CHARACTERIZATION OF THE ZOOPLANKTON COMMUNITY STRUCTURE OF POLLUTED ERUVBI STREAM, BENIN CITY, NIGERIA

IMOOBE, T. O. T.
Department of Animal and Environmental Biology, University of Benin,
P.M.B. 1154, Benin City, Nigeria.
timoobe@yahoo.co.uk +2348023322605

ABSTRACT
The zooplankton community of a polluted section of Eruvbi stream was analyzed emphasizing composition and abundance of organisms. Samples were collected monthly between March and August, 2009 from three stations in the system: upstream, discharge point, and downstream. Margalef's species richness index (D), Shannon-Weiner index of general diversity (H') and Evenness index (E) measures of diversity were used to describe the zooplankton community. Forty species made up of nine species of cladocerans, nine species of copepods and their developing stages and 22 species of rotifers were encountered during the study period with rotifers being the dominant taxa at all stations. The species richness of the zooplankton communities, at the polluted station 2 (discharge point) was however less than what obtained at the upstream and downstream stations. The most frequent zooplankton species in the polluted part of the stream were the rotifers Brachionus calyciflorus, Brachionus falcatus, Brachionus caudatus, and Testudinella patina. Regarding relative abundance, there was a common trend where rotifers were dominant in the three sampling stations, followed by copepods and cladocerans. All of these zooplankton groups showed lowest abundance in station 2 (discharge point).
Keywords: bio-indicators, primary consumers, rotifers, polluted stream

INTRODUCTION

Zooplankton species inhabit all freshwater habitats of the world, including industrial and municipal wastewaters (Mukhopadhyay *et al*., 2007), and they play a very important role in the food chain as primary consumers and also serving as food for the higher trophic levels (Qasim, 1977). However, because the zooplankton are so closely linked to the environment and they tend to respond to changes more rapidly than do larger aquatic animals such as fish, they have proved valuable indicators of apparent and subtle alterations in the quality of aquatic environments (MBO, 2007). They indicate the effect of low levels of chemical pollution in a water body and are good indicators of pollution in biological monitoring (Rutherford *et al.,* 1999; Soberon *et al.,* 2000; MBO, 2007). Zooplankton are not only useful as bio-indicators to help us detect pollution load, but are also helpful in ameliorating polluted waters (Mukhopadhyay *et al*., 2007).

Due to the various types of waste disposal, the biota of the stream water are subjected to environmental stresses which may eventually cause alteration in the structure of natural ecosystem. As a result, the possible biological effect may be deleterious, beneficial or neutral to specific organisms, to a population or to a community. The abundance and diversity of zooplankton vary according to limnological features and trophic state (Jeppesen *et al*., 2002; Imoobe and Adeyinka, 2010). It is also especially influenced by climatic, physical and chemical parameters, bio-geographical factors, and biotic interactions, therefore some species could be found in a wide range of environmental conditions, while others are limited by many physical and chemical factors including pollution (Neves *et al*., 2003). The majority of studies about the composition of zooplankton communities have focused on rotifers, cladocerans, and copepods (Green, 1960; Kudari *et al*., 2005; Kumari *et al*., 2008; Imoobe and Adeyinka, 2010). Calanoid copepods are generally abundant in oligotrophic environments, while rotifers, cyclopoids and cladocerans dominate in eutrophic waters and in highly polluted environment (José De Paggi, 1976; Margalef, 1983; Wetzel, 2001).

In Nigeria, investigation of the response of zooplankton to pollution is not common (Imoobe *et al*., 2008). The Eruvbi stream in Benin City, Nigeria, receives effluents from a Soft Drink industry, 7up Bottling Company Plc. Effluents from similar industries are known to be rich in organic and inorganic substances capable of producing adverse effects on the physical, chemical and biotic components of the environment and either directly or indirectly on human health (Mason, 1981; Ogbeibu and Ezeunara, 2002; Ogbonnaya, 2008).

Some of the documented information on water quality studies on Eruvbi stream and Ikpoba River are those of Olomukoro (1983), Ogbeibu and Edutie

(2002) and Imoobe and Okoye (2011). While, Olomukoro (1983) investigated the physico-chemical parameters and macrobenthic fauna of the stream, Imoobe and Okoye (2011) studied the impact effluent discharged into Eruvbi stream had on water quality and concluded that water quality at the discharge point and downstream had deteriorated due to the effluent inflow. They stated that the low nutrient levels of the stream were fundamental to the river's oligotrophic status. However, water temperature, turbidity, alkalinity, hardness, calcium and magnesium were found to be significantly higher at a Soft Drink production industry effluent discharge point. Compared with Federal Environmental Protection Agency (FEPA 1991) limit for discharge into Nigeria surface waters and WHO (2006) guidelines, turbidity at the discharge point and downstream were found to exceed the maximum allowable limit (5 NTU). Dissolved oxygen levels were also lower than the minimum allowable limit (5 mg/L) for aquatic life. This physico-chemical regime gave an indication of the deteriorating water quality of the stream at the discharge point and downstream due to effluent inflow. Ogbeibu and Edutie (2002) observed a significant spatial variation in the physico-chemical conditions and a reduction in rotifer composition and density at the effluent discharge point in Ikpoba River, following the discharge of brewery effluent into the river. The present study is therefore the first attempt to characterize the structure of the zooplankton community and to investigate spatial fluctuations in response to the changing physico-chemical environment in a normally oligotrophic Eruvbi stream receiving effluent from a Soft Drink industry.

STUDY AREA

Eruvbi stream is a low altitude (265 m above sea level) heterotrophic stream which is located about 15 km north of Benin City, Edo State, Southern Nigeria (Lat. 6.5º N; Long. 5.8º E). This spring-fed stream is a small tributary of the Ikpoba River, flowing in a southeasterly direction (Fig. 1). It is approximately 5 km long and according to Horton (1945) classification, it should be designated as a first order (1º) stream. This region consists of secondary rainforest, which has been greatly subjected to deforestation and other human activities. The dominant vegetation comprises rubber trees (*Hevea brasiliensis*), bamboo (*Bambusa bambusa*), and palm trees (*Elaeis guineensis*) with epiphytic ferns growing on them. Typically, the area had the characteristic features of the humid tropical wet and dry climate governed primarily by rainfall. There are two distinct seasons, rainy season covers March to October and the dry season begins in November and terminates in April. A summary of the physical and chemical conditions of the study stations as reported in Imoobe and Okoye (2011) and presented in Table 1.

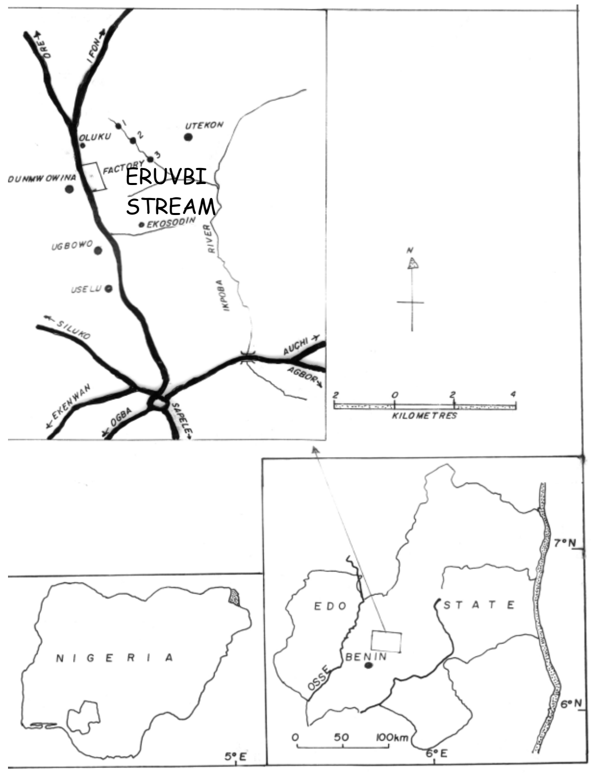


Fig 1: Map of the study area (Maps of Nigeria and Edo State inset)

Table 1: Mean (± SD) values of some physical and chemical conditions at the three sampling stations in Eruvbi stream in March to August 2009 (minimum and maximum values in parentheses) (Imoobe and Okoye, 2011)

Environmental Parameter	Station 1	Sampling Stations Station 2	Station 3	FEPA (1991) Limit	WHO (2006) Limit	P-value
Water Temperature (°C)	22.67±0.63[b] (20-24)	26.66±0.99[a] (25 - 31)	23.13±0.67[b] (22 - 26)	30	27	P<0.01
Total Dissolved Solids (mg/l)	11.0±0.90 (8.7-13.3)	57.9±9.44 (33.6 -82.2)	31.1±6.90 (13.3 - 48.9)	2000	1000	***P>0.05***
Turbidity (NTU)	4.13±1.29[b] (0 - 8.4)	88.92±26.47[a] (3.5 - 145.6)	12.65±3.86[b] (0.4 - 22.4)	-	5	P<0.01
pH	6.48±0.69[b] (6.3 -6.7)	6.85±0.79[a] (6.6 - 7.2)	6.75±0.73[a] (6.5 -7.0)	6 - 9	6.5-9	P<0.01
Conductivity (µS/cm)	14.50±0.91(10.7-16.5)	155.23±73.51 (43 - 518)	41.08±8.37 (21.2 - 68.7)	1000	-	***P>0.05***
Dissolved Oxygen (mg/l)	3.26±0.46 (2.3 -5.2)	3.18±0.44 (2.2 - 4.8)	3.27±0.44 (2.5 - 5.4)	4-6	5	***P>0.05***
BOD_5 (mg/l)	16.13±5.52 (1.8 -31.2)	18.05±6.25 (0.7 - 35.8)	18.47±5.41 (0.6 - 29.9)	30	28-30	***P>0.05***
Total Alkalinity (mg/l)	18.27±2.70[b] (12.2 - 30.3)	149.52±51.30[a] (61 - 396.5)	34.57±6.23[b] (18.3 - 54.9)	100		P<0.05
Chloride (mg/l)	21.00±0.96 (18.5 - 24.8)	24.36±19.19 (18.1 - 32)	23.53±2.58 (19.2 - 36.2)	600	400	***P>0.05***
Hardness (mg/l)	5.50±0.22[b] (5 -6)	14.67±1.52a (12 - 22)	6.67±0.33[b] (5 - 6)	100		P<0.001
Calcium (mg/l)	1.27±0.19[b] (0.8 -2.0)	3.14±0.86[a] (1.2 - 7.2)	1.27±0.16[b] (0.8 - 1.6)	200	-	P<0.05
Magnesium (mg/l)	0.65±0.05[b] (0.5 - 0.7)	1.66±0.18[a] (1.0 - 2.2)	0.85±0.10[b] (0.5 - 1.2)	200		P<0.001
Nitrate (mg/l)	0.42±0.06 (0.2 -0.6)	0.67±0.15 (0.3 - 1.3)	0.47±0.08 (0.2 - 0.8)	20	50	***P>0.05***

Note: Similar letters indicate means that are not significantly different P<0.05 = Show significant difference
P<0.01, P<0.001 = Show highly significant difference P>0.05 = Show no significant difference

MATERIALS AND METHODS

Sampling Stations

Three sampling stations were selected. Station 1 was located upstream with a width exceeding 5 m; at this point the stream was fast flowing. The substratum was muddy and relatively less disturbed than the other two stations. Dominant macrophytes were *Nymphaea lotus* and *Cyclosorus* sp. There was no effluent input in this station and human activities such as swimming and laundering were noticed during the study, and the colour of the water was clear.

Station 2, the discharge point was located 1 km downstream of station 1, consisting of pool and riffle areas. It was the contact point of the Soft Drink effluent with the stream water before it flowed down to station 3 then into Ikpoba River. The substratum is coarsely sandy with pebbles. The south bank is muddy and the stream width is less than 1 m at this site. Surface runoff was heavy at this station during rains and current velocity was relatively fast. *Sagittaria* sp and *Cyclosorus* sp were dominant macrophytes, especially at the upstream section of the main channel. The colour of the water changed from clear water to muddy water due to the mixing of the effluent with the water.

Station 3 was located about 500 m downstream of station 2, consisting of a shallow riffle, less than 2 m wide, and flows downstream in to Ikpoba River. Substratum was coarse sand, except for few patches of clay. This site gets heavily silted during the rains and the current velocity was very high. Dominant macrophytes were *Nymphaea lotus* and *Sagittaria* sp.

Sampling and analysis

Sampling stations were sampled monthly between March and August, 2009 for zooplankton. Sampling was carried out between 0800 and 1100 h starting from station 1, 2, and then 3.

Quantitative samples were collected by filtering 100 litres of water fetched with a bucket through a 55 µm mesh hydrobios Plankton net. Samples were immediately preserved in 4% formaldehyde solution. In the laboratory, specimens were sorted and dissected where necessary under a binocular dissecting microscope (American Optical Corporation, Model 570), while counting and identifications were done with an Olympus Vanox Research Microscope (Model 230485). Identification of specimens was carried out at the University of Benin, Zooplankton laboratory using relevant literature (Smirnov, 1974; Van de Velde, 1984; Gabriel, 1986; Jeje and Fernando, 1986; Jeje, 1988; Boxshall and Braide, 1991 and Imoobe, 1997).

The relative abundance of the specimens was estimated by direct count. Each sample was concentrated to 10 ml and from this; 1 ml of sample was taken and all individual taxa present were counted. Three measures of diversity were used to describe the zooplankton community in the sampling stations in the stream. These indices are Margalef's species richness index (D), Shannon-Weiner index of general diversity (H') and Evenness index (E). The BASIC programme SPDIVERS for diversity indices were used for diversity while inter-station comparison was carried out to test for significant differences in the abundance of the zooplankton using one-way analysis of variance (ANOVA) (Zar 1984).

Analysis of the definition of the frequency of occurrence of species in the samples was based on the percentages suggested by Dajoz (1973); 0 to 25% - occasional species; > 25 to 50% - accessory species and > 50% - constant species. From the abundance data of species with a constant frequency in the system, it was possible to test the hypothesis that zooplankton would exhibit quantitative differences among sampling stations.

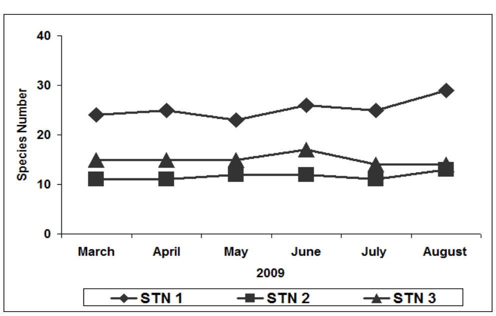
RESULTS

Zooplankton community structure and diversity

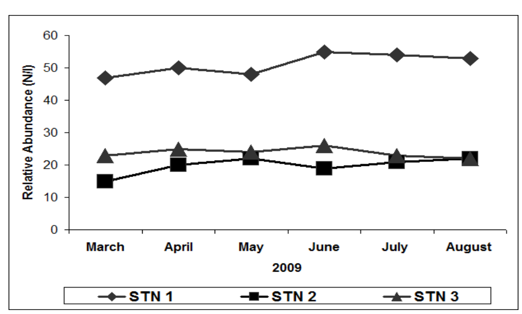
The zooplankton community in Eruvbi stream was composed of 40 species made up of nine species of cladocerans, nine species of copepods and their developing stages and 22 species of rotifers (Table 2). The number of species observed in stations 1, 2 and 3 were 39, 22 and 28 respectively, with rotifers being the dominant taxa at all stations. There was low species diversity and abundance of zooplankton in the polluted station 2. Greatest taxa richness was observed in station 1, an average of 23 to 29 were found in each sample from the unpolluted station 1 and the corresponding number in samples from the polluted station was 11 and 13 species (Fig. 2). Spatial variations in diversity, evenness and richness indices of community structure are also given in Table 2.The species richness value was lowest for the polluted sampling station 2 and highest for the stabilized station 1. Margalef's richness index (*D*), which considers both abundance and species numbers, varied between 4.459 and 6.6701. The highest *D* value of 6.6701 was calculated at Station 1, followed by Station 3 (5. 496); the least diverse being station 2 (4.459) (Table 2). Shannon–Wiener species diversity index (*H*), based mainly on the proportional species abundance, was almost similar for all the three stations, *viz.,* Station 1 (3.4519), Station 2 (2.9223) and Station 3 (2.2335). At the most stressful station 2, *H* value was slightly higher than Station 3, though only twenty-two species occurred at former station. Evenness index (*E*) of zooplankton was high across the three stations, however, it was maximum in station 3 (0.9704) and minimum at station 1(0.9422). The low values of Margalef's index and Shannon-Wiener index at station 2 indicate low diversity of the zooplankton.

Table 2: Species Composition and diversity indices of the zooplankton community in Eruvbi stream between March and August 2009

Species Composition	STATION 1 (Upstream)	STATION 2 (Discharge Point)	STATION 3 (Downstream)
Cladocera			
Alona rectangular	+	-	+
Alona eximia	+	+	+
Chydorus sphaericus	+	-	-
Ilyocryptus spinifer	+	-	-
Kurzia longirostris	+	+	+
Kurzia latissima	+	+	+
Camptocercus lilljeborgi	+	+	+
Macrothrix spinosa	+	-	+
Moina micrura	+	-	+
Copepoda (Cyclopoida)			
Ectocyclops phaleratus	+	-	-
Eucyclops agiloides	+	+	+
Halicyclops korodiensis	+	-	-
Mesocyclops leukarti	+	+	+
Microcyclops varicans	+	+	+
Thermocyclops neglectus	+	+	+
Copepodids	+	+	+
Nauplii	+	+	+
Copepoda (Calanoida)			
Thermodiaptomus galebi	+	+	+
Tropodiaptomus incognitus	+	-	+
Copepoda (Harpacticoida)			
Bryocamptus minutes	+	+	+
Rotifera			
Ascomorpha ovalis	+	-	-
Asplanchna priodonta	+	-	+
Brachionus diversicornis	+	+	+
Brachionus angularis	+	+	+
Brachionus calyciflorus	+	+	+
Brachionus caudatus	+	+	+
Brachionus falcatus	+	+	+
Brachionus patulus	+	+	+
Collotheca sp	+	-	-
Conochilus dossuarius	+	-	-
Conochilus unicornis	+	-	-
Euchlanis dilatata	+	-	-
Kellicottia longispina	+	-	+
Keratella cochlearis cochlearis	+	+	+
Keratella longispina	-	+	+
Lecane bulla	+	-	-
Polyarthra remata	+	-	+
Proales decipiens	+	+	+
Synchaeta longipes	+	-	-
Trichocerca cylindrica chattoni	+	+	-
Trichocerca similis	+	+	+
Testudinella patina	+	+	+
Diversity			
Species Richness	39	22	28
Margalef's Index	6.6701	4.459	5.496
Shannon-Weiner's Index	3.4519	2.9223	3.2335
Evenness Index	0.9422	0.9487	0.9704



(a)



(b)

Fig 2: Spatial and temporal variation in the species number (a) and relative abundance (b) of total zooplankton in Eruvbi stream

Zooplankton Abundance

Among the crustacean zooplankton (cladocerans and copepods), except *Alona rectangula, Chydorus sphaericus, Ilyocryptus spinifer, Macrothrix spinosa, Moina micrura, Ectocyclops phaleratus, Halicyclops korodiensis and Tropodiaptomus incognitus* that preferred unpolluted station 1 all others were found in all the three sampling stations (Table 2). All stages of copepods (nauplii, copepodites, and adults) were found during the study in all the stations.

Crustacean species occurred only occasionally in polluted station 2, but in the other stations, their population densities were relatively higher. Among cladocerans, when absolute abundance is considered, *Kurzia longirostris, Kurzia latissima, Camptocercus lilljeborgi and Alona eximia* were the dominant species in stations 1 and 3 while only *Kurzia longirostris* was of significant population in station 2 during the study period (Fig. 3). At station 1 *Kurzia longirostris* reached a maximum mean density of 26 individuals/l while the other dominant species recorded a maximum mean density of six to eight individuals/l. Density of cladocerans was much lower at station 2 in comparison with station 1. *Thermodiaptomus galebi*, *Mesocyclops leukarti, Microcyclops varicans, Bryocamptus minutus, Eucyclops agiloides, Ectocyclops phaleratus* and *Tropodiaptomus incognitus* were the dominant copepods in station 1 with between six and 24 individuals/l. *Mesocyclops leukarti, Thermodiaptomus galebi* and *Thermocyclops neglectus* with between six to nine individuals/l were also relatively abundant in station 3 (Fig. 3) while *Thermodiaptomus galebi* and *Bryocamptus minutus* were the only dominant species in the polluted station 2.

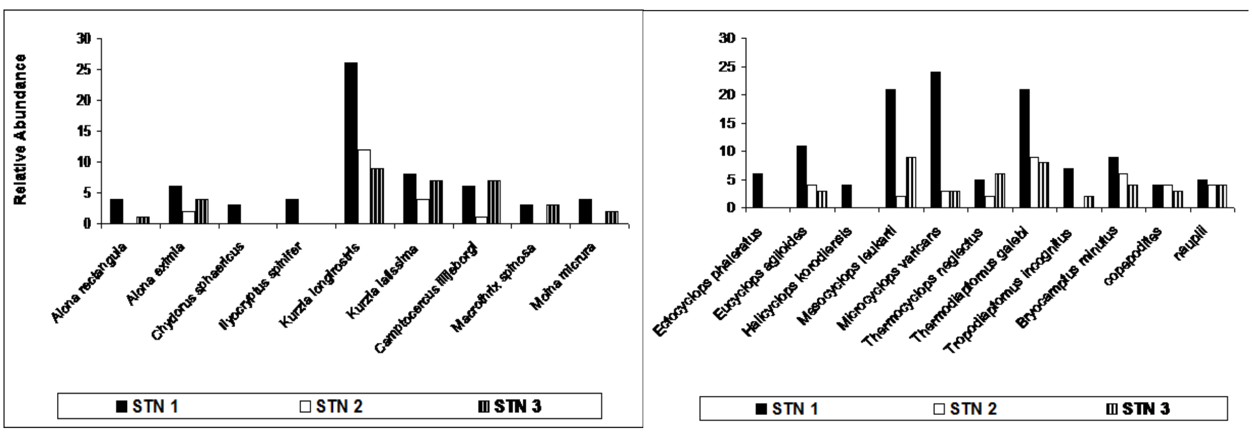


Fig 3: Spatial variation in the relative abundance of crustacean zooplankton in Eruvbi stream

Among the rotifers, *Ascomorpha ovalis, Asplanchna priodonta, Collotheca sp, Conochilus dossuarius, Conochilus unicornis, Euchlanis dilatata, Kellicottia longispina, Lecane bulla, Polyarthra remata, Synchaeta longipes and Trichocerca cylindrica chattoni* preferred unpolluted station 1 as they were absent from station 2 and some of them from station 3 (Fig. 4). However, all species of *Brachionus*, *Keratella cochlearis cochlearis, Proales decipiens, Trichocerca similis* and *Testudinella patina* were recorded at all the sampling stations including the discharge point of the effluent (Station 2) (Fig. 4). Twelve rotifer species were fairly abundant at station 1 and only five and four at stations 2 and 3 respectively during the study period, with peaks of mean abundance that varied between six and 10 individuals/l, however, the mean density was much lower in station 2 in comparison with the other stations.

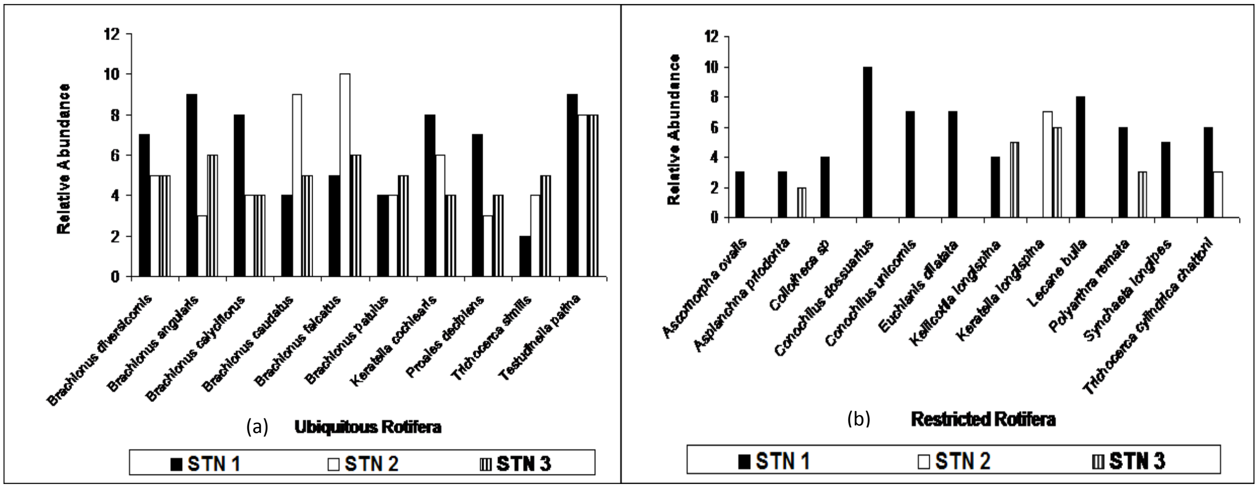


Fig 4: Spatial variation in the relative abundance of (a) ubiquitous and (b) restricted rotifer species in Eruvbi stream

The most frequent zooplankton species in the polluted part of the stream were the rotifers *Brachionus calyciflorus, Brachionus falcatus, Brachionus caudatus,* and *Testudinella patina* (Table 3). Species with higher frequencies and densities in the other stations were *Kurzia longirostris and Kurzia latissima* (cladoceran), *Thermodiaptomus galebi, Mesocyclops leukarti, Microcyclops varicans, Bryocamptus minutus* and *Eucyclops agiloides (copepods)* and *Conochilus dossuarius, Keratella cochlearis cochlearis, Brachionus angularis* and *Euchlanis dilatata* (rotifers). Excluding the brachionids and *Testudinella patina*, the frequencies and abundance of all rotifers species were lower in polluted station 2 than in unpolluted station 1 and slightly polluted station 3 (Table 3). Regarding relative abundance, there was a common trend where rotifers were dominant in the three sampling stations, followed by copepods and cladocerans. All of these zooplankton groups showed lowest abundance in station 2 (Fig. 5).

Table 3: Percentage frequencies and relative abundance of some common species of zooplankton in Eruvbi stream

	STATION 1 (Upstream)		STATION 2 (Discharge Point)		STATION 3 (Downstream)	
CLADOCERA	% Freq	Relative Abundance	% Freq	Relative Abundance	% Freq	Relative Abundance
Kurzia longirostris	100	26	67	12	67	9
Kurzia latissima	83	8	50	4	67	7
Alona eximia	67	6	33	2	50	4
Camptocercus lilljeborgi	67	6	17	1	83	7
Moina micrura	50	4	0	0	33	2
Alona rectangular	50	4	0	0	17	1
Ilyocryptus spinifer	50	4	0	0	0	0
COPEPODA						
Bryocamptus minutes	83	9	67	6	50	4
Thermodiaptomus galebi	100	21	50	9	50	8
Eucyclops agiloides	83	11	50	4	33	3
Nauplii	67	5	50	4	67	4
Mesocyclops leukarti	100	21	33	2	67	9
Microcyclops varicans	100	24	33	3	33	3
Thermocyclops neglectus	50	5	33	2	67	6
Ectocyclops phaleratus	67	6	0	0	0	0
Rotifera						
Testudinella patina	83	9	83	8	67	8
Brachionus calyciflorus	67	8	83	4	67	4
Brachionus falcatus	67	5	83	10	67	6
Brachionus caudatus	50	4	83	9	50	5
Keratella cochlearis cochlearis	83	8	50	6	50	4
Trichocerca similis	17	2	50	4	50	5
Keratella longispina	0	4	50	0	50	5
Brachionus angularis	83	9	33	3	67	6
Proales decipiens	67	7	33	3	50	4
Conochilus dossuarius	100	10	0	0	0	0
Euchlanis dilatata	83	7	0	0	0	0
Polyarthra remata	67	6	0	0	33	3
Lecane bulla	67	8	0	0	0	0
Collotheca sp	50	4	0	0	0	0
Conochilus unicornis	50	7	0	0	0	0
Synchaeta longipes	50	5	0	0	0	0

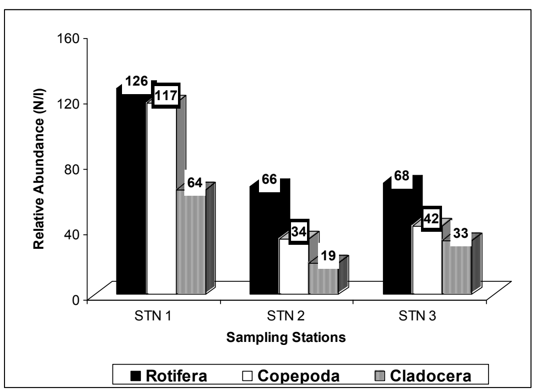


Fig 5: Spatial variation in the relative abundance of rotifers, copepods and cladocerans in Eruvbi stream

DISCUSSION

The taxonomic dominance of Rotifera as reported in this study has been reported in several other water bodies. This pattern is common in tropical and subtropical fresh waters, whether in lakes, ponds, reservoirs, rivers or streams (Green, 1960; Jeje and Fernando, 1986; Cavlli *et al*., 2001; Nogueira, 2001; Sampaio *et al.,* 2002; Neves *et al.,* 2003; Kudari *et al*., 2005; Imoobe and Akoma, 2008, 2009; Arimoro and Oganah, 2010). The species composition of zooplankton with dominance of rotifers was also observed by Olaifa and Leilei (2007) in Ekole River. Mathivanan *et al*., (2007) also noticed dominance of rotifers in Cauvery River, with the predominant genus usually being *Brachionus*, *Keratella* or *Lecane*.

Rotifers, in general, feed on detrital materials, bacteria and small algae and are capable of filtering one thousand times their own body volume in one hour (Brönmark and Hansson, 1998). In addition to the availability of food, the numerical abundance of rotifers in aquatic environments has been attributed to their parthenogenetic reproductive pattern and that they are r-strategists organisms, with a short life-cycle under favourable conditions, and a wide tolerance to fluctuations of environmental factors (Herzig, 1983; Pourriot *et al.,* 1997; Wetzel, 2001; Neves *et al*., 2003).

All the 22 rotifer species recorded are known for natural environments, however, the dominance of the genus *Brachionus* in the polluted section of the stream is characteristic of a polluted environment (Kumari *et al*., 2008, Sampaio *et al*., 2002) and the species of *Brachionus* found in this study show a wide range of tolerance to pollutants. The presence of pollution indicator species as *Brachionus* and *Keratella* along with clean water indicator species like *Mesocyclops* and nauplius indicates a good water quality with presence of some organic pollution (Kumari *et al*., 2008). The overall presence of *Brachionus caudatus* and *Keratella cochlearis* confirms that the water is slightly polluted. Such results were also reported by Dar *et al*. (2009) and Kundannagar and Zutshi (1985), these species thus indicate changes in the conditions of the environment.

Copepods and cladocerans are organisms broadly represented in aquatic ecosystems and constitute an important portion of the biomass in the zooplankton community of freshwater environment (Margalef, 1983; Wetzel, 2001). The species of crustacean zooplankton found in the present work have been reported as abundant in natural environments (Sendacz, 1984). The presence of juveniles is of great importance for the structure of zooplankton communities since different young forms and adult stages occupy different trophic niches (Neves *et al*., 2003). The availability of food would also contribute to the differential abundance of juveniles and adults, since nauplius, copepodite, and adult stages feed on different particle sizes.

The response of crustacean zooplankton to effluent pollution varied greatly among groups and individual species even in the same genus react quite differently to pollution (Hynes, 1960). Sensitive species normally disappear as the water becomes polluted, while tolerant ones survive the pollution stress and readily recovers downstream of the point of discharge. The results of this study suggest that *Alona rectangula, Chydorus sphaericus, Ilyocryptus spinifer, Macrothrix spinosa, Moina micrura, Ectocyclops phaleratus, Halicyclops korodiensis and Tropodiaptomus incognitus* are sensitive to the effluent discharge, while *Kurzia longirostris, Thermodiaptomus galebi* and *Bryocamptus minutus* were less sensitive.

Generally, the low density of zooplankton in Eruvbi stream could possibly be due to their inability to develop a stable community necessary for reproduction success in a lotic environment (Dejen *et al*., 2004*)*. The extremely low zooplankton densities of 15 – 55 individual/L at the sampling sites recorded during the study period is within the range found by Ibrahim (2009) who reported zooplankton densities of between 0.00 – 64.48 Org/L in Challawa river, Kano, a river that similarly receives raw industrial effluent, primarily from food, textile and tannery industries. This is an indication that the discharge of untreated effluent into the stream could have caused pollution in a localized state at the effluent inflow site and thus lowered the population. Therefore, the lower diversity and population of the zooplankton recorded from the industrial effluent discharge site is a clear indication of the presence of pollution that resulted in high turbidity level and high suspended material load among other factors in the water. This is in agreement with earlier studies (Ogbeibu and Edutie 2002) on the impact of brewery effluent on the water quality and rotifers of Ikpoba River where low faunal diversity was experienced in the effluent discharge point throughout the duration of sampling. Nwankwo (1998) also reported that low species richness and diversity in water body may be due to turbid effluents and high suspended material load.

CONCLUSION

Rotifers, cladocerans and copepods were present in the zooplankton community of Eruvbi stream during the study period, and were represented by species characteristic of both clean and polluted water environments. Eruvbi stream had a low diversity of zooplankton species with relatively low densities perhaps due to their inability to develop a stable community in the lotic environment. However, the low diversity of the zooplankton recorded from the industrial effluent discharge site is a clear indication of pollution. It is concluded from this study that the plankton population of Eruvbi stream is highly influenced by the discharge of industrial effluents. The shift in the planktonic community structure and dominance of pollution tolerant forms at discharge zone indicated deterioration of water quality in this stretch of the river. Consequently, government should ensure that industries adhere strictly to the set guidelines for discharging their wastes into the environment.

REFERENCES

Arimoro, F. O. and Oganah, A. O. (2010). Zooplankton Community Responses in a Perturbed Tropical Stream in the Niger Delta, Nigeria. *The Open Environmental & Biological Monitoring Journal,* 3: 1-11.

Boxshall, G. A and Braide, E.I (1991). The freshwater cyclopoid copepods of Nigeria with an illustrated key to all species. *Bull. Br. Mus. Nat.Hist. (ZOOL).* (2), 185-212.

Brönmark, C., Hansson, L. A. (1998). *The biology of lakes and ponds*. 1998. Oxford University Press, Oxford. 216pp.

Cavlli, L., A. Miquelis and Chappaz, R. (2001). Combined effects of environmental factors and predatory-prey interactions on zooplankton assemblages in five high alpine lakes. *Hydrobiologia* (455), 127- 135.

Dajoz, R (1973). Ecologia geral. Vozes/Edusp, São Paulo. 472pp.

Dar I.A. , Rather H.A. and Dar M.A. (2009). Dynamics of Zooplankton in Relation to Physico-chemical Factors. *Our Nature 7:* 168-176.

Dejen, E., Vijverberg, J., Nagelkerke, L. A. J. and Sibbing, F. A. (2004): Temporal and Spatial Distribution of Microcrustacean Zooplankton in Relation to Turbidity and Other Environmental Factors in Large Tropical Lake (L. Tana, Ethiopia). *Hydrobiologia* 513:39– 49.

Federal Environmental Protection Agency (FEPA) (1991). Guideline and Standard for Environmental Pollution Control in Nigeria. FG Press 238pp.

Gabriel, C. (1986). Copepoda of Warri River. Nigeria. Ph.D thesis. University of Benin .Benin City. Nigeria. 200pp.

Green, J. (1960). Zooplankton of the river Sokoto. The Rotifera. *Proc. Zool. Soc. Lond.* 135: 491-523.

Herzig, A. (1983). Comparative studies on the relationship between temperature and duration of embryonic development of rotifers. *Hydrobiol.* 104: 237-246.

Horton, R.E. (1945). Erosional Development of Streams and their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. *Bulletin of the Geological Society of America* 56.

Hynes, H.B.N. (1960). *The Biology of Polluted Water*. University of Toronto Press, 202pp.

Ibrahim, S. (2009). A Survey of Zooplankton Diversity of Challawa River, Kano and Evaluation of Some of its Physico-Chemical Conditions. *Bayero Journal of Pure and Applied Sciences, 2(1):* 19 – 26.

Imoobe, T.O.T (1997). Crustacean of Jamieson River, Nigeria. Ph. D Thesis, University of Benin, Benin city, Nigeria. 155pp.

Imoobe, T.O.T. and Akoma, O.C. (*2008*). Assessment of Zooplankton Community Structure of the Bahir Dar Gulf of Lake Tana, Ethiopia. *Ethiopian Journal of Environmental Studies of Management 1 (2): 26-34*.

Imoobe, T.O.T and Akoma, O.C. (2009). Spatial variations in the composition and abundance of zooplankton in the Bahir Dar Gulf of Lake Tana, Ethiopia. *African Journal of Ecology*, 48, 72-77.

Imoobe T. O. T. and Okoye, P. I.(2011). Assessment of the Impact of Effluent from a Soft Drink Processing Factory on the Physico-Chemical Parameters of Eruvbi Stream Benin City, Nigeria. *Bayero Journal of Pure and Applied Science, 4(1): In press.*

Imoobe T. O. T., Tawari-Fufeyin, P., & Ejoh, A. S. (2008) Community structure of crustacean zooplankton in Ekpan Creek, a perturbed tributary of Warri River, Niger Delta, Nigeria. *African Scientist*, 9(4): 123 – 134.

Imoobe, T. O. T., and Adeyinka M. L. (2010). Zooplankton-based assessment of the trophic state of a tropical forest river. *International Journal of Fisheries and Aquaculture* 2(2): 64-70.

Jeje, C.Y. and Fernando, C.H. (1986). A practical guide to the identification of Nigerian Zooplankton (Cladocera, Copepoda and Rotifera). Kainji Lake Res. Inst. 142pp.

Jeje, C.Y. (1988). A revision of the Nigeria species of the genera Mesocyclops, Sars 1914 and Thermocyclops Kiefer, 1927 (Copepoda, Cyclopoida). *Hydrobiologia* 164 ; 171-184.

Jeppesen, E., Jensen, J.P. and Sondergaard, M. (2002). Response of phytoplankton, zooplankton and fish to re-oligotrophication: an 11-year study of 23 Danish lakes. *Aquatic Ecosystems Health and Management.* 5: 31-43.

José De Paggi, S. (1976). Distribuicion espacial y temporal del zooplacton de un cuerpo de agua eutrofico (Lago del Parque Gral. Belgrano, Santa Fe). *Physis, Buenos Aires*, 35: 171-183.

Kudari, V.A., Kadadevaru, G.G. and Kanamadi, D. (2005). Zooplankton composition in some ponds of Haveri District, Karnataka. *Zoo's print. Journal, 20 (12),* 2094-2099.

Kumari, P. Dhadse, S. Chaudhari, P.R. and Wate, S.R. (2008). A Biomonitoring of Plankton to Assess Quality of Water in the Lakes of Nagpur City. Sengupta, M. and Dalwani, R. (Editors). Proceedings of Taal 2007: The 12th World Lake Conference: 160 – 164.

Kundannagar, M.R. and Zutshi, D.P. (1985). Environmental features and plankton communities of two Himalayan rural lakes. In: Adoni, A.D. (Ed.) Proc. Nat. Symp. Pure and Applied Limnology, Bull. Bot. Soc., Sagar 32**:** 40-47.

Margalef, R. (1983). *Limnologia*. Ômega, Barcelona. 1010pp.

Marine Biology Organization (MBO) (2007). *Zooplankton*. Retrieved February 18, 2011, from http://www.marine.bio.com/oceans/zooplankton.asp- 62k.

Mason, C.F. (1981). *Biology of Freshwater Pollution*. Longman. U.K. 239pp.

Mathivanan, V. Vijayan, P. Sabhanayakam, S and Jeyachitra, O. (2007). An assessment of plankton population of Cauvery river with reference to pollution. *Journal of Environmental Biology,* 28(2)*:* 523-526.

Mukhopadhyay, S.K, Chattopadhyay, B, Goswami, A. R .and Chatterjee, A. (2007). Spatial variations in zooplankton diversity in waters contaminated with composite effluents. *J. Limnol.,* 66(2): 97-106.

Neves, I. F.; Rocha, O.; Roche, K.F.; Pinto, A.A. (2003). Zooplankton community structure of two marginal lakes of the River Cuiabá (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. *Brazilian Journal of Biology*, 63: 329-343.

Nogueira, M.G. (2001). Zooplankton composition dominance and abundance as indicators of environmental compartmentalization in Jaramirim Reservoir (Paranapanema River), Sao Paulo, Brazil. *Hydrobiologia, 455:* 1-18.

Nwankwo, D.I. (1998). The influence of sawmill woodwastes on diatom population at Okobaba, Lagos, Nigeria. *Nigeria Journal of Botany*, 11: 15 – 24.

Ogbeibu, A.E. and Edutie, L.O. (2002). Impact of Brewery Effluent on the Water Quality and Rotifers of Ikpoba River, Southern Nigeria. *African Journal of Environmental Pollution and Health. 1 (1):* 1 – 12.

Ogbeibu, A.E. and Ezeunara, P.U. (2002). Ecological Impact of Brewery Effluent on the Ikpoba River, Using the Fish Communities as Bioindicators. *Journal of Aquatic Sciences. 17 (1):* 35 – 44.

Ogbonnaya, C. (2008). Impact of Liquid Wastes of Food Processing Industries on Quality of Receiving Streams. *AU J.T. 12(2):* 121-125.

Olaifa, F. E. and Leilei, K.E. (2007). A Study of the Plankton and Benthos of Ekole River in Bayelsa State, Nigeria. *Asset Series A 7 (1):* 144-150.

Olomukoro, J.O. (1983). Limnological Investigations of the Macrobenthic Fauna of Eruvbi Stream, a Tributary of Ikpoba River, Benin City. Unpublished M.Sc. Thesis University of Benin, Benin City. 104pp.

Pourriot, R., Rougier, C. & Miquelis, A. (1997). Origin and development of river zooplankton: example of the Marne. *Hydrobiol.* 345: 143-148.

Qasim, S.Z. (1977). Contribution of zooplankton in the water environments. Proc. Symp. Water Zool. P. Goa. India., 700-708.

Rutherford, S., D'Hondt, S. and Prell, W. (1999). Environmental controls on the geographic distribution of zooplankton diversity. Nature 400(6746): 749-753.

Sampaio, E.V., Rocha, O., Matsumura Tundisi, T. and Tundisi, J.G. (2002). Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil. *Brazil Journal Biology,* 62(3)*,* 525-545.

Sendacz, S. (1984). A study of the zooplankton community of Billings Reservoir - São Paulo. *Hydrobiologia*, Dordrecht, 113: 121-127.

Smirnov, N.N. (1974). Fauna of the USSR.Crustacea vol 1No 2 Chydoridae. Academy of science of the USSR p 644 English Transl., Israel program scientific translation, Jerusalem.

Soberon, J., Rodriguez, P. and Vazquez-Dominguez. (2000). Implications of the hierarchial structure of biodiversity for the development of ecological indicators of sustainable use. *Ambio* 29(3): 136-142.

Van De Velde, I. (1984). Revision of the African species of the genus Mesocyclops Sars, 1914 (Copepoda; Cyclopidae). *Hydrobiologia* 109, 3–66.

Wetzel, R. G. (2001). *Limnology: Lake and rivers ecosystems.* Academic Press. San Diego. 1006pp.

World Health Organization (2006). *Guidelines for Drinking Water Quality* Vol. 1 Geneva, Switzerland.

Zar, J.H. (1984). Biostastistical analysis. 2nd end. Prentice hall Inc. New Jersey, 718pp.