

Spatio-temporal Distribution, Abundance and Species Composition of Zooplankton of Woji-okpoka Creek, Port Harcourt, Nigeria

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Abstract: Woji-Okpoka Creek is situated in a strategic location in Port Harcourt, Rivers State, Nigeria and it receives domestic and industrial wastes from the Trans-amadi industrial Layout, main Port Harcourt abattoir and riverine communities. There is little information on the zooplankton of this creek. The study investigated species composition, diversity, abundance and distribution of zooplankton as well as some physico-chemical parameters that affect this organism. Zooplankton and surface water samples were collected monthly from May 2004 – April 2006 at low and high tides from ten stations according to APHA methods. These were analysed for temperature, turbidity, transparency, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), pH and nutrients. Zooplankton was identified microscopically. Species diversity was calculated using standard indices. Data was analysed using analysis of variance, Duncan multiple range and descriptive statistics. Zooplankton demonstrated significant temporal variation ($P < 0.05$). A total of 85 species dominated by copepods (43.4%) were identified. Diversity indices for copepods were: 1.0 ± 0.03 (Margalef) and 0.5 ± 0.02 (Shannon). Water temperature $28.6 \pm 0.06^\circ\text{C}$, turbidity 3.6 ± 0.32 NTU and transparency $0.7 \pm 0.01\text{m}$ showed significant temporal variations ($P < 0.05$). Water chemical parameters were: salinity, $14.4 \pm 4.67\%$; DO, $5.0 \pm 0.10\text{mg/l}$; BOD, $3.3 \pm 0.09\text{mg/l}$ and alkalinity, $84.1 \pm 1.41\text{mg/l}$. Phosphate and ammonia exceeded FEPA and USEPA acceptable levels for natural aquatic bodies. Phosphate demonstrated significant spatial variation ($P < 0.05$). The presence of dominant copepods indicates an environment under stress. The domestic and industrial effluents should be recycled or and treated instead of being discharged into this creek.

Key words: Copepods, diversity indices, effluents discharges, physico-chemical parameters, stress, zooplankton population.

INTRODUCTION

Zooplankton occupy an important trophic niche in the aquatic ecosystem as they constitute the most important link in energy transfer between phytoplankton and higher aquatic fauna (Iloba, 2002). Also, they make up an invaluable source of protein, amino acids, lipids, fatty acids, minerals and enzymes and are therefore an inexpensive ingredient to replace fishmeal for cultured fish (Kibria *et al.*, 1997; Ovie and Eyo, 1994; Fernando, 1994). However, they indicate the effect of low levels of chemical pollution in water body and because of their very important role in the food chain and energy flow, they are good indicator of pollution in biological monitoring (Rutherford *et al.*, 1999; Soberon *et al.*, 2000; MBO, 2007a). The copepod crustaceans are free-living filter feeder zooplankton and are used in bio-monitoring of pollution. They are homoisotonic thus any introduction of pollutants into the ecosystem will have effect on the metabolism of the fauna and will also cause ecological disturbance in the system.

The Bonny Estuary east of the Niger has been of great concern to the scientific community, governmental agencies and non-governmental bodies due to its location and the various industrial set-ups and jetties located along its shores. These industries and jetties discharge effluents

including crude oil and its products directly into the system. Apart from these effluents, wastes are released into the system from domestic sources. Other human activities (dredging, transportation [boating, navigation], fishing, etc.) impact on this estuary. Many works on physico-chemical and bacteriological parameters, microbial, phytoplankton, zooplankton and pollution studies have been carried out on other creeks of the estuary (Ajayi and Osibanjo, 1981; Ekweozor, 1985; Egborge, 1987; Kakulu and Osibanjo, 1992; Chindah and Pudo, 1991; Okoye *et al.*, 1991; Dambo, 1992; Falomo, 1998; Chindah and Osuamkpe, 1994; Allison *et al.*, 1997; Edoghotu, 1998; Chindah *et al.*, 2000; Davies *et al.*, 2002; Izoafuo *et al.*, 2004; Hart and Zabbey, 2005) to mention but a few. However, there has been very little information on the zooplankton of the Okpoka Creek, a tributary of Upper Bonny Estuary. In order to bridge the existing gap in knowledge of the biotic and abiotic features of this estuary, there is therefore the need to provide useful information on the zooplankton and their relationship with water physico-chemistry of the Okpoka Creek.

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, thus these organisms have proved valuable indicators of

apparent and subtle alterations in the quality of aquatic environments (MBO, 2007a). They are useful indicators of future fisheries health because they are a food source for organisms at higher trophic levels. Zooplankton biomass, abundance and species diversity are used to determine the conditions of the aquatic environment (MBO, 2007b). Generally, copepods dominate the zooplankton community in most aquatic ecosystems (Oronsaye, 1995; Oronsaye and Okaka, 2000; Kolo *et al.*, 2000; Aminu and Ahmed, 2000; Davies *et al.*, 2002; Okayi, 2003; Ekwu and Sikoki, 2005).

The season of maximum abundance of planktonic organisms differ in water bodies. Also, their composition and distribution vary from place to place and year to year due to the dynamic nature of the aquatic systems (FAO, 2006; MBO, 2007a). These characteristics of different species of zooplankton can sometimes help scientists distinguish one water mass from another. The productivity of aquatic systems including the production of fish which depends on the quality and quantity of planktonic organisms present may be influenced. Many factors such as dissolved oxygen, transparency, salinity, pH and temperature influence the occurrence, abundance and distribution of planktonic organisms. The effects of these factors have been reported in a number of researches (Adeniji 1978; Egborge, 1987; Adeniji and Ovie, 1981, 1982). The copepods were found to be more abundant at the refinery axis and little appearance of the species was noticed within the NAFCON-Onne axis. The zooplankton were found to be present throughout the estuary but were more prevalent in Okrika-Refinery axis. The copepods being dominant followed by cladocera and rotifera (Falomo, 1998). A preliminary checklist and distribution of zooplankton in the lower Cross River Estuary were reported by Ekwu and Sikoki (2005) and they observed 66 species dominated by copepods.

MATERIALS AND METHODS

Study area: The Woji-Okpoka Creek is located between longitudes 7°00"E and 7°15"N and latitudes 4°28"E and 4°40"N. It is a tributary of the Upper Bonny Estuary in the Niger Delta, South South of Nigeria (Fig.1). The vegetation is dominated by *nypa* palm (*Nypa fructican*) and mangroves, red mangrove (*Rhizophora racemosa*) and white mangrove (*Avecennia nitida*). It passes through many communities namely: Oginigba, Woji, Azubiae, Okujagu, Okuru-ama, Abuloma, Ojimba, Oba, Kalio and Okrika. Many man's activities going on within and around this creek include dredging, fishing, boating, navigation, washing, disposal of excreta, bathing and swimming, to mention but a few. This aquatic body receives effluent discharges from the many industries (Snig, Far East paints, RIVOC, General-agro, Michelin tyres, Cocacola, Hallibuton, Schlumberger, Acorn, etc) and main abattoir house sited close to it.

Sampling stations: A total of ten stations were chosen at least 500 metres apart along the main creek course

namely: Oginigba (upstream), Trans-Amadi by Schlumberger, Trans-Amadi by Slaughter, Azubiae, Woji, Okujagu, Okuru-Ama, Ojimba, Oba and Kalio-Ama (downstream).

Field collection of zooplankton: Plankton net of 55mm mesh was used to collect zooplankton sample in each station. It is the most efficient device for concentrating zooplankton (Boyd, 1981). The net was towed on a slow-moving engine boat for five minutes and the filtrate was kept in a one-litre wide mouth plastic container and fixed with few drops of 10% formalin.

Laboratory analysis of zooplankton: In the laboratory, samples were allowed to stand for a minimum of 24 h before decanting the supernatant. The supernatant was removed carefully until a 50ml concentrated sample was properly shaken and 1ml of sub sample was collected from it and transferred into a Sedgwick-Rafter counting chamber using a stampel pipette. Identification and enumeration (standing crop estimation) was carried out under a binocular compound microscope with magnification 40 x 400. Three replicates of the subsamples were analysed. For each sample, each solitary cell or group of cells were counted as one unit except for the diatoms which were counted in a cell by cell base. Results were expressed in a number of organisms per ml of sample. The Sedgwick-Rafter counting chamber contains exactly 1ml (50 mm long x 20 mm wide x 1 mm deep) and has a surface area of 1000 mm². The exact area viewed within the ocular micrometer grid is also known. The following formula was used for the calculation of plankton density: Density of plankton (Number of plankters per ml)

$$= \frac{(T)}{AN} \times \frac{\text{Volume of concentrate ml}}{\text{Volume of sample (ml)}}$$

Where: T = Total number of plankters counted

A = area of grid in mm²

N = number of grids employed

1,000 = area of counting chamber in mm² (Boyd, 1981)

Identification and characteristics of planktonic species were made by the descriptive keys by Mill (1932) Needham and Needham (1962); Newell and Newell (1963); Han (1978) Durans and Leveque (1980), Prescott (1982); Kadiri (1988) amongst others. Species diversity was estimated by this formula:

$$H = \frac{S - 1}{\ln N}$$

where S = the number of species (or other taxonomic group)

N = total number of phytoplankters (Boyd, 1981)

Index of dominance (C) was determined by the formula:

$$C = \sum (ni/N)^2$$

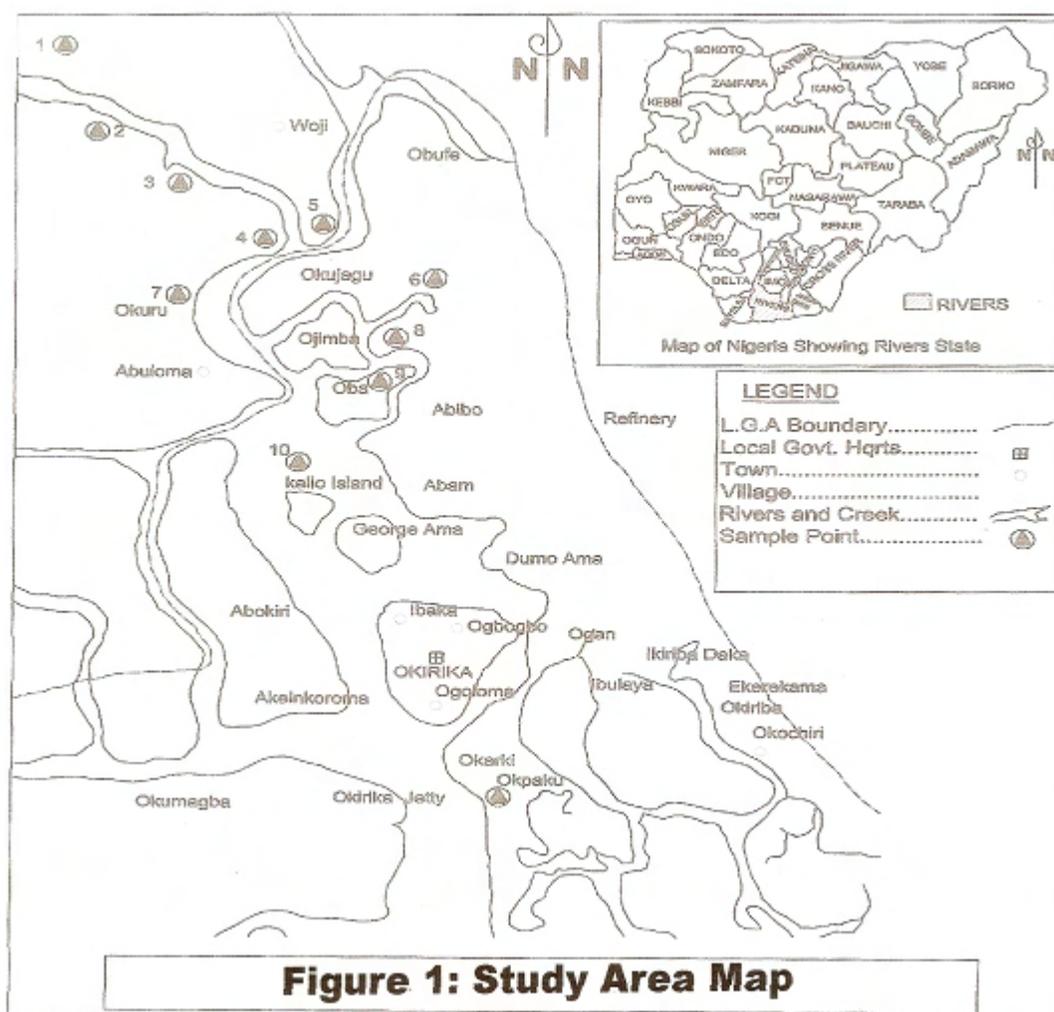


Figure 1: Study Area Map

Table 1: Important values assigned to ith species abundance

Range	Importance value
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-80	8
81-90	9
91-100	10
100 and above	11

Where n_i = importance value for each species (number of individual, biomass, production, etc)

N = total of importance values.

Importance values were assigned to the phytoplankton species based on the contribution of each species to total net primary production (Odum, 1971) and also to pollution Table 1. Index of similarity (S) in phytoplankton species diversity between the different stations was determined by index of similarity (S)

between 2 adjacent samples (Odum, 1971).

$$S = 2C/A+B$$

Where A = number of species in sample A

B = number of species in sample B

C = number of species common in both samples

Index of dissimilarity = $1 - S$

Other indices of species diversity calculated are as follows:

1) Shannon index of general diversity (H) was calculated thus.

$$H = - \sum \left(\frac{n_i}{N} \right) \log \left(\frac{n_i}{N} \right) \text{ or } - \sum P_i \log P_i$$

Where n_i = importance value for each species

N = total of importance values

P_i = importance probability for each species =

2) Evenness index (e)

$$e = \frac{H}{\log_e S} \text{ where } H = \text{Shannon index}$$

S = number of species

- 3) Three species richness or variety indices (d)

$$d_1 = di = \frac{S - I}{\text{Log}_e N} \quad d_2 = \frac{S}{\sqrt{N}} \quad d_3 = S \text{ per } 1000$$

individuals

Where S = number of species

N = number of individuals, etc

Physico-chemical parameters of the water:

Temperature, turbidity, transparency, pH, dissolved oxygen (DO), biological oxygen demand (BOD), salinity, alkalinity, nitrate, phosphate and sulphate were measured in-situ and in laboratory following standard methods (APHA, 1985). One litre clean containers were used to collect water samples for physico-chemical parameters at each station. All the kegs containers were kept in ice-chest box for laboratory analyses.

Data analysis: SAS (2003) was used to analyse data for analysis of variance (ANOVA), Duncan Multiple Range (DMR) and microsoft excel (2003) for descriptive statistics.

RESULTS

Zooplankton: The study recorded 30,742 zooplankton made up of 7 taxa, 66 genera and 85 species. They included *Rotifera* (29 species), *Copepoda* (26 species), *Cladocera* (12 species), *Protozoa* (11 species), *Ostracoda* (5 species), *Euphausiacea* (1 species) and *Branchiura* (1 species).

Rotifera (Rotifers): Rotifers density ranged between 284.00±61.49 no/ml (Station 10) and 1303.52±642.59 no/ml (Station 1) with a mean of 789.11±124.12 no/ml in the study area (Figs. 2a, 2b). This represented 9.05% of the zooplankton abundance. Spatial variation on all parameters were insignificant (P>0.05). Margalef index was between 0.19±0.08 (Station 6) and 0.56±0.25 (Station 10) with a mean of 0.41±0.04 (Figs. 3a, 3b). Shannon index varied from 0.15±0.05 (Station 8) to 0.27±0.05 (Station 4) with a mean of 0.21±0.02 (Figs. 4a, 4b). Evenness ranged between 0.15±0.05 (Station 1) and 0.8±0.04 (Station 3) with a mean of 0.0±0.02 (Figs. 5a, 5b) and Dominance between 0.15±0.05 (Station 1) and 0.29±0.08 (Station 9) with a mean of 0.22±0.02 (Figs. 6a, 6b). The observed year 1 parameters were less than year 2 (Figs. 7a to 7e). Temporal variation was significant (P<0.05, 0.01, 0.001, DMR) and ranged between 210.00±19.28 no/ml and 1329.73±225.59 no/ml (density), 0.30±0.05 and 0.51±0.05 (Margalef) 0.11±0.02 and 0.30±0.03 (Shannon), 0.13±0.02 and 0.29±0.02 (Evenness) and 0.15±0.22 and 0.29±0.22 (Dominance) for year 1 and 2, respectively.

Ten genera and 29 species of rotifers recorded (Fig. 8a). The prominent species were: *Cryptochrysis commersalis* (56.78±33.70%), *Vorticella sp.* (60.24±11.14%), *Condonella uncinata* (53.97±12.03%), *Rotaria rotatoria* (55.11±7.74%), *Cephalodella catellina*

(56.25±6.25%), *Branchionus angularis* (46.31±4.91%), *Notonunata aurita* (32.56±6.55%), *Dicranophonus forcipatus* (33.22±3.95%), *Lindia torulosa* (26.05±10.51%) and *Diurella porellus* (24.77±5.14%). Rotifers were higher in year 1 study than year 2, *B. angularis* (59.18±8.08%), *Lindia torulosa* (41.67±25.00%), *Notonunata aurita* (50.00±0.00%), *Dicranophonus forcipatus* (36.67±3.34%) and *Condonella uncinata* (56.65±13.88%) were higher in year 1 than year 2. *B. angularis* (34.61±3.13%), *Lindia torulosa* (15.64±4.92%), *Notonunata aurita* (23.87±5.60%), *Dicranophonus forcipatus* (26.32±0.00%) and *Condonella uncinata* 37.93±0.00% (Fig. 8b). *Cephalodella catellina* (62.50±0.00%) and *Rotaria rotatoria* (62.84±0.00%) were higher in year 2 study than in year 1. *Cephalodella catellina* (50.00±0.00%) and *Rotaria rotatoria* (42.37±0.00%). *Cryptochrysis commersalis* was absent while *Vorticella sp.* was present in year 1. Similarity index ranged between 11.17±4.53% (Stations 5 to 6) and 39.23±5.91% (Stations 3 to 4) with a mean of 23.00±2.85% and dissimilarity index varied between 60.77±5.86% with a mean of 77.59±2.80%. Species composition of rotifers were highly dissimilar throughout. (Tables 2, 3).

Copepoda (Copepods): The density of copepods ranged between 3044.71±620.37 no/ml (Station 10) and 4512.63±898.41 no/ml (Station 5) with a mean of 3783.80±248.33 no/ml. This accounted for 43.40% of zooplankton population and the highest among the zooplankton. Copepods had the highest species diversity indices: Margalef (0.98±0.03), Shannon (0.50±0.02), Evenness (0.35±0.01) and Dominance (0.25±0.01). Spatial effects on parameters were not significant (P>0.05). Copepods species diversity indices in the stations were Margalef, 0.74±0.09 (Station 6) and 1.17±0.09 (Station 1), Shannon 0.44±0.05 (Station 6) and 0.59±0.03 (Station 1), Evenness 0.33±0.03 (Stations 3, 7, 9) and 0.41±0.01 (Station 1) and Dominance 0.22±0.02 (Stations 2 and 3) and 0.31±0.08 (Station 9). Year 2 study had higher density of copepods (8172.94±372.89 no/ml) than year 1 study (857.71±77.97 no/ml). Temporal variation was highly significant (P<0.001, DMR).

Twenty-three genera and 26 species of copepods were recorded (Fig. 9a). The 10 abundant species include *Temora longicornis* (22.84±3.06%), *Cyclops strenus* (16.07±1.94%), *Centropages typicus* (16.24±0.94%), *Anomalocera patersoni* (14.57±1.48%), *Acartia longiremis* (12.52±1.59%), *Paracyclops fimbriatus* (12.68±1.82%), *Acanthocyclops bicuspidatus* (13.55±0.65%), *Onchocamptus sp.* (12.11±1.89%), *Metridia lucens* (12.04±1.30%) and *Mesocyclops leukarti* (12.80±0.22%). Out of the 26 species identified, 15 species were calanoid copepods and others were cyclopoid copepods. From Fig. 9b, temporal variations were similar. Out of the 10 prominent species, 50% had higher percentage distribution in year 1 study and others had lower percentage distribution in year 2 and vice versa.

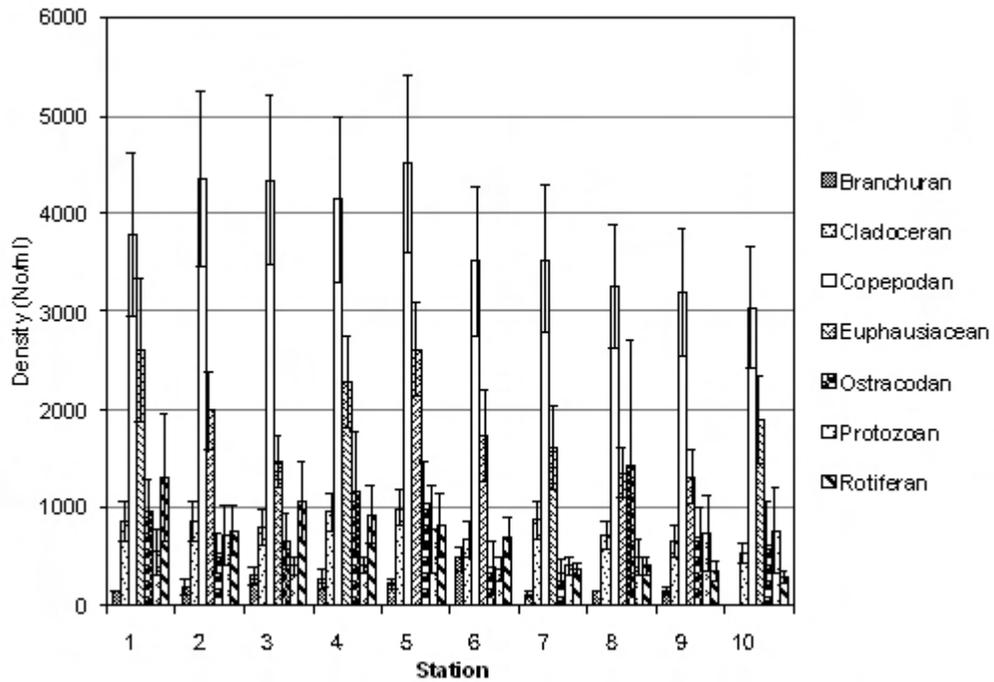


Fig 2a: Variation of zooplankton density in relation to station in Woji-Okpoka Creek

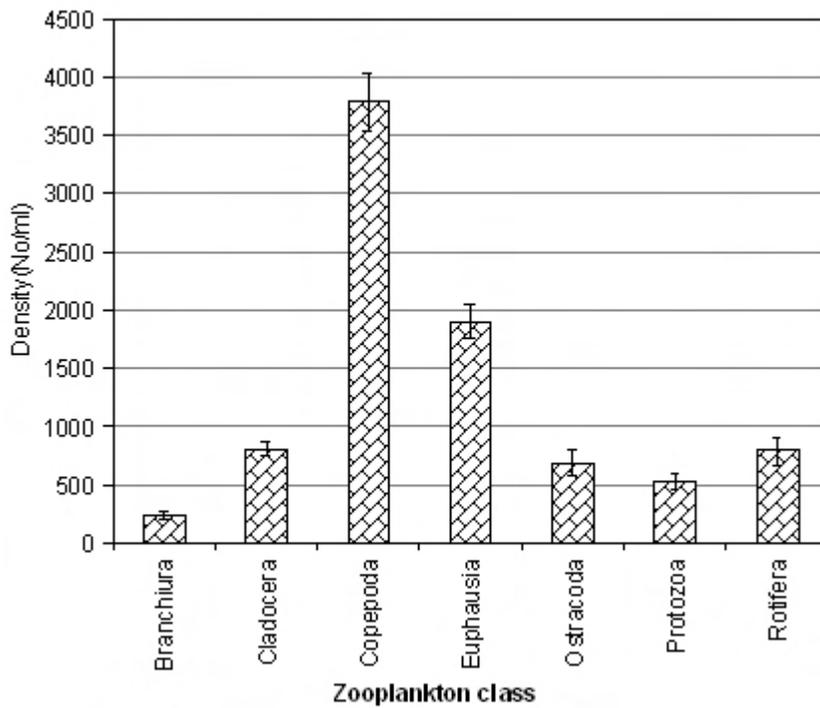


Fig. 2b.: Overall mean values of zooplankton density in Woji-Okpoka Creek

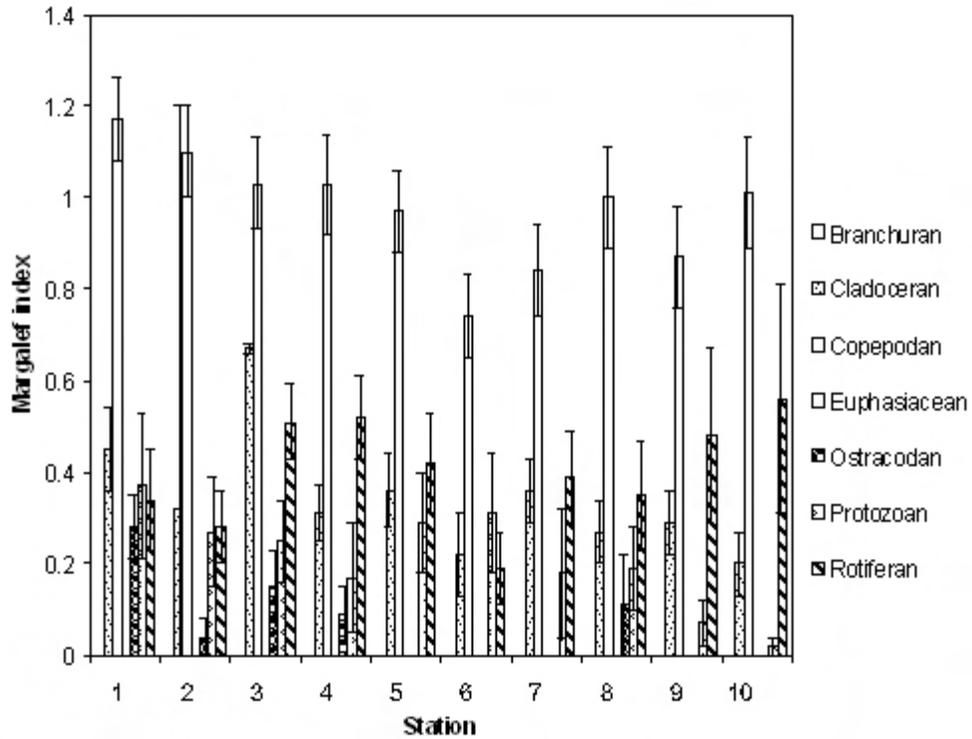


Fig. 3a.: Variation of zooplankton Margalef index in relation to station in Woji-Okpoka Creek

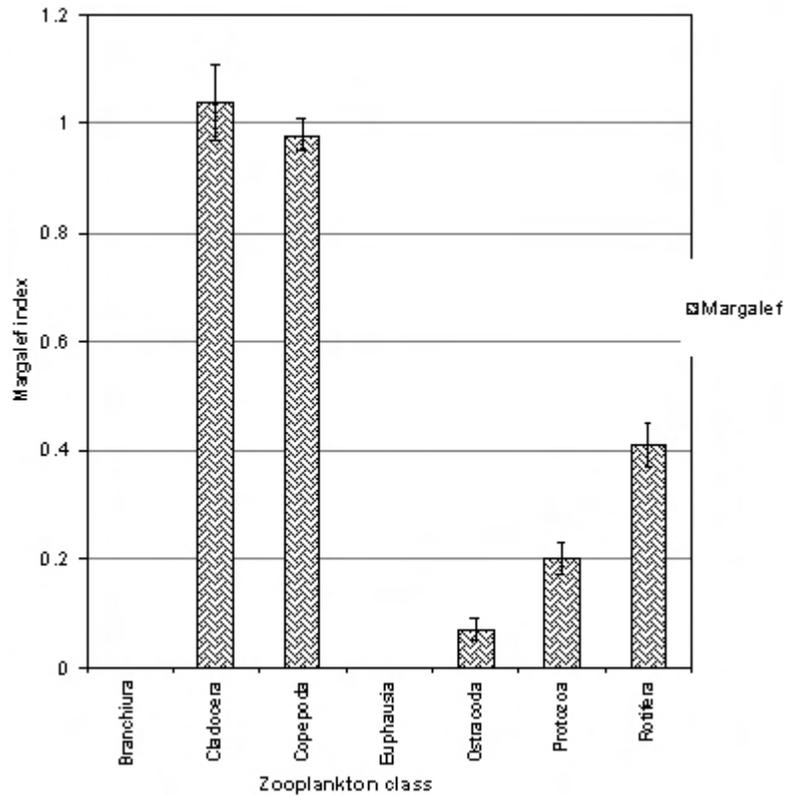


Fig. 3b: Overall mean values of zooplankton Margalef index in Woji-Okpoka Creek

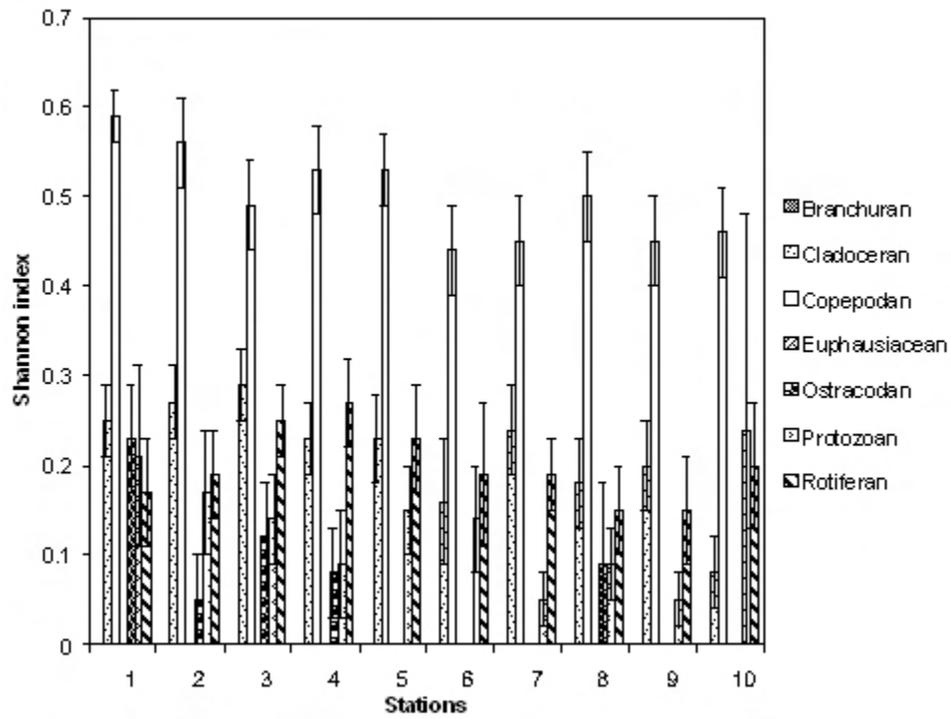


Fig 4a: Variation of zooplankton Shannon index in relation to station in Woji-Okpoka Creek

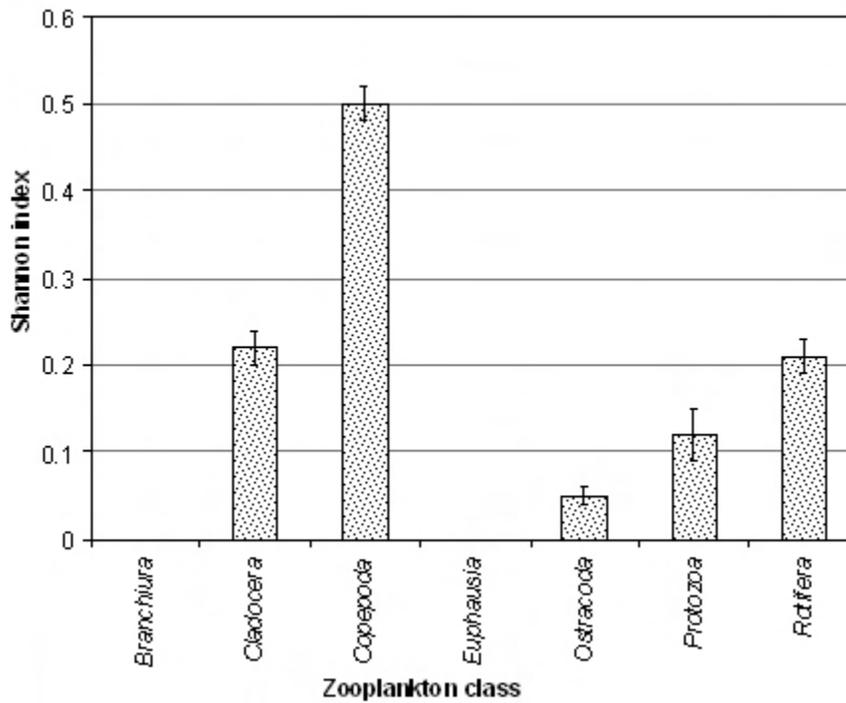


Fig 4b: Overall mean values of zooplankton Shannon index in Woji-Okpoka Creek

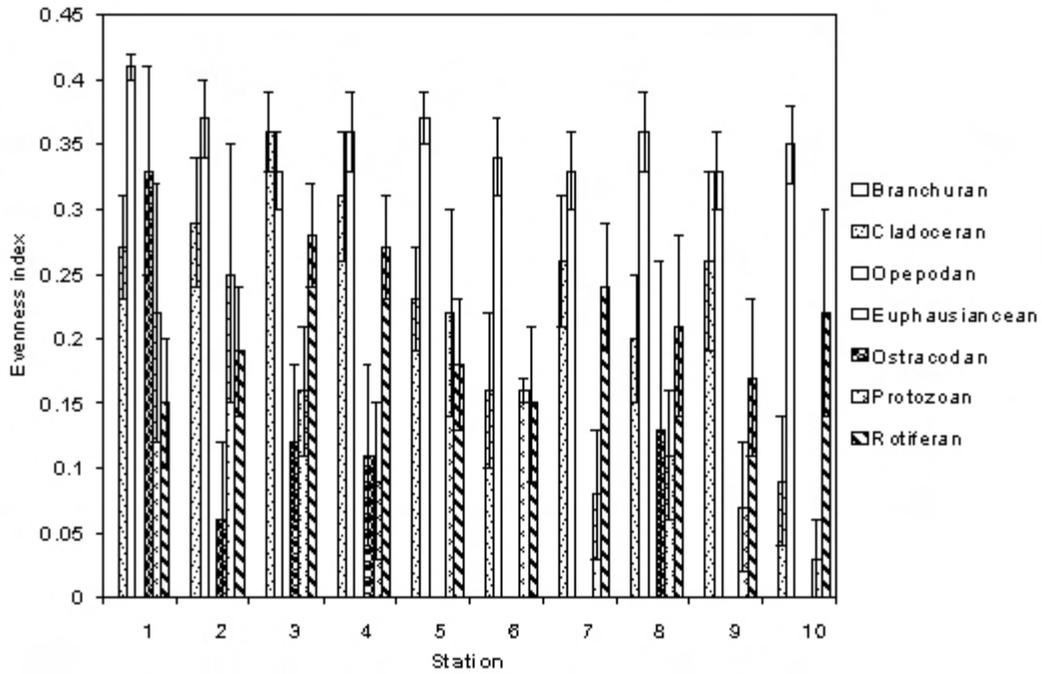


Fig 5a:. Variation of zooplankton Evenness index in relation to station in Woji-Okpoka Creek

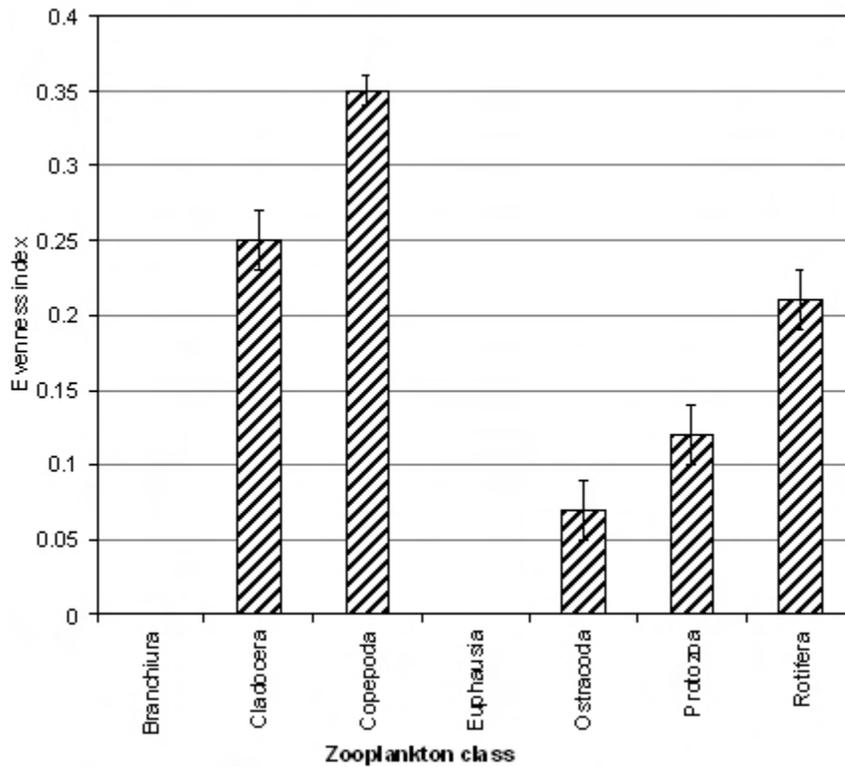


Fig 5b: Overall mean values of zooplankton Evenness index in Woji-Okpoka Creek

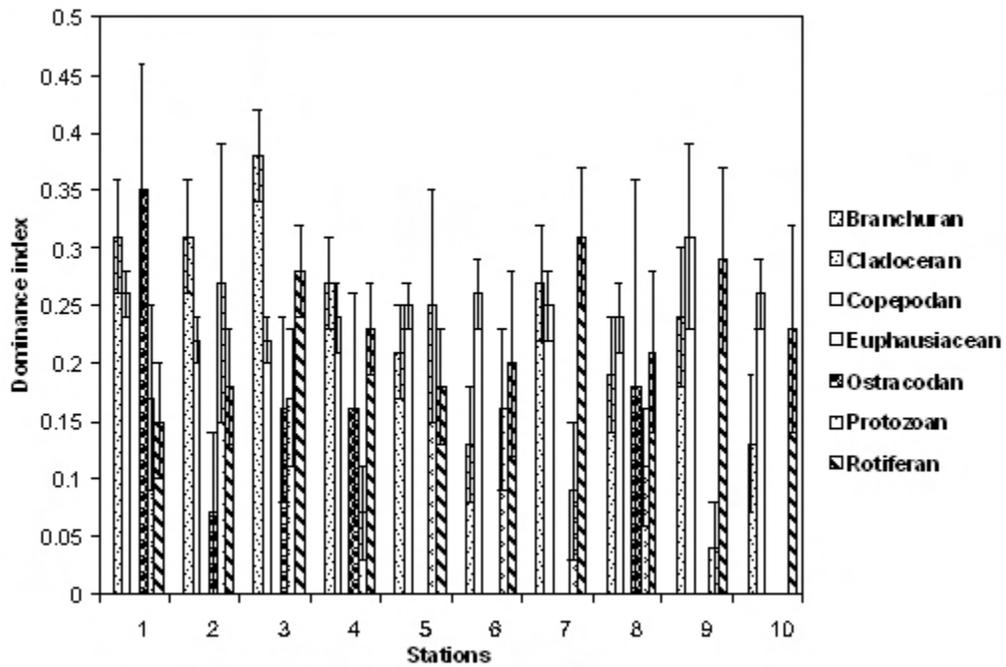


Fig 6a: Variation of zooplankton Dominance index in relation to station in Woji-Okpoka Creek

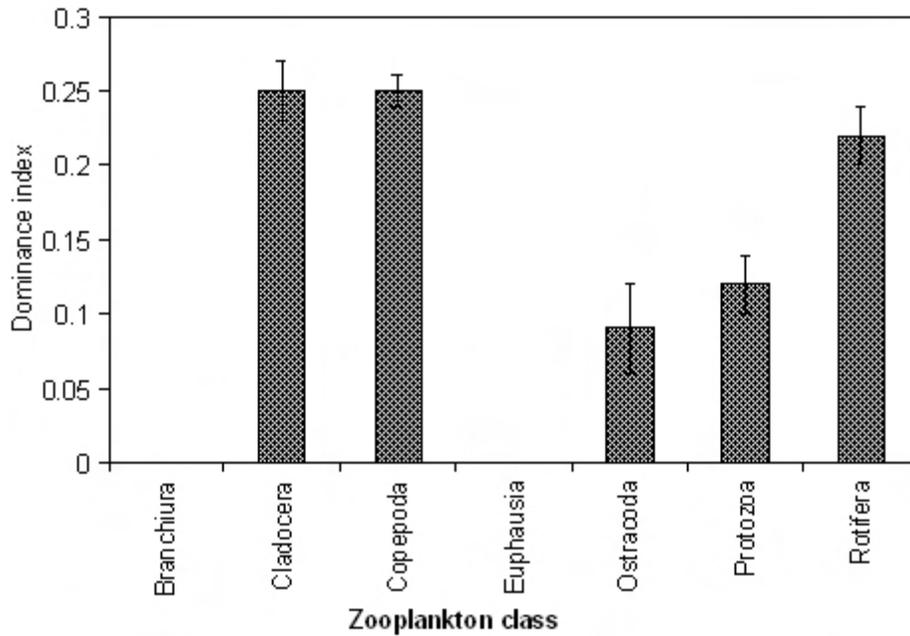


Fig 6b: Overall mean values of zooplankton Dominance index in Woji-Okpoka Creek

Table 2: Variations of species similarity and dissimilarity indices of zooplankton in relation to station in Woji-Okpoka Creek

Station	Branchiura	Protozoa	Cladocera	Ostracoda	Rotifera	Copepoda	Euphausiacea
Similarity Index (%)							
1-2	20.00±20.00 ^a	30.00±14.64 ^a	42.35±7.92 ^a	62.63±14.69 ^a	21.63±14.69 ^a	52.89 ±5.26 ^a	71.73±8.69 ^a
3-4	00.00±0.00 ^b	13.53±5.44 ^a	37.41±6.97 ^a	33.42±13.09 ^{ab}	39.23±5.91 ^a	50.74 ±5.80 ^a	73.08±8.87 ^a
5-6	00.00±0.00 ^b	8.87±4.84 ^a	21.30±5.50 ^a	00.00±0.00 ^c	11.17±4.53 ^b	39.13 ±5.72 ^a	66.67±8.75 ^a
7-8	00.00±0.00 ^b	19.44±8.22 ^a	35.08±7.52 ^a	0.00±0.00 ^c	13.52±5.49 ^b	42.29±6.03 ^a	75.00±9.03 ^a
9-10	00.00±0.00 ^b	28.13±11.15 ^a	33.05±8.14 ^a	16.67±20.00 ^{bc}	18.93±8.84 ^b	49.87±5.96 ^a	65.52±8.98 ^a
Dissimilarity Index (%)							
1-2	80.00±20.00 ^b	70.00±14.64 ^a	57.65±8.11 ^a	37.35±12.19 ^a	78.37±5.76 ^a	47.11±5.26 ^a	28.57±8.69 ^a
3-4	100.00±0.00 ^a	86.47±5.44 ^a	63.52±6.71 ^a	66.58±12.33 ^b	60.77±5.86 ^b	49.26±5.80 ^a	26.92±8.87 ^a
5-6	100.00±0.00 ^a	9.13±4.84 ^a	78.70±5.92 ^a	100.00±0.00 ^a	88.83±4.53 ^a	60.87±5.72 ^a	33.33±8.75 ^a
7-8	100.00±0.00 ^a	80.56±8.22 ^a	64.92±8.26 ^a	100.00±0.00 ^a	86.48±5.49 ^a	57.71±6.14 ^a	25.00±9.03 ^a
9-10	100.00±0.00 ^a	71.88±11.15 ^a	67.18±8.14 ^a	83.33±16.67 ^{ab}	81.27±8.34 ^{ab}	50.14±5.96 ^a	34.48±8.98 ^a
Species Index (%)							
Similarity	2.50 ± 2.50	18.67 ± 3.77	33.59 ± 3.21	22.27 ± 5.71	23.00 ± 2.85	46.36 ± 2.59	70.07 ± 3.93
Dissimilarity	97.44 ± 2.56	81.33 ± 3.77	66.41 ± 3.29	77.51 ± 5.54	77.59 ± 2.80	53.12 ± 2.59	29.93 ± 3.93

Table 3: Variations of zooplankton similarity and dissimilarity indices in relation to time Woji-Okpoka Creek

Year	Branchiura(%)	Protozoa(%)	Cladocera	Ostracoda	Rotifera	Copepoda	Euphausiacea
Similarity Index (%)							
1	00.00±0.00 ^a	11.54±6.39 ^a	28.13±4.80 ^a	24.38±7.65 ^a	14.47±7.65 ^a	34.34±2.98 ^b	51.39±5.93 ^b
2	5.26±5.26 ^a	22.45±4.62 ^a	35.18±4.25 ^a	24.63±8.79 ^a	32.48±4.21 ^a	65.03±3.83 ^a	90.77±3.62 ^a
Dissimilarity Index (%)							
1	100.00±0.00 ^a	88.46±6.39 ^a	71.87±4.94 ^a	75.62±8.18 ^a	85.53±3.41 ^a	65.66±2.98 ^a	48.61±5.93 ^a
2	94.44±5.56 ^b	77.55±4.62 ^a	64.82±4.35 ^a	75.37±7.50 ^a	67.52±42.13 ^b	34.97±3.75 ^b	9.23±3.62 ^b

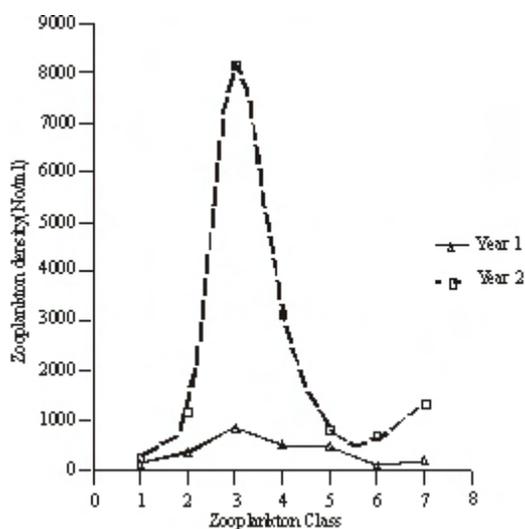


Fig 7a: Variation of zooplankton density in relation to time in Woji-Okpoka Creek, (1=Branchiura,2=Cladocera, 3=Copepoda,4=Euphausiacea,5=Ostracoda,6=Protozoa and 7=Rotifera)

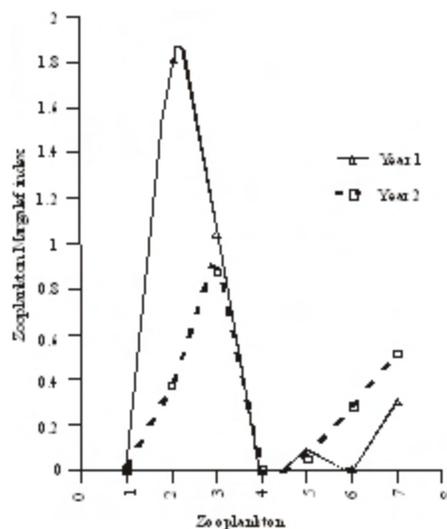


Fig 7b: Variation of zooplankton Margalef index in relation to time in Woji-Okpoka Creek, (1=Branchiura, 2=Cladocera, 3=Copepoda, 4=Euphausiacea, 5=Ostracoda, 6=Protozoa and 7=Rotifera)

The mean species similarity and dissimilarity indices of copepods were 46.36±2.59 and 53.12±2.59% indicating that copepods were differently distributed within the creek. ANOVA showed significant difference (P<.001). Species composition along the stations were not similar except in Stations 1 and 2 with similarity index of 52.89±5.26% and Stations 3 and 4 of 50.57±5.80% similarity index. There was significant spatial difference (P<0.05).

Cladocera: Density of *cladocera* ranged along the station from 527.79±101.80no/ml (Station 10) to

989.61±191.12no/ml (Station 5) with a mean value of 810.96± 57.93no/ml (9.30%). Mean value of Margalef, Shannon, Evenness, and Dominance species diversity indices were: 1.04±0.07, 0.22±0.02, 0.25±0.02 and 0.25±0.02, respectively. The ANOVA of parameters were significant (P<.01, 0.001) except Margalef index. There was no significant spatial effect on cladocera density. Significant differences were observed on all diversity in indices except Margalef and Shannon. Cladocera density was higher in year 2 (1191.49±88.09no/ml) than in year 1 (386.93±46.38no/ml). There was significant temporal influence on parameters (P<0.001, DMR).

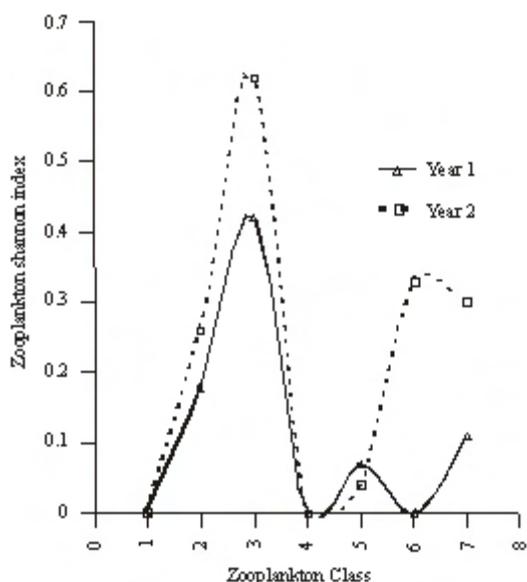


Fig 7c: Variation of zooplankton Shannon index in relation to time in Woji-Okpoka Creek, (1=*Branchiura*, 2=*Cladocera*, 3= *Copepoda* ,4= *Euphausiacea*,5=*Ostracoda*, 6=*Protozoa* and 7=*Rotifera*)

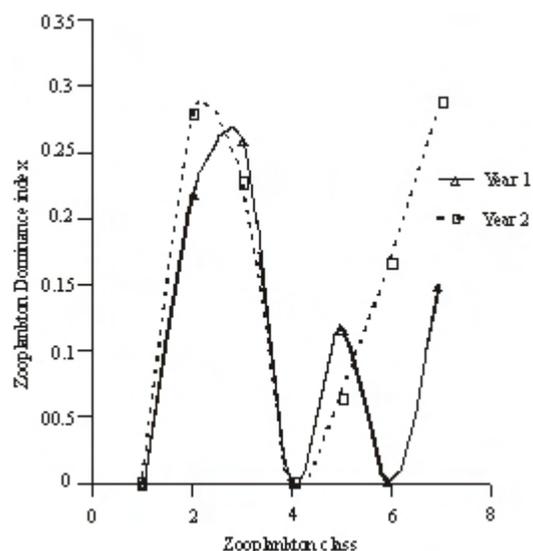


Fig 7d: Variation of zooplankton Evenness in relation to time in Woji-Okpoka Creek, (1=*Branchiura*, 2=*Cladocera*, 3= *Copepoda* ,4= *Euphausiacea*,5=*Ostracoda*, 6=*Protozoa* and 7=*Rotifera*)

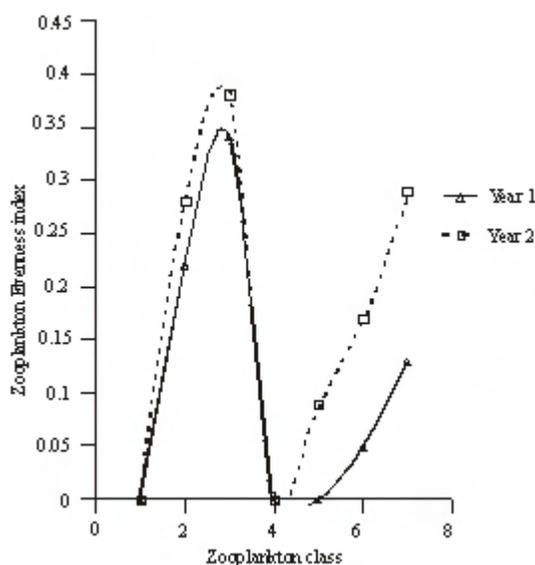


Fig 7d: Variation of zooplankton Evenness in relation to time in Woji-Okpoka Creek, (1=*Branchiura*, 2=*Cladocera*,3=*Copepoda*,4=*Euphausiacea*,5=*Ostracoda*,6=*Protozoa* and 7=*Rotifera*)

Eight genera and 12 species of cladocera were recorded (Fig.10a). The most abundant species was *Bosmina sp* (55.50±2.05%) followed by *Alona affinis* (48.72±5.92%) *Simocephalus serrulatus* (19.02±5.54%) and *Penilia avirostris* (44.87±4.18%). From Fig.10b temporal effect was high on species distribution in year 1 than in year 2. 8 out of 12 species recorded occurred more in year 1 study than in year 2 study.

The mean similarity and dissimilarity indices were 33.59±3.21 and 66.41±3.29%, respectively. Species composition in the creek varied not similar. The dissimilarity index was higher in all cases (station and time) and variations were not significant (P<0.05).

Protozoa: Density of protozoa ranged along stations from 371.00±117.15no/ml (Station 6) to 771.14±444.06no/ml (Station 5) with a mean of 529.37±23no/ml (6.07%). Spatial variation was not significant. The species diversity indices were generally low: Margalef (0.20±0.03), Shannon (0.12±0.03), Evenness (0.12±0.02) and Dominance (0.12±0.02). ANOVA showed significant differences for parameters except density and Shannon index. Mean density ranged between 125.43±9.44no/ml (year 1) and 721.71±105.81no/ml (year 2). Temporal variation of density was significant (P<0.001, DMR). Diversity indices for year 1 were zero.

Seven genera and 11 species of protozoa were observed (Fig.11a). The abundant species were *Strobilidium gyrans* (63.47±6.74%), *Halteria sp* (48.56±9.86%) *Tintinnopsis wangi* (40.44±8.40%) and *T. sinensis* (22.76±3.56%). Fig. 11b shows temporal variation of species distribution in Woji-Okpoka creek. Species abundant was high in year 1 than in year 2. *T. wangi* was the only species out of the 4 prominent species that occurred most in year 2 than in year 1.

The means similarity and dissimilarity indices of 18.67±3.77 and 81.33±3.77% showed high dissimilarity of protozoa species composition in the creek.

Ostracoda: Ostracod density ranged between 333.27±131.27no/ml (Station 7) and

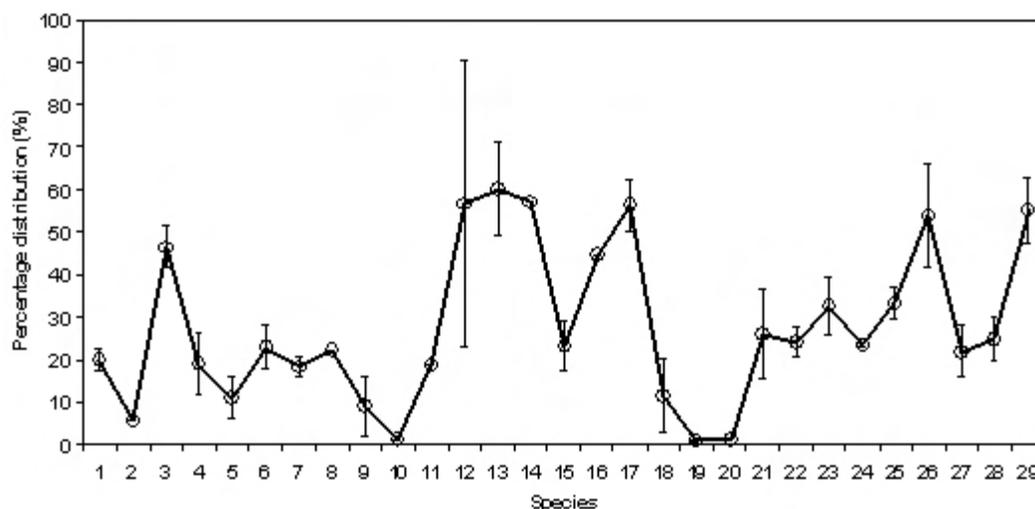


Fig 8a: Overall mean values of rotifer species of Woji-Okpoka Creek

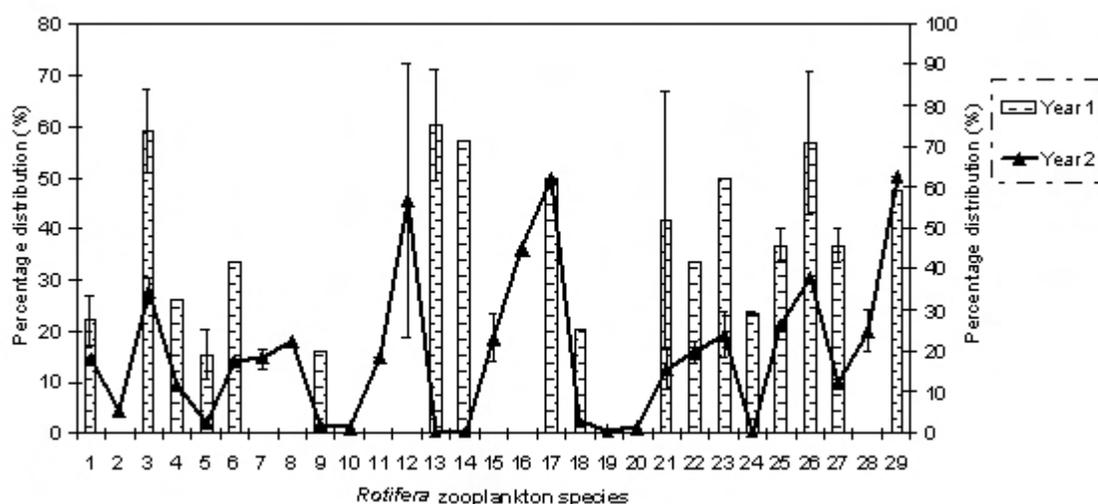


Fig 8b: Percentage distribution of rotifer species in relation to time in Woji-Okpoka Creek

(1=*Philodina acuticomus*; 2=*Branchionus sp*; 3= *B. angularis*; 4= *B. urceus*; 5= *B. leydigi*; 6=*B. calyciflorus*; 7=*Trichocerca bicristata*; 8=*T. lophoessa*; 9=*Monostyla sp*; 10=*M. lunaris*; 11=*Anuraopsis fissa*; 12=*Cryptochrysis commersalis*; 13=*Vorticella sp*; 14=*Epiphaenea sp*; 15= *Collurella uncinata*; 16=*Gastropus hypotopus* ; 17=*Cephalodella catellina*; 18=*Lecane ungulata*; 19=*Kellicottia longispina*; 20=*Keratella cochlearis*; 21=*Lindia torulosa*; 22=*Eosphora najas*; 23= *Notonunata aurita*; 24=*Lacinularia sp*; 25=*Dicranophonus forcipatus*; 26=*Condonella uncinata*; 27= *Eothinia elongata*; 28= *Diurella porellus* and 29= *Rotaria rotatoria*)

1421.00±1279.00no/ml (Station 8) with a mean of 674.37±110.57no/ml .This represented 7.73% of the zooplankton community. Spatial variation was not significant ($P>0.05$). The means of the species diversity indices were 0.07±0.02 (*Margalef*), 0.05±0.01 (*Shannon*), 0.07±0.02(*Evenness*), and 0.09±0.03 (*Dominance*). There were significant spatial variations of *Margalef*, *Evenness* and *Dominance* indices. Temporal influence on parameters was not significant. Year 2 study had higher

ostracod density (866.34±145.57no/ml) than year 1 (488.41±161.26no/ml).

Four genera and 5 species of ostracoda were identified (Fig. 12a). The most abundant was *Conchoecia spinostris* (94.62±3.90%) followed by *Heterocypris sydneya* (64.00±0.00%). *C. spinostris* and *H.sydneya* had higher distribution percentage in year 1 than in year 2 (Fig. 12b). *Condonella sp* and *Philomedes sp* were absent in year 1 study but *Metacypris sp* occurred more in

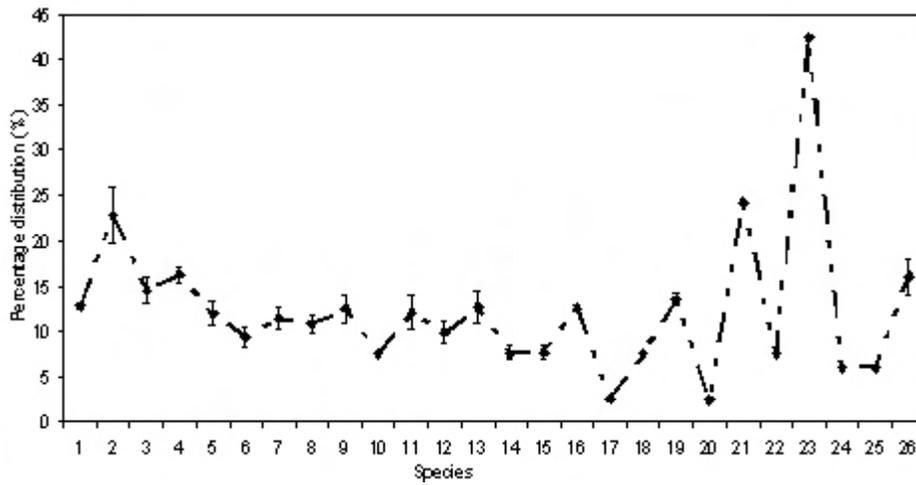


Fig 9a: Overall mean values of copepod species in Woji-Okpoka Creek

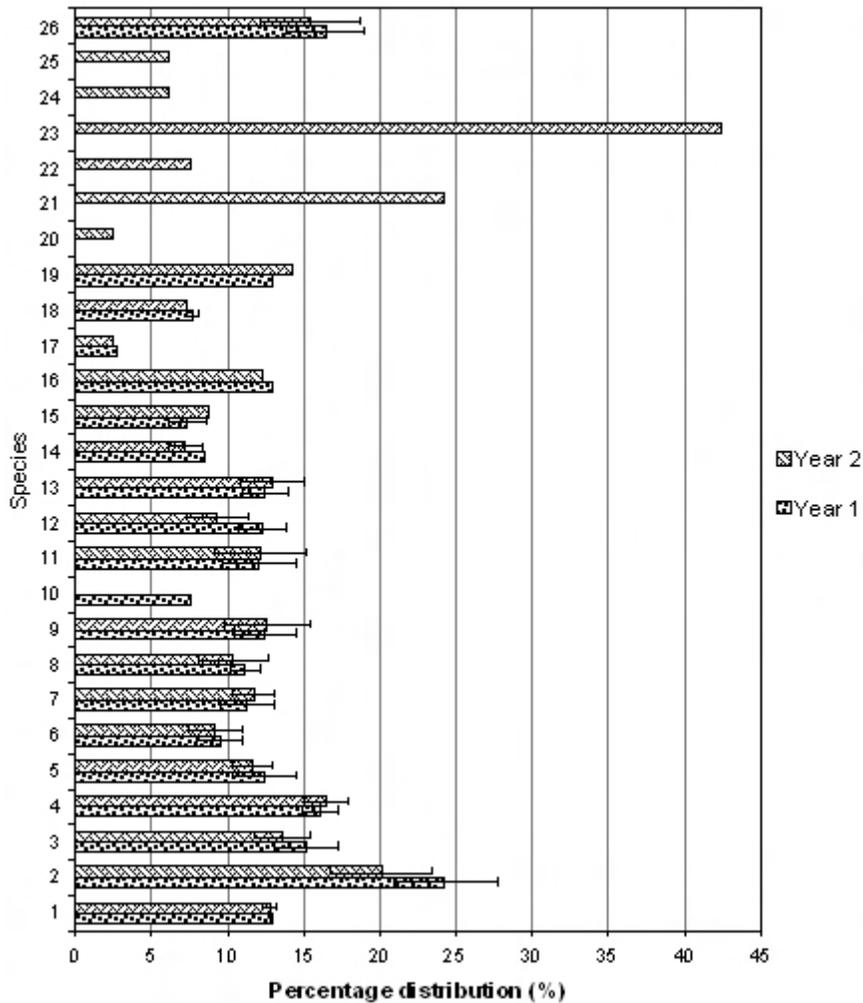


Fig 9b: percentage distribution of copepod species in relation to time in Woji-Okpoka Creek

(1=*Mesocyclops leukarti*; 2=*Temora longicornis*; 3=*Anomalocera patersoni*; 4=*Centropages typicus*; 5=*Metridia lucens*; 6=*Oithona similis*; 7=*Pseudocanus elongatus*; 8=*Candacia armata*; 9=*Acartia longiremis*; 10=*Acartia sp*; 11=*Onchocamptus sp*; 12=*Paracyclops affinis*; 13=*Paracyclops fimbriatus*; 14=*Calanus sp*; 15=*Macrocyclus distinctus*; 16=*Schmackeria inopinus*; 17=*Onchocamptus mohammed*; 18=*Eurytemora hirundoides*; 19=*Acanthocyclops bicuspidatus*; 20=*Pareachaeta norvegica*; 21=*Candacia sp*; 22=*Microcalanus sp*; 23=*Paracalanus sp*; 24=*Parapontella sp*; 25= *Temora sp*; and 26=*Cyclops strenus*)

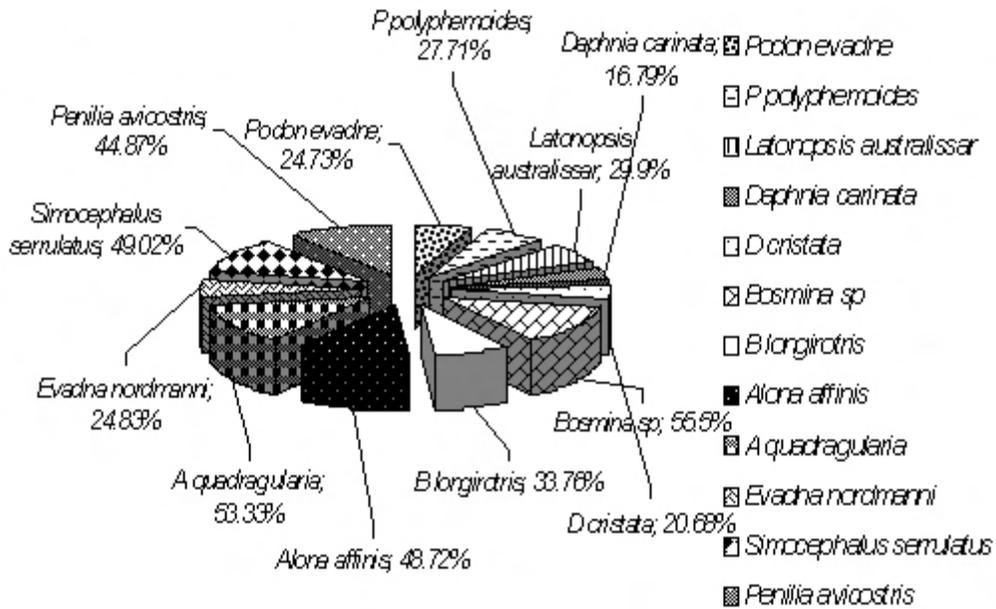


Fig 10a: Overall mean values of cladocera species in Woji-Okpoka Creek

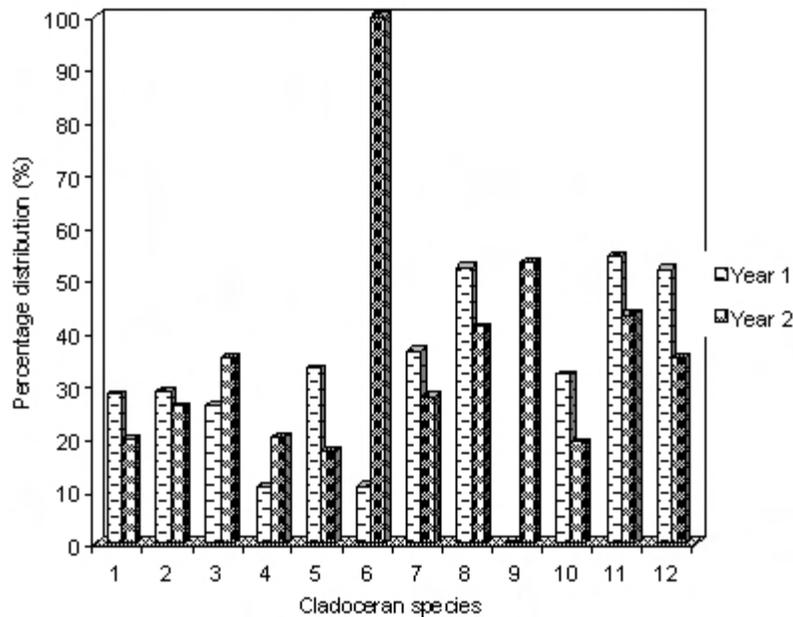


Fig 10b: Percentage distribution of cladocera species in relation to time in Woji-Okpoka Creek

(1=*Podon evadne*;2=*P. polyphemoides*;3=*Alatonopsis australissar*;4=*Daphnia carinata*;5=*D. cristata*;6=*Bosmina sp*;7=*B. longirostris*;8=*Alona affinis*;9=*A. quadragularia*;10=*Evadne nordmanni*;11=*Simocephalus serrulatus* ;and 12=*Penilia avirostris*;)

year 2 ($57.45 \pm 0.00\%$) than in year 1 ($32.33 \pm 3.67\%$). The mean similarity and dissimilarity indices were $22.27 \pm 5.71\%$ and $77.51 \pm 5.54\%$. Species composition of ostracoda was not similar along the stations ($P > 0.05$).

Euphasiacea: Density of *euphasiacea* ranged from 1309.00 ± 272.29 no/ml (Station 9) to

2617.44 ± 476.17 no/ml (Station 5) with a mean value of 1897.34 ± 142.72 no/ml (21.76%). Euphasiacea was the second dominant zooplankton fauna (21.76%), copepods being the highest (43.10%). Only 1 species (*Meganyctiphanes norvegica*) was observed. Species diversity indices were zero. Mean density ranged between

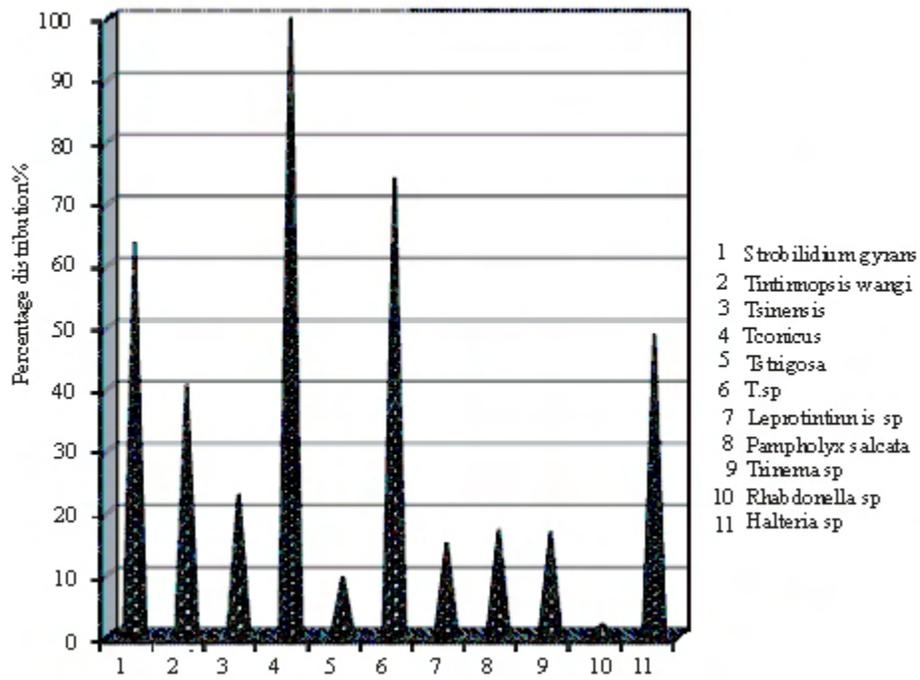


Fig 11a: Overall Percentage distribution of Protozoan species in Okpoka Creek

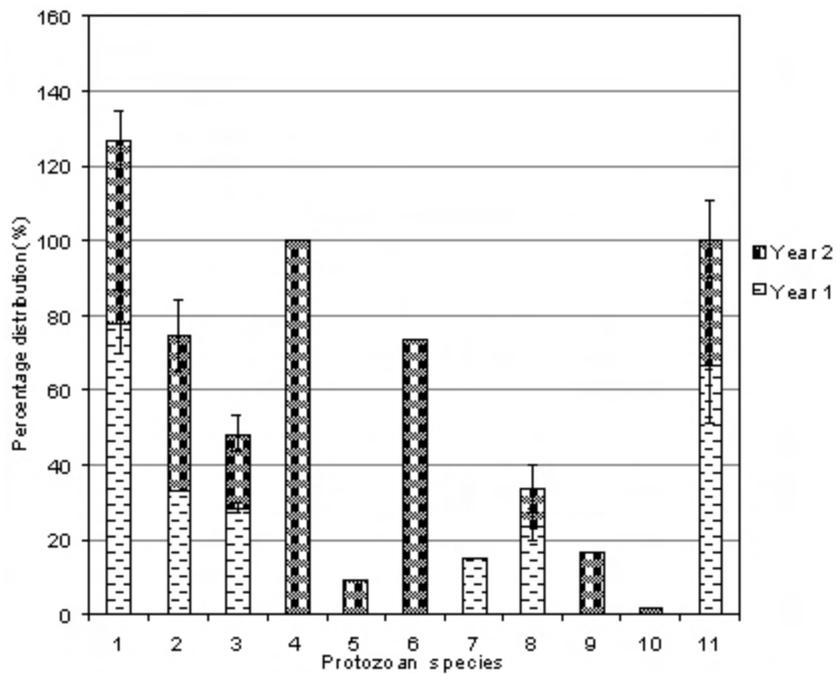


Fig 11b: Percentage distribution of protozoa species in relation to time in Woji-Okpoka Creek

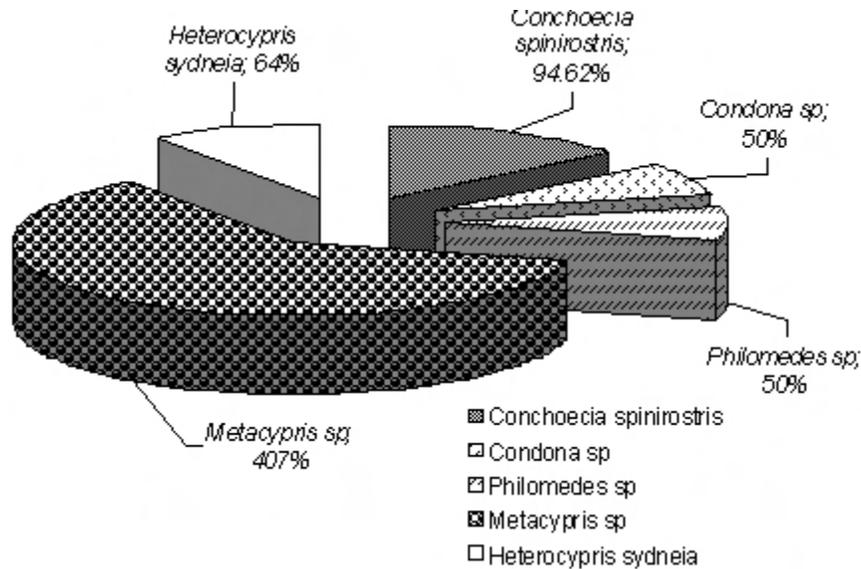


Fig 12a: Overall mean value of Percentage distribution of ostracoda species in Woji-Okpoka Creek

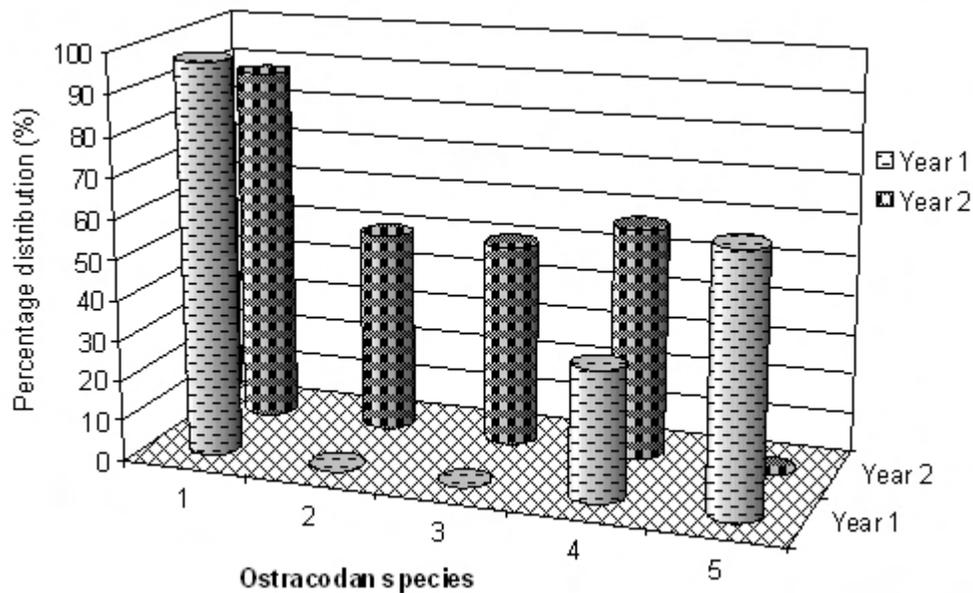


Fig 12b: Percentage distribution of *ostracoda* species in relation to time in Okpoka Creek

528.17±90.13no/ml (year 1) and 3156.10±203.91no/ml (year 2). The mean similarity and dissimilarity indices were 70.07±3.93 and 29.93±3.93% respectively. Species composition of euphasiacea was similar in this creek.

Branchiura: Branchiura density ranged between 142.00±0.00 no/ml (Station 1) and 473.67 ±125.55 no/ml (Station 6) with a mean of 234.54±31.47 no/ml). Branchiurans were 2.69% of the zooplankton community. Only 1 species *Argulus macropterus* was identified thus species diversity indices were zero. Temporal density ranged between 165.67±31.91no/ml (year 1) and

273.91±44.20no/ml (year 2) but temporal effect was significant (DMR). The mean similarity and dissimilarity indices were 2.50±2.50% and 97.44±2.56 %. Species composition of branchiura was not similar along the stations (P>0.05).

Surface water turbidity: The surface water turbidity ranged between 1.74±0.34NTU and 5.67± 1.42NTU with a mean value of 3.59 ± 0.32 NTU (Table 4). Turbidity in year 1 study turbidity was low (2.85±0.32 NTU) and in year 2, it was high (4.76±0.66 NTU) (Table 5). Temporal effect was significant (DMR).

Table 4: Physical parameters of surface water in relation to station of Woji-Okpoka Creek

Station	Turbidity (NTU)	Transparency (m)	Temperature (°C)
1	4.39±1.73ab	0.64±0.03bcd	28.46±0.20a
2	1.74±0.34b	0.64±0.03bcd	28.57±0.20a
3	4.44±1.29ab	0.59±0.03d	28.71±0.19a
4	3.21±0.83ab	0.67±0.03abcd	28.63±0.17a
5	2.21±0.43b	0.68±0.02abc	28.72±0.19a
6	2.64±0.46ab	0.72±0.03ab	28.68±0.21a
7	3.87±0.88ab	0.62±0.03cd	28.69±0.21a
8	3.51±0.69ab	0.65±0.03bcd	28.55±0.20a
9	4.18±1.12ab	0.65±0.03abcd	28.60±0.20a
10	5.67±1.42a	0.74±0.04a	28.76±0.21a

Means with the same alphabet in the same column are not significantly different ($P>0.05$)

Table 5: Physical parameters of surface water in relation to time of Woji-Okpoka Creek

Year	Turbidity (NTU)	Transparency (m)	Temperature (°C)
1	2.85±0.32b	0.65±0.01b	28.90±0.07a
2	4.76±0.66a	0.68±0.02a	28.22±0.10b

Means with the same alphabet in the same column are not significantly different ($P>0.05$)

Surface water transparency: The surface water transparency ranged from 0.59±0.03m (Station 3, abattoir wastes point) to 0.74±0.04m (Station 10) with a mean value of 0.66±0.01m and spatial variation was not significant ($P>0.05$). Transparency was higher in year 2 study (0.68±0.02m) than in year 1 (0.65±0.01m) though temporal variation was significant (DMR).

Surface water temperature: ⁻¹The surface water temperature ranged from 28.46±0.02 °C (Station) to 28.76±0.21°C (Station 10) with a mean value of 28.64±0.06°C. There was no significant spatial variation. Temporal variations of temperature are insignificant ($P>0.05$). Nevertheless, tidal variation was significant (DMR).

Surface water salinity: The salinity ranged between 4.71±0.51‰ (Station 1) and 14.83±0.83‰ (Station 10) with a mean value of 14.41±4.67‰ (Table 6). Salinity increased downstream and its variation was not significant ($P>0.05$). Temporal variation was significant (DMR) (Table 7).

Surface water dissolved oxygen (DO): The range of dissolved oxygen recorded was 4.12±0.37mg/l (Station 3, slaughter wastes discharge point) and 5.81±0.27mg/l (Station 9, free from wastes discharge) with a mean of 4.95 ± 0.10mg/l. Spatial influence on dissolved oxygen was significant ($P<0.01$). There was no significant temporal variation ($P>0.05$).

Surface water biological oxygen demand (BOD): The biological oxygen demand ranged between 2.68±0.24mg/l and 3.84±0.36gm/l and mean value of 3.26±0.09mg/l. Station 7 had the highest biological oxygen demand (3.84±0.36mg/l) and Station 5 the lowest biological oxygen demand (2.68±0.24mg/l) ($P>0.05$). Temporal influence was significant (DMR).

Surface water pH: The water pH ranged between 6.49±0.10 (Station 1) and 6.80±0.11 (Station 6) with a means values of 6.70 ± 0.02. had the highest pH (6.80 ± 0.11) and the lowest pH (6.49 ± 0.12). Spatial effect was not significant ($P>0.05$). Temporal variation was significant ($P<0.05$, DMR).

Alkalinity: The alkalinity values were 69.92± 2.78mg/l (Station 1) to 96.57±3.44mg/l (Station 10) with a mean value of 84.05±1.41mg/l. had alkalinity value of 69.92±2.78mg/l and was 96.57±3.44mg/l. Alkalinity fluctuations within the stations were highly significant ($P<0.001$).

Ammonia: Ammonia concentrations ranged between 0.14±0.11mg/l (Station 1) and 0.21±0.03mg/l (Station 3) with a mean of 0.17±0.01mg/l (Table 8). Spatial influence was not significant ($P>0.05$). Temporal variation was significant at $P<0.05$ (Table 9).

Nitrate: Nitrate values of the creek were between 0.44±0.04mg/l (Station 7) and 1.11±0.089mg/l (Station 1) with a mean of 0.64±0.02mg/l. Spatial variation of nitrate was highly significant at $P<0.001$. Temporal effect on nitrate was significant at $P<0.05$.

Phosphate: Phosphate concentrations ranged from 0.44 ± 0.09mg/l (Station 5) to 0.96±0.20mg/l (Station 8) with a mean of 0.70±0.05mg/l. Spatial variation was significant ($P<0.01$). Temporal influence was significant ($P<0.01$, DMR).

Sulphate: Sulphate concentrations ranged between 325.76±42.11mg/l (Station 1) and 881.60±173.37mg/l (Station 9) with a mean value of 560.05±28.87mg/l. Spatial fluctuations were highly significant ($P<0.001$). The temporal effect was significant at $P<0.01$.

DISCUSSION

The copepods were the dominant zooplankton class. This observation is consistent with other studies on the aquatic ecosystem (Falomo, 1998; Oronsaye, 1995; Oronsaye and Okaka, 2000; Kolo *et al.*, 2001; Aminu and Ahmed, 2000; Davies *et al.*, 2002; Ekwu and Sikoki, 2005). The dominance of copepods in terms of abundance indicates pollution according to Ruivo (1972). That study recommended that the use of organisms for monitoring pollution is based on the belief that natural unpolluted environments are characterized by balanced biological conditions and contains a great diversity of plants and animal life with no one species dominating. Falomo (1998) reported the dominance of copepods in the Oil Refinery-Axis of the Okrika Creek and their absence in the NAFCON-ONNE axis of the creek. That study attributed this observation to oil pollution at that axis. Furthermore, Edoghotu (1998) recorded copepods as the dominant zooplankton in *Okpoka* Creek. The observed

Table 6: Chemical parameters of surface water in relation to station of Woji-Okpoka Creek

Station	Salinity(‰)	Dissolved Oxygen (mg/l)	Biological oxygen demand (mg/l)	pH	Alkalinity (mg/l)
1	4.71±0.51b	4.74±0.29bcd	3.05±0.26ab	6.49±0.12d	69.92±2.78b
2	5.90±0.53b	4.57±0.30bcd	3.28±0.30ab	6.58±0.06dc	70.03±4.51b
3	7.14±0.51b	4.12±0.37d	2.79±0.29b	6.62±0.06bcd	88.90±7.01a
4	7.57±0.55b	4.28±0.32cd	3.13±0.33ab	6.65±0.05abcd	73.26±2.96b
5	8.99±0.71b	4.73±0.33bcd	2.68±0.24b	6.74±0.06abc	87.05±4.41b
6	10.28±0.61ab	5.19±0.32abc	3.73±0.34a	6.80±0.11ab	84.77±3.94a
7	12.04±0.71a	5.43±0.36ab	3.84±0.36a	6.75±0.06abc	90.10±4.45a
8	12.62±0.71a	5.13±0.29abc	2.94±0.25ab	6.73±0.06abc	90.97±3.80a
9	13.63±0.73a	5.81±0.27a	3.44±0.23ab	6.83±0.06a	89.56±3.78a
10	14.83±0.83a	5.55±0.32ab	3.72±0.30a	6.78±0.07abc	96.57±3.44a

Means with the same letter in the same column are not significantly different (P>0.05)

Table 7: Chemical parameters of surface water in relation to time of Woji-Okpoka Creek

Year	Salinity(‰)	Dissolved Oxygen (mg/l)	Biological Oxygen demand (mg/l)	pH	Alkalinity (mg/l)
1	17.41±7.61b	5.04±0.12a	3.46±0.11a	6.78±0.03a	87.19±1.56a
2	9.65±0.44a	4.81±0.19a	2.93±0.17b	6.57±0.03b	79.07±2.63b

Means with the same letter in the same column are not significantly different (P>0.05)

Table 8: Variations of water nutrients in relation to station in Woji-Okpoka Creek

Station	Ammonia (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Sulphate (mg/l)
1	0.14 ± 0.01 ^b	1.11 ± 0.09 ^a	0.50 ± 0.17 ^{ab}	325.76 ± 42.11 ^c
2	0.17 ± 0.02 ^{ab}	0.85 ± 0.06 ^b	0.80 ± 0.21 ^{ab}	346.93 ± 42.85 ^{dc}
3	0.21 ± 0.03 ^a	0.73 ± 0.06 ^{bc}	0.89 ± 0.14 ^{ab}	347.19 ± 43.86 ^{dc}
4	0.18 ± 0.02 ^{ab}	0.77 ± 0.05 ^b	0.62 ± 0.13 ^{ab}	425.69 ± 47.20 ^{cde}
5	0.19 ± 0.02 ^{ab}	0.61 ± 0.04 ^{cd}	0.44 ± 0.09 ^a	525.14 ± 42.85 ^{bcd}
6	0.19 ± 0.02 ^{ab}	0.47 ± 0.04 ^{cd}	0.94 ± 0.18 ^a	751.17 ± 189.02 ^{ab}
7	0.17 ± 0.02 ^{ab}	0.44 ± 0.04 ^c	0.85 ± 0.16 ^{ab}	616.25 ± 48.83 ^{abcd}
8	0.15 ± 0.02 ^{ab}	0.46 ± 0.05 ^{cd}	0.96 ± 0.20 ^a	667.88 ± 52.05 ^{abc}
9	0.17 ± 0.02 ^{ab}	0.48 ± 0.06 ^{cd}	0.58 ± 0.14 ^{ab}	881.60 ± 173.37 ^a
10	0.18 ± 0.02 ^{ab}	0.50 ± 0.04 ^{cd}	0.49 ± 0.09 ^{ab}	712.91 ± 42.77 ^{ab}

Means with the same letter in the same column are not significantly different (P>0.05)

Table 9: Variations of water nutrients in relation to time in Woji-Okpoka Creek

Year	Ammonia(mg/l)	Nitrate(mg/l)	Phosphate(mg/l)	Sulphate(mg/l)
1	0.19 ± 0.01 ^a	0.66 ± 0.02 ^a	0.80 ± 0.05 ^a	632.51 ± 45.05 ^a
2	0.15 ± 0.01 ^a	0.61 ± 0.04 ^b	0.49 ± 0.09 ^a	444.12 ± 26.49 ^b

Means with the same letter in the same column are not significantly different (P>0.05)

spatial and temporal variations of the zooplankton abundance might be traced to the varied salinity, turbidity, temperature, nutrients and other physico-chemical parameters. The low species diversity values might be associated with environment under stress. It is agreed by pollution biologists that species diversity declines as pollution effects are more severe. The lower the dominance, the higher the species diversity. The different similar and dissimilarity indices indicated varied environmental influences on the zooplankton community along the stations.

Turbidity is a vital water quality parameter due to sediment loading and the concomitant effect it will have on the light available for phytoplankton and epiphyton growths as well as other aquatic life (IADC, 2007). Turbidity controls the dynamic of phytoplankton (Chen *et al.*, 2003) and invariably zooplankton. The record of this present study did not exceed the level found in natural water bodies. Boyd (1981) reported that turbidities in natural waters seldom exceed 20,000mg/l and even muddy waters usually have less than 2000mg/l. Also, the observed turbidity level in this study agrees with the range of 2 NTU to 47 NTU reported by Asonye *et al.* (2007) for the turbidity of Nigerian rivers, streams and waterways.

The observed turbidity might be attributed to plankton. Swann (2006) reported that plankton is one of the causes of turbidity. The high turbidity of the creek in year 2 study might have reduced the zooplankton biomass. It has been reported that high turbidity reduces photosynthesis of phytoplankton, submerged and rooted aquatic vegetation which results to reduce plant growths and in turn suppress zooplankton productivity.

Sterner and Grover (1998), Chrzanowski and Grover (2001, 2005) and Roelke *et al.* (2007) reported that balance of light energy is assumed to regulate algae ecosystem structure. The recorded transparency favours the growth of phytoplankton that the zooplankton depends on. The observed temperature demonstrated narrow amplitude of variation. It showed the characteristic of the tropical environment and falls within the acceptable ranges (Obire *et al.*, 2003; Chindah *et al.*, 2005; Hart and Zabbey, 2005; Sikoki and Zabbey, 2006). The spatial variations of temperature was insignificant, an indication of similar temperature along the creek. All stations received relatively equal amount of heat from the sun and this might be responsible for the presence of zooplankton in all the stations. The observed significant temporal variations could be attributed to the heavy and prolonged

rainy seasons. Rains started earlier and encroached into the dry season.

Salinity affects the distribution patterns and relative abundance of organisms (Rendall and Wilkinson, 1986; Chindah, 2004; Sharipova, 2005). Salinity variations that could be expected are due to the distribution of rainfall. The observed increased salinity downstream could be attributed to proximity to the Estuary and sea. The heavy and prolonged rainy season during year 2 study might be reason for the lower salinity compared to the higher one in year 1 study.

Dissolved oxygen is probably the most universal applied water quality criterion. The observed dissolved oxygen concentrations were within the acceptable range. McNeely *et al.* (1979) reported that natural surface water has dissolved oxygen less than 10mg/l. Biological oxygen demand is of vital importance in pollution monitoring. The recorded biological oxygen demand is within the acceptable range for aquatic environments. Waters with biological oxygen demand levels less than 4mg/l are regarded clean and those with levels greater than 10mg/l are considered as polluted as they contain large amounts of degradable organic material (McNeely *et al.*, 1979). The lowered biological oxygen demand level in year 2 study could be as a result of reduced anthropogenic inputs. The pH is an index of hydrogen ion concentration and a very important environmental variable. The spatial variation was not significant. The difference between the highest and lowest pH recorded was not up to 0.5 pH units. This is an indication that the various anthropogenic inputs did not alter the ambient pH. The narrow pH range recorded favours many chemical reactions inside aquatic organisms (cellular metabolism) that are necessary for their survival and growth. Alkalinity is the buffering (alkaline) capacity of the water. The range of alkalinity observed is characteristic of estuarine environment. The reported alkalinity in this present study is within the acceptable range for natural surface water. Department of National Health and Welfare (1969) recommended an acceptable range of 30mg/l to 500mg/l for natural waters. The water of this creek is desirable for zooplankton and other aquatic life. The observed higher concentrations of alkalinity in the year 1 study suggest that increased runoffs and discharges had increased the alkalinity of the creek.

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