt animals and associated bloodstains. An average of 400 animals are slaughtered daily which makes up an enormous volume of wastes discharge regularly in the stream without treatment. Furthermore, the river is influenced by frequent disturbance of humans and domestic animals and if not properly managed can pose severe health risk to the population. Downstream from the Agbor abattoir, water is used for vegetable farming in the catchment as oppose to its use as portable water upstream. The continuous discharge of these organic wastes into the water body and the dearth of information on the responses of aquatic biota including zooplankton to these wastes necessi-

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tate this research. In the Niger delta area of Nigeria, zooplankton has been mostly monitored in lake studies [16, 17]. There have been no comprehensive zooplankton studies in the Delta State River system. This paper aims to partly fill an existing gap in zooplankton biodiversity knowledge of the Niger Delta area in Nigeria and their use to evaluate river health. Also the zooplankton community characteristics will be utilized in assessing the recovery of the river following stress caused by anthropogenic activities.

MATERIALS AND METHODS

Description of Study Area

Orogodo River lies between latitude 5.10[1]-6.20[1]N and longitude 6.10[1]- 6.21[1]E (Fig. **1**). The river is fed principally by ground seepage from an aquifer in the thick rainforest of Mbiri and secondarily by precipitation, municipal effluence and surface run off from the riparian communities. The river flows through the major town of Agbor in southern Nigeria. The river substratum consists mainly of fine sand mixed with mud and occasionally with coarse sand and pebbles. Decaying macrophytes and debris also form part of the substratum. The climate of Agbor town and its environs is characterized by a rhythm of rainfall occurring in conjunction with movements of the southwest Monsoon winds across the Atlantic Ocean and the timing of these movements varies from year to year. The dry season is from November to March and the wet season is from April to October. The sampling sites and their location are given below:

Station 1

The station is located approximately 2km from the river's source (Fig. **1**). The water here flows beneath a dense tree canopy in a shallow channel (0.5m deep, 5.4m wide at the station) joining shallow pools at various points. Aquatic vegetation is thick consisting of both submerged macrophytes (*Ceratophyllum submersum* L, *Azolla Africana* (Desv.), *Utricularia* sp) and emergent macrophytes (*Pycreus lanceolatus* Pol, *Cytosperma senegalense* (EngL.), *Scirpus jacobi* (Fisher) and *Vossia cuspidata* (Griff)). The streambed is loam and silt with fallen leaves. No point source of pollution is found here [18]. The marginal vegetation is composed of terrestrial plants including oil palm (*Elaeis guineensis*) and Indian bamboo (*Bambusa* sp). The water velocity at this station is considerably low with a mean of 0.20m/s. Human activity is considerably less than at downstream stations, but fishing with hook and line is commonly practiced at this station.

Station 2

The station is located at the point of discharge of effluents from the Agbor Abattoir. The abattoir effluent is mainly organic, made up of faeces, blood and ashes produced during the slaughter, roasting and burning of animals (donkeys and cows). This station is exposed to direct heat of the sun and has heavy algal growth in some areas but, with very few macrophytes (*Nymphae lotus, Azolla* sp., *Utricularia* sp and *Salvinia* sp) and duckweeds (*Lemna*) closed to the banks. The streambed is covered by coarse sand. The current veloc-

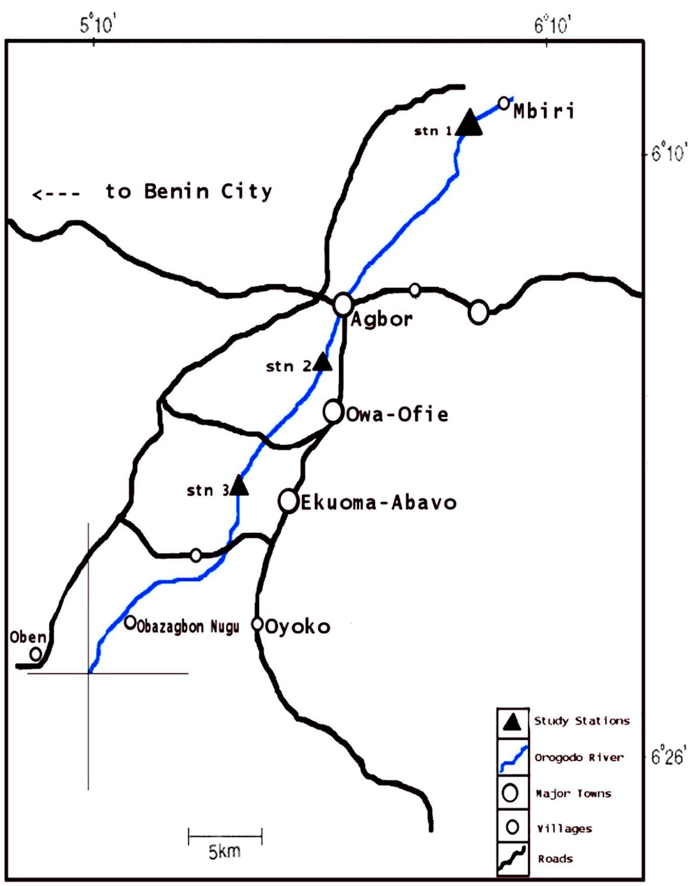

Fig. (1). Map of Orogodo River showing the location of the sampling stations.

Table 1. Environmental Factors Measured at the Sampling Stations of Orogodo River, (Jan-Jun 2008) Showing Physico-Chemical Parameters (n = 6).

Physicochemical Parameters	Station 1	Station 2	Station 3
Dissolved oxygen (mg/l) *	7.57 ± 0.38^{a} (7.01 – 9.52)	2.48 ± 0.37^{b} (1.70 – 4.00)	6.25 ± 0.32^{a} (5.30 – 7.20)
Water temperature (^{o}C)	20.51 ± 0.22^{a} (20.05-21.00)	21.50 ± 0.22^{a} (21.00-22.00)	21.67 ± 0.21^{a} (21.00-22.00)
Air temperature (^{o}C)	22.80 ± 0.07^{a} (22.00-23.48)	24.3 ± 0.21^{a} (24.00-25.35)	23.17 ± 0.31^{a} (22.00-24.48)
Depth (metres) *	1.46 ± 0.02^{a} (1.36-1.60)	0.70 ± 0.04^{b} (0.58-0.80)	1.33 ± 0.03^{a} (1.25-1.40)
Flow velocity (m/s) *	0.04 ± 0.00^{a} (0.04-0.05)	0.32 ± 0.03^{b} (0.21-0.43)	0.21 ± 0.02^{c} (0.11-0.25)
BOD_5 (mg/l) *	2.45 ± 0.08^{a} (2.22-2.74)	4.59 ± 0.19^{b} (4.21-5.56)	2.87 ± 0.07^{a} (2.58-3.00)
Conductivity (µS/cm) *	24.78 ± 3.89^{a} (21.18-32.43)	39.67 ± 9.16^{b} (28.26-44.87)	24.39 ± 3.76^{a} (21.34-32.56)
Alkalinity (mg/l) *	14.93 ± 0.55^{a} (13.32-17.85)	5.17 ± 0.67^{b} (4.11-7.54)	8.54 ± 1.87^{c} (6.08-17.86)
pH	5.8 (5.3-6.1)	5.9 (5.8-6.7)	5.9 (5.4-6.4)
Nitrates (mg/l) *	0.43 ± 0.19^{a} (0.22-0.88)	1.72 ± 0.39^{b} (0.89-2.87)	1.56 ± 0.18^{b} (1.28-2.34)
Phosphates (mg/l) *	0.05 ± 0.01^{a} (0.01-0.08)	0.08 ± 0.01^{b} (0.06-0.10)	0.04 ± 0.02^{a} (0.01-0.09)

Note. Values are mean ±SE, range in parenthesis, * indicates significantly calculated F-value detected by ANOVA. Different superscript letters (a, b and c) in a row show significant differences ($P < 0.05$) indicated by Tukey Honest (HSD) significant difference tests.

ity is relatively fast (mean value = 0.58m s-1). Average depth is about 0.5m and width 5.8m. Domestic wastes from the town are emptied few kilometers from this station during heavy down pour. In addition, washing of cars and clothes with detergents occurs regularly here. This station has the greatest anthropogenic impact [18].

Station 3

The station is located 5km downstream from the Agbor Abattoir close to Abavo by Owa-Ofie village. The riverbed widens considerably (10.4m) at this point. Farming and sand dredging are the predominant land uses, so the riparian vegetation of the area could be described as farm bush. Most of this section of the river is flanked by Indian bamboo (*Bambusia* sp) and palm (*Elaeis guineenis*), *Pandanus* sp., and *Mitragyna ciliata*. The current velocity is relatively fast (mean = 0.47m s-1). The substratum is predominantly clay and silt. Human activities include bathing, fishing, contamination with uneaten food by worshippers, etc. The water depth is approximately 0.75m.

Samples Collection

Samples of water and zooplankton were collected monthly from each site from January to June 2008 covering three months each in the dry season (January – March) and wet season (April – June) respectively on same sampling days. Surface water temperatures were recorded with mercury in glass thermometer. Conductivity, pH, total alkalinity, dissolved oxygen and biochemical oxygen demand (BOD) were determined according to [19] methods. The surface water velocity measured in mid channel by timing a float (average of three trials) as it moved over a distance of 10 m [20]. Depth was measured in the sample area using a calibrated stick. Nitrate-nitrogen (NO3-N) and phosphate phosphorus (PO4-P) were measured spectrophotometrically after reduction with appropriate solutions [19]. Substratum composition in each 25m sampling reach was estimated visually as percentage of silt, loam and sand [21]. Zooplankton was sampled quantitively in the mid channel at all sites. Vertical hauls were taken using plankton townet of mesh size 80 m (172 meshes/inch) as described by [22]. The samples were preserved in 4% buffered formalin solution and transported back to the laboratory. Taxonomic identification was conducted under a microscope at a magnification of 40 x and 100 x. Zooplankton organisms were identified to the species level according to [23-26] and abundance estimated.

Data Collection and Analysis

A faunal list was compiled by recording all zooplankton taxa found in the sampling stations (Table **2**). The range, mean and standard error for each parameter and station were

Table 2. Composition, Distribution and Mean Abundance of Zooplankton in Orogodo River from January to June 2008

TAXONOMIC GROUP	Code	STATIONS			Percentage Composition	Seasonal Occurrence	
		1	2	3		DS	RS
ORDER PLIOMA							
Family Asplanchnidae							
Asplanchna brightwellii Gosse, 1850		x	-	x	0.1		+
Family Branchionidae							
Platyias quadricornis Ehrenberg, 1832		x	-	-	0.1		+
Keratella sp. Bory de St. Vincent, 1822	Ker	x	-	x	1.3	+	+
Branchionus calyciflorus Pallas, 1776	Bra	x	-	x	0.6	+	+
Branchionus variabilis Hempel, 1896	Bra	x	-	x	0.8	+	+
Family Collurellidae							
Lepadella patella Müller, 1786	Lep	x	-	x	0.8	+	+
Colurella uncinata Müller, 1773		x	-	x	0.2		+
Lepadella (Xenolepadella) monodactyla Berzins, 1960		x	-	x	0.5		+
Family Dicranophoridae							
Aspelta tilba Koste & Shiel, 1987	Asp	x	-	x	1.1	+	+
Family Euchlanidae							
Euchlanis dilatata Ehrenberg, 1832		x	-	-	0.2		+
Family Gastropodidae							
Ascomorpha ecaudis Perty, 1850	Asc	x	-	x	0.8	+	+
Family Ituridae							
Itura viridis Stenroos, 1898		x	-	x	0.4		+
Family Lecanidae							
Lecane leontina Turner, 1892	Lec	x	-	x	2.3	+	+
Lecane pyriformis Daday, 1905	Lec	x	x	x	1.0	+	+
Lecane unqulata Gosse, 1887	Lec	x	-	x	0.2	+	
Lecane acronycha Harrings and Myers	Lec	x	x	x	1.9	+	+
Lecane luna Müller, 1776	Lec	x	-	x	0.2		+
Lecane papuana Murray, 1913	Lec	x	-	x	0.5	+	
Lecane monostyla Daday, 1897	Lec	x	-	x	0.6	+	+
Lecane quadrindentata, Ehrenberg, 1832	Lec	x	x	x	0.8		+
Lecane decipiens Murray 1913	Lec	x	-	x	0.9	+	+
Lecane grandis Murray, 1913	Lec	x	x	x	1.1	+	+
Monostyla sinuate Hauer, 1938	Mon	x	-	x	1.0		+
Monostyla bulla bulla Goose, 1851	Mon	x	-	x	0.5	+	+
Monostyla cornuta Mueller, 1786	Mon	x	-	x	2.5	+	+
Monostyla lunaris Ehrenberg, 1832	Mon	x	-	x	3.0	+	+
Family Proalidae							
Proales sp Goose, 1886	Pro	x	x	x	0.9		+
Family Trichocercidae							
Trichocerca tropis Hauer, 1937	Tri	x	-	x	0.1		+

Table 2. contd…

TAXONOMIC GROUP		**STATIONS**			**Percentage Composition**	**Seasonal Occurrence**	
	code	1	2	3		DS	RS
Trichocerca elongata Murray, 1913	Tri	x	-	x	0.4	+	
Trichocerca longiseta Schrank, 1802	Tri	x	-	x	0.5	+	+
Trichocerca iernis Gosse, 1887	Tri	x	x	x	0.3		+
Trichocerca obtusidens Olofssons, 1918	Tri	x	x	x	0.5		+
Family Trichotridae							
Macrochaetus collinsi Gosse, 1867	Mac	x	x	x	0.5	+	+
ORDER BDELLOIDAE							
Family Adinetidae							
Adineta gracilis Janson, 1893		x	-	-	0.2		+
Family Habrotrochidae							
Otostephanus sp Milne, 1916	Oto	x	x	x	1.9	+	+
Habrotrocha sp Bryce, 1910	Hab	x	x	x	2.0	+	+
Family Philodinavidae							
Philodinavus paradoxus Murray, 1905	Phi		x	x	1.6	+	+
Family Philodinidae							
Rotaria rotatoria Pallas, 1766	Rot	x	x	x	6.0	+	+
Rotaria tridens Montet, 1915	Rot	x	x	x	9.0	+	+
Rotaria tardigrada Ehrenberg, 1832	Rot	x	x	x	1.0	+	+
Rotaria macroceros Gosse, 1851	Rot	x	x	x	2.4	+	+
Rotaria macrura Schrank, 1802	Rot	x	x	x	1.7	+	+
Philodina roseola Ehrenberg, 1832		x	x	x	1.3	+	+
Dissotrocha aculeata Ehrenberg, 1832		x	-	x	0.2		+
Macrotrachela sp Milne, 1886		x	x	x	1.5	+	+
Family Notominatidae							
Cephalodella sp Bory de St. Vincent, 1826		x	-	x	0.4		+
ORDER FLOSCULARIACEA							
Family Testudinellidae							
Testudinella patina Hermann, 1783	Tes	x	-	x	1.4	+	+
Heraelia brema Dona, 1994		x	-	x	0.7	+	+
Testudinella sp Bory de St. Vincent, 1826		x	-	x	<0.1		+
Family Trochosphaeridae							
Trochosphaera aequatorialis Semper, 1872		x	x	x	1.3	+	+
SUBCLASS COPEPODA							
ORDER CALANOIDA							
Family Diaptomidae							
Thermodiaptomus galebi Kiefer, 1927	Dia	x	-	x	0.2		+
Tropodiaptomus incognitus Dussart, 1966	Dia	x	-	x	0.4		+
Tropodiaptomus processifer Kiefer, 1927	Dia	x	-	x	2.1		+
Thermodiaptomus yabensis Wright & Tressler, 1928	Dia	x	-	x	0.6	+	+
Family Cyclopidae							
Microcyclops rubellus Lilljeborg, 1901	Mic	x	-	x	2.8	+	+
Microcyclops varicans Sars, 1863	Mic	x	-	x	2.0	+	+

Table 2. contd…

TAXONOMIC GROUP		STATIONS			Percentage Composition	Seasonal Occurrence	
	Code	1	2	3		DS	RS
Halicyclops korodiensis Onabamiro, 1952	Hal	x	-	x	0.7		+
Thermocyclops neglectus Sars, 1901	The	x	x	x	2.1	+	+
Family Canthocamptidae							
Bryocamptus birsteini Borutskii, 1940	Bry	x	-	x	5.3	+	+
ORDER CLADOCERA							
Family Moinidae							
Moina micrura Kurz,1874	Moi	x	x	x	3.3	+	+
Family Chydoridae							
Eurylona orientalis Daday, 1898		x	-	x	0.3		+
Eurylona sp Sars, 1901		x	-		0.1	+	+
Chydorus reticulatus Daday, 1898	Chy	x	-	x	5.8	+	+
Chydorus ventricosus Daday, 1898	Chy	x	-	x	4.6	+	+
Alona eximia Kiser, 1948	Alo	x	-	x	0.5	+	+
Alona davidi Richard, 1895	Alo	x	-	x	2.1		+
Alona rectangular Sars, 1861	Alo	x	-	-	0.1		+
Oxyurella sp Dybowski & Grochowski, 1894		x	-	x	0.3	+	
Family Bosminidae							
Bosmina longirostris Müller, 1785	Bos	x	-	x	0.3		+
Bosminopsis deitersi Richard, 1895	Bos	x	-	x	0.6		+
Family Macrothricidae							
Macrothrix goeldi Richard, 1897		x	-	x	0.7		+
Echinisca capensis Sars, 1916		x	-	-	0.2		+
Guernella raphaelis Richard, 1892		x	-	-	0.4	+	+
Echinisca triseralis Brady, 1886		x	-	x	0.6	+	+
Family Daphnidae							
Diaphanosoma excisum Sars, 1885	Dap	x	x	x	0.4	+	+
Cerodaphnia cornuta Sars, 1888	Dap	x	-	x	1.6	+	+
Family Sisidae							
Pseudosida sp Herrick		x	-	x	2.3	+	+
OSTRACODA							
Eucypris sp Vavra,1891		x	-	x	0.5		+
Nebalia bipes Fabricius, 1780		x	-	x	0.4	+	+

Note x-present, - absent, D.S- dry season, R.S- Rainy season, codes abbreviated for CCA analysis.

calculated. Physical and chemical features of stations were compared using one way ANOVA on log (x+1) transformed data except for pH. Fixed effect ANOVAs were performed using dates as replicates. Significant ANOVAs ($P<0.05$) were followed by post hoc {Tukey Honest (HSD)} tests to identify differences between station means. Canonical correspondence analysis (CCA) was used to evaluate relationships between zooplankton communities and environmental variables with Brodgar statistical package (version 2.0, Highland Statistics Ltd, 2000). Before using CCA, variables that covaried with other variables (Pearson correlation $r > 0.80$, $P< 0.05$) were removed. Rare species (< 2% at a sampling site) were not included in the CCA. Although all physicochemicalparameters were included in the early CCA ordinations,

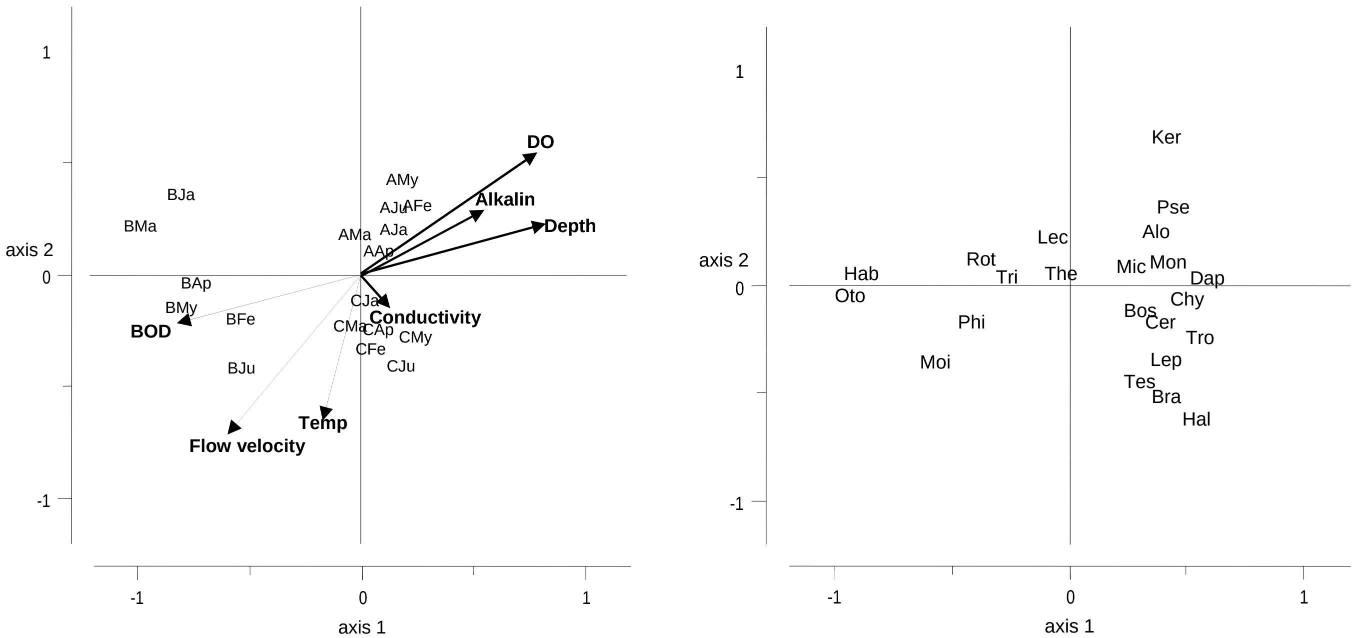

Fig. (2). Canonical correspondence analysis (CCA) ordination plots for **A,** sites/stations and environmental variables and **B,** species Code for genera in Table **2**, (Monthly codes are Ja, January; Fe, February; Ma, March; Ap, April; My, May; Ju, June. Stations are 1, A; 2, B; and 3, C (Axes have a total eigenvalues of 0.19 and total inertia of 0.24).

those variables with high variance inflation factors (VIF>20 indicating very strong multicollinearity) were eliminated from the analyses. In addition, variables were log transformed {log (x+1)} before the CCA analysis to prevent extreme values (outlier) from unduly influencing the ordination. Species-environment correlation coefficients provided a measure of how well variation in community composition could be explained by individual environmental variables. A Monte Carlo permutation test with 199 permutations [27] was used to assess the significance of the canonical axes extracted. Taxa richness (Margalef & Menhinick indices), diversity (Shannon, & Simpson dominance indices), evenness indices and Hutcheson T-test for inter-station comparison were calculated using the computer BASIC programme SP DIVERS [28].

RESULTS

The range, mean and standard error of some selected water quality parameters used in delineating the effect of organic wastes (Abattoir effluent) and other anthropogenic activities on the distribution and abundance of zooplankton are summarized in Table **1**. CCA ordination plots for sites and environmental variables and for species is shown in Fig. (**2A** and **2B**) respectively. The CCA ordination showed a good relationship between zooplankton species distribution and measured environmental variables. The strongest explanatory factors were flow velocity, dissolved oxygen (DO) and biochemical oxygen demand (BOD). BOD was strongly negatively correlated with depth, dissolved oxygen and alkalinity. There was very weak correlation between DO and conductivity same as for BOD and conductivity. *Moina*, *Philodinavus* and *Otostephanus* species were common with the site with high BOD values. Similarly, *Pseudosida*, *Keratella*, *Alona* and *Microcyclops* species were common in the site with high DO values. Above 69% of variation in the species abundance data was accounted for by the environmental variables measured. Monte Carlo permutation test indicated that all axes were significant. The main environmental variables (axis 1) were determined by DO, depth, flow velocity, BOD and alkalinity (Fig. **2**, Table **3**). The second environmental variable was associated mainly with factors that changed seasonally, as shown by strong correlations with temperature and flow velocity. The composition and seasonal occurrence of zooplankton recorded in the various stations during the period of the study is shown in Table **2**. Qualitatively, the fauna of each station was dominated by rotifers followed by cladocerans, copepods, and ostracods in that order. A combined total of 79 taxa were encountered. The rotifer fauna consisted of 49 species belonging to the orders, Plioma, Bdelloidea, and FloscularIacea. Station 1, had more representative taxa (78 species) in terms of diversity and abundance. The only species that was not recorded in this station was the bdelloid rotifer, *Philodinavus paradoxus*. Station 2 recorded very few representative taxa [22] in relatively low abundance. The zooplankton community was restricted to bdelloid rotifers, the cladoceran, *Moina micrura* and *Daphnanosoma excisum*. In contrast however,

Table 3. Pearson Correlation Between Zooplankton Density and Environmental Variables and Weighted Intraset Correlation with the Axes of Canonical Correspondence Analysis (CCA) in the Study Area

Environmental Variables	Total Zooplankton Density	Axis 1	Axis 2
Dissolved oxygen (mg/l)	0.96**	0.79**	0.54*
Water temperature (^{0}C)	0.29	-0.16	-0.66**
Water depth (m)	0.95**	0.93**	0.22
Flow velocity (m/s)	0.60*	-0.60*	-0.76**
BOD_5 (mg/l)	0.74**	-0.92**	-0.25
Conductivity (µS/m)	-0.72**	0.14	-0.18
Total alkalinity(mg/l)	0.48*	0.64*	0.34*

* Significantly different at p<0.05
** Significantly different at p<0.01

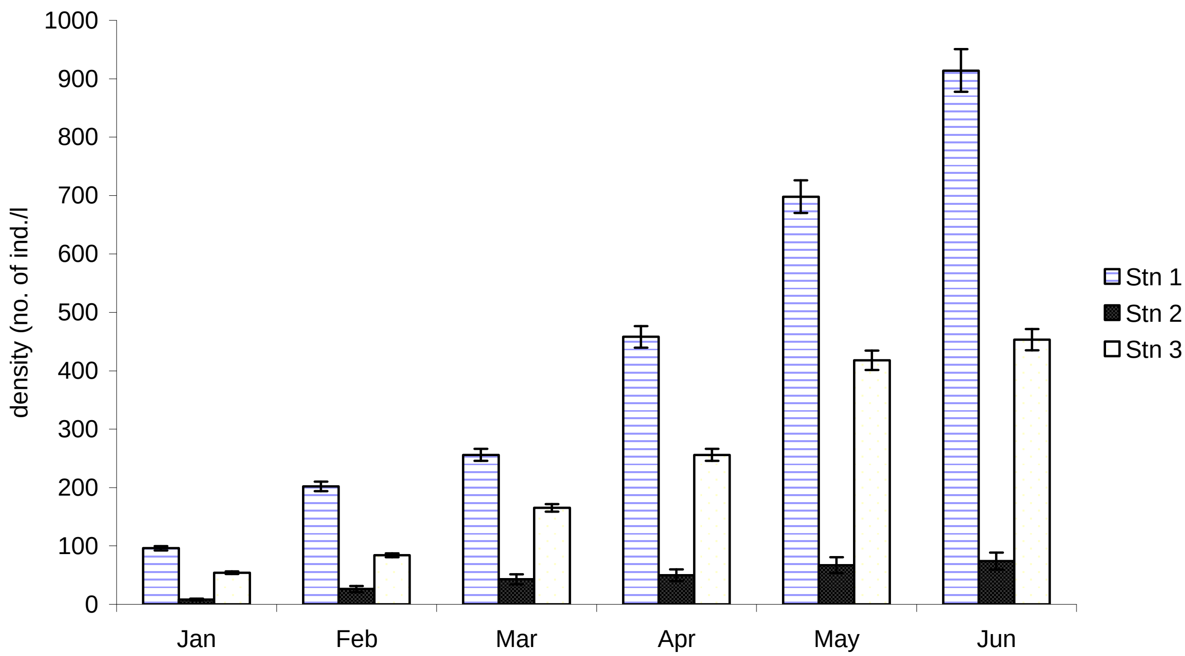

Fig. (3). Monthly abundance of zooplankton in the sampling stations of Orogodo River from January - June 2008.

station 3 recorded a total of 72 taxa. Generally, the bdelloid rotifers dominated the entire zooplankton abundance. The rotifer, *Rotaria tridens* was the most abundant species recorded in the study with a percentage contribution of 9% to the total zooplankton abundance. Copepods and cladocerans were well represented in stations 1 and 3 but only sporadically present in station 2 (the abattoir impacted site). Quantitatively, the rotifer, *Rotaria* species were the most abundant and preponderant species present in appreciable numbers in all the stations sampled. *Lecane*, *Monostyla* and *Trichocerca* species were the other dominant rotifer genera encountered, while *Chydorus* was the dominant cladoceran. Ostracods were poorly represented in the stream in terms of abundance and diversity. Only two genera, *Eucypris and Nebalia* were recorded sporadically in stations 1 and 3. Generally, most zooplankton species were recorded in the rainy season months (April- June) as compared to the dry season months (January – March). However, *Lecane unqulata*, *L. papuana* and *Trichocerca elongata* were only recorded in the dry season months. Total zooplankton abundance varied significantly (p<0.05) among months and inversely with depth suggesting strong seasonal effects. The minimum values were recorded n the dry season month of January while maximum values were recorded in the peak of the raining season (June). There was a progressive increase of abundance from January to June in all the stations examined and less evident abundance variation for station 2 between months (Fig. **3**).

Taxa Richness, Diversity, Evenness and Dominance Indices

A summary of the taxa richness, diversity, evenness and dominance indices is shown in Table **4**. Stations 1 and 3 recorded high taxa richness (*Margalef* index) and diversity index values but were low in station 2. Similarly stations 1

Table 4. Diversity, Evenness and Dominance Indices of Zooplankton at the Different Sampling Stations of Orogodo River

	Station 1	Station 2	Station 3
No. of taxa	78	22	72
Number of individuals/l	2624	268	1430
Taxa Richness (Margalef index)	9.78	3.76	9.77
Shannon-wiener diversity	1.63[a]	1.19[b]	1.64[a]
Simpson dominance index	0.04	0.08	0.03
Evenness	0.86	0.78	0.89

Note. Diversity values with the same letter superscript indicate that these values were not significant among the sampling stations (*Hutcheson* T-test for Comparison).

and 3 recorded higher evenness values. Simpson's dominance index values was high in station 2 compared to the other two stations examined. Hutcheson T-test for comparison between the stations revealed that the diversity between stations 1 & 2 and stations 2 & 3 were significantly different whereas the diversity between stations 1 and 3 was not significantly different.

DISCUSSION

Change in water depth was mainly due to increasing successive rainfall all throughout the months. There was a significant difference in the water depth at the different stations and this can be ascribed to the morphometry of the river bed which is uneven. The mean air and water temperature obtained are typical of tropical rivers [11]. The gradual increase in the flow velocity attained particularly in stations [2, 3] during the wet season can be attributed to high flood from precipitation and increased runoff. [15] opined that since most of the physical parameters are influenced by rainfall, rainfall regime is therefore considered a dominant factor affecting zooplankton dynamics in tropical waters. The level of nitrates was higher in station 2 and 3 indicating a substantial amount of organic input coming from effluent discharge. BOD values indicate the extent of organic pollution in aquatic system which affects the water quality [30]. Based on BOD classification, station 1 and 3 are not polluted since they have BOD ranges 2.22-2.74 and 2.58- 3.00mg/l respectively but for station 2 it was moderately polluted since it recorded a value of 5.56mg/l. Most of the zooplankton encountered in the study area appears to be normal inhabitants of natural lakes, ponds, streams and artificial impoundments in the tropics and subtropics [10, 15, 24, 26, 29], oriental regions [31] and in India [32]. The rotifers constitute the largest group of zooplankton recorded in all the sites. The ability of rotifers to undergo vertical migration, which minimizes competition through niche exploitation and food utilization, could be probably the reason for their dominance. Also, rotifer richness in the stream probably could be due to high microhabitat diversity especially at stations 1 and 3. The dominance of rotifers in Nigerian aquatic ecosystems has been documented by several authors [17, 24, 26, 33-36]. The high population abundance of rotifer may also be attributed to their parthenogenetic reproductive pattern and short developmental rates under favourable conditions in most fresh water systems [37]. Crustacean zooplankton communities in the present study were typified by the dominance of Chydoridae in terms of species richness and diversity. This finding is consistent with [38-40] in various tropical freshwater systems. Our CCA indicated that zooplankton organisms responded to a number of physicochemical variables. Dissolved oxygen, BOD, flow velocity and conductivity have been found to be important in other tropical studies [14, 16, 29, 33]. The discharge of organic wastes directly into station 2 significantly reduced the dissolved oxygen in spite of the high flow velocity. Other components of the organic wastes like blood and animal faeces increased nitrate levels which in turn increased the biochemical oxygen demand values of the site. In addition, the biodegradation of the organic materials exerted oxygen tension in the water and increased the BOD [18]. The increased level of conductivity, nitrates and few other parameters are product of decomposition which was active in station 2, while most of these impacted parameters easily recovered to their original state downstream (station 3). The abundance of zooplankton in the study area is a reflection of the stream order (1o) characterized by wide width and slow flow velocity in Station 1 and relatively fast velocity in station 3 which permitted the development of stable zooplankton community. The relatively long period of sampling (covering 3 months of dry season and 3 months of rainy season) may partly account for the rich zooplankton recorded. This is typical of all cases of organically polluted lotic water bodies [41]. Once the natural community of invertebrates and other organisms can be predicted, deviations due to organic and anthropogenic activities can be more easily accused. In our study, zooplankton abundance increased with increase in the amount of rainfall. This may be due to the ability of rains to bring in allochthonous nutrients from the drainage basin as well as the mixing of autochthonous materialsthat will accelerate primary production and as a consequence, zooplankton production and abundance [29, 42]. This is however in contrast with the findings of [34] in Benin River and [40] in coastal western rivers of Nigeria reported negative correlation between rainfall and zooplankton abundance.

However in consonance with this investigation, [15, 43] reported rotifer maxima at the peak period of water level. They attributed the rainy season maxima to the dilution effect of salinity. The responses of zooplankton to organic effluent pollution varied greatly among families and individual species. The Rotifer families; Asplanchnidae, Branchionidae, Colurellidae, Dicranphoridae, Euchlanchinidae, Gastropididae, Adinetidae, Notominatidae, Testudinellidae the crustacean families; Diaptomidae, Chydoridae, Bosminidae, Sisidae and the ostracods disappeared completely in station 2. Sensitive species normally disappears as the water becomes polluted while tolerant ones survive the pollution stress and readily recovers downstream of the point of discharge. It has been observed that different species in the same genus may react differently to pollution [44] and this was also corroborated in this investigation. The result of this study suggest that the rotifers, *Itura viridis*, some Lecanids, Habrotrochids, the bdelloid, *Philodinavus paradoxus*, philodinids, Trichocercids and Trochosphaeridae and the crustacean; *Thermocyclops neglectus*, *Moina micrura* and *Diaphnosoma excisum* were less sensitive to nvironmental perturbation. The unusual tolerance of the philodinids to environmental stress imposed by organic pollution has long been documented [16, 45]. However the absence of a particular species or group from a river may not be indicative of pollution because not all reaches in a water body are suitable for all invertebrates [46, 47]. Pearson's correlation coefficient indicated that several environmental variables exert a considerable influence on the zooplankton abundance especially dissolved oxygen, temperature, total alkalinity, total nitrogen, phosphate and pH. Consistent with our findings, [4] reported significant multiple correlations between plankton abundance and several physical and chemical variables in their study. Our study confirms the influence of these abiotic factors on zooplankton population.

CONCLUSIONS

This study revealed that zooplankton communities responded to changes in water quality and this was seen in changes in composition of species assemblages and abundance at the various stations. Abattoir wastes, domestic wastes and residential urban settlements around Agbor area, were suspected to negatively influence environmental conditions in Orogodo River thus adversely affecting the zooplankton composition structure at station 2. The high zooplankton abundance and diversity in stations 1 and 3 was due to the high microhabitat diversity. Overall, our 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 biomonitoring of the river 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 the influence on water quality.

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