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Spatio-temporal distribution, abundance and diversity of zooplankton community structure in River Shasha, Southwestern Nigeria

A. A. Adedeji, T. A. Adesakin*, T. M. Oni, S. P. Oyebamiji, V. T. Olowogboyega

Department of Zoology, Obafemi Awolowo University, P.M.B. 13, Ile-Ife, Osun State, Nigeria

*Email address: ataiwinelson@gmail.com

ABSTRACT

This study was carried-out to investigate the abundance and diversity of zooplankton in River Shasha, Southwest Nigeria. The zooplankton community constitutes an important component in the faunal composition of the water body. Samples were collected bi-monthly between February 2006 to February 2008, with a mind of capturing various seasons in the period of study, at two sampling stations (Ipetumodu and Edun-abon) established along River Shasha. A total number of 54 zooplankton species were identified, comprising five classes, namely Rotifera (29 species), Ostracoda (8 species), Arthropoda (5 species), Copepoda (5 species), Protozoa (4 species) and Cladocera (3 species). The most abundant species were *Brachionus*, *Lecane* and *Keratella* recorded the highest distribution among the zooplankton observed during the sampling period. Among the Rotifers, *Branchions patulus* and *Filina opoliensis* were found abundant. *Holopedium amazonicum* and *Scapholebris armata* were predominant among the Cladoceras. Among the Copepods the dominant species was *Ectocyclops phaleratus* and *Hemicypris ovate* and *Cypris subglobosa* among Ostracoda. Among the Protozoa, *Diffugia sp* and *Vorticella sp* were observed. *Ceratopogonid sp.* was most dominant among Arthropoda. The density of zooplankton population was maximum during dry season (158702 Org/L) and minimum (12402 Org/L) during rainy season due to the different environmental conditions of the water bodies. The overall mean abundance of zooplankton population was in the following order: Rotifera > Protozoa > Arthropoda > Copepoda > Cladocera > Ostracoda. The few species of Zooplankton identified in River Shasha may reflect the moderate level of limit nutrient and there is a need for regular monitoring of the waterbody to avoid the excess input of nutrients from domestic and agricultural waste that could lead to eutrophication.

Keywords: Zooplankton, eutrophication, environmental condition and monitoring, Rotifera, Ostracoda, Arthropoda, Copepoda, Protozoa, Cladocera

1. INTRODUCTION

Alteration in water quality affects organisms living in the waterbodies. In most cases, its effects cause damage not only to individual species and population, but also to the natural biological communities [1]. Species assemblages in aquatic environment reflect interactions between organisms and the abiotic environment, as well as among organisms [2]. Plankton species are one of major valuable indicators of environmental conditions and since they are ecological indicators of many physical, chemical and biological factors [3, 4]. Zooplankton is one of the most biotic components and major groups of plankton that are highly sensitive to environmental variation. They are delicate microscopic organisms and they make a beautiful assemblage of minute floating animals that form the bases of food chains and food webs in any aquatic ecosystems. Due to their large density, shorter life span, drifting nature, high group or species diversity and different tolerance to the stress, they are being used as an indicator organism for the physical, chemical and biological process in the aquatic ecosystem [5]. Zooplankton communities are excellent bio-indicators in aquatic environment, as well as help in measuring the pollution level of any waterbody and play vital fundamental role in energy flow and nutrient cycling in aquatic ecosystems [6, 7]. They are inhabiting the pelagic zone of ponds, lakes, rivers and oceans where light penetrates. Fishes relied on them as a source of feed either directly or indirectly in aquatic environment [8]. Changes in their abundance, species diversity, or community composition can provide status on how impact as disturb the ecological condition of aquatic ecosystem. Any alteration in environmental factors, including water temperature, light, chemistry (particularly pH, oxygen, salinity, toxic contaminants), food availability (algae, bacteria), and predation by fish and invertebrates have a negative effect on plankton community [9, 10]. Several studies have been carried out on Zooplankton groups worldwide to evaluated environmental assessment especially aquatic ecosystem [11-18]. In this study we outline a two-year study of the zooplankton community in the habitat, in order to analyse species composition and seasonal dynamic of the zooplankton community.

2. RESULT/EXPERIMENTAL

2. 1. Area of study

River Shasha is located in Ife-North local government area of Osun State, Nigeria and it rises from Shasha village in Ile-Ife and empties into Lekki Lagoon at Imobi via Epe. It is one of the major rivers in the Ogun-Osun River Basin, as presented in **Figure 1**. It drains Southwestern parts of Osun State through Ogun State and southwards to empty into Lekki Lagoon in Lagos State, Nigeria. Some of the major tributaries of River Opa which discharges into Osun River in Ife North Local Government Area, River Owena and River Oni that empties into it just before it enters the lagoon. The river serves as a great economic importance to the people of Southwest part of Nigeria. There are two distinct seasons in Ife north local government just the rest of the country, the wet and dry seasons. The dry season extends from November to March, while the rainy season lasts from April to October. The rainfall pattern is characterized by two peaks; the first peak usually occurs between June and July, while the second peak occurs either in September or October. About 75,000 dwellers depend on it as their major source of water for drinking, other domestic reliance on the water are befits derived from this river and for agricultural purposes like irrigation, fishing activities and recreation.

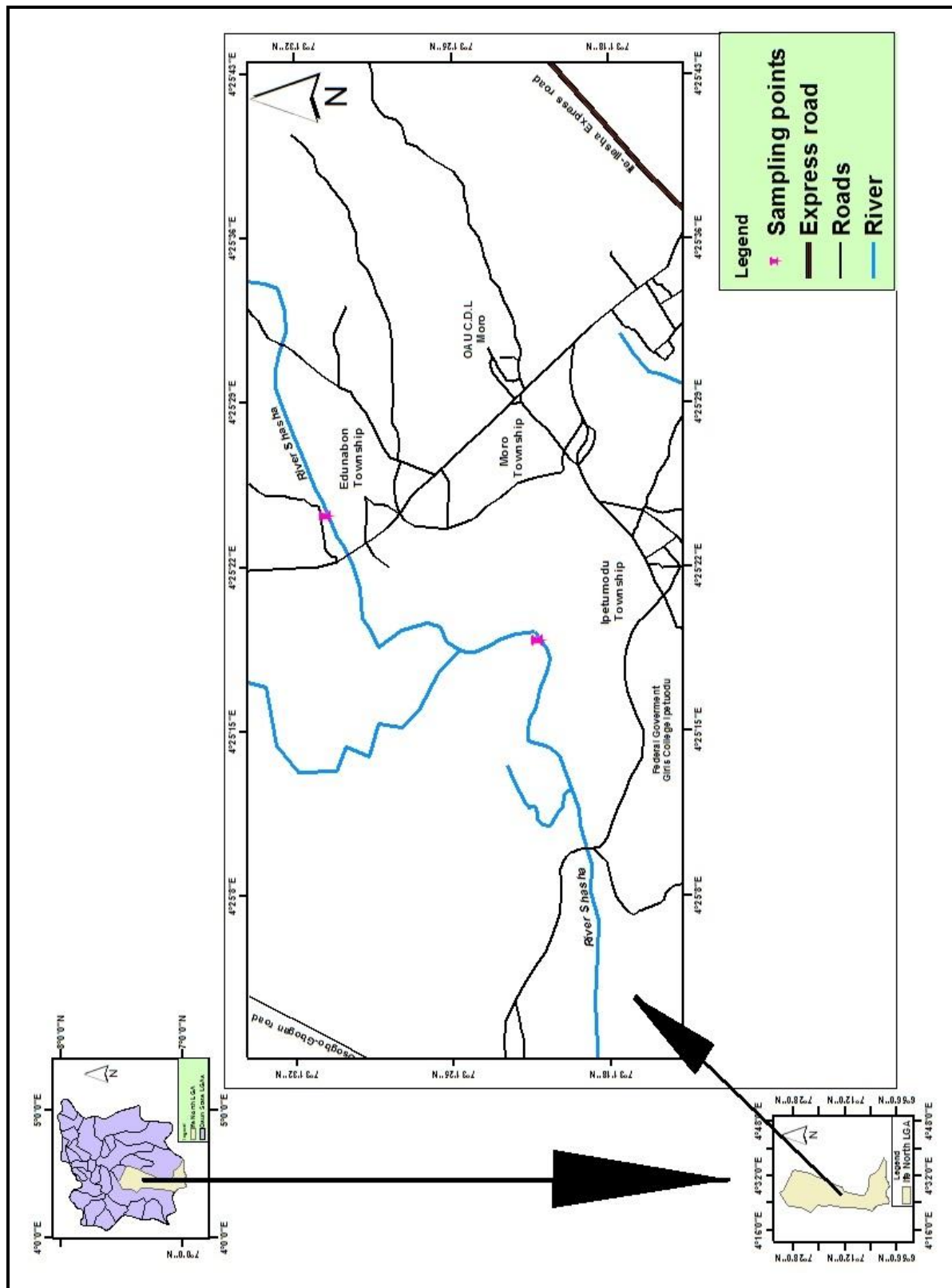


Figure 1. Map showing two sampling stations along River Shasha, Southwest, Nigeria

2. 2. Sampling procedure and collections

Two sampling stations were established along River Shasha, which are: River Shasha in Ipetumodu town with coordinate (Longitude 07°52.182' N; latitude 004°43.106' E) on altitude of 221 m above the sea level and River shasha in Edun-abon town with coordinate (Longitude 07°31.915' N; latitude 004°25.288' E) on altitude of 223 m above the sea level. The coordinate of the sampling locations was determined with Global position system (GPS). Samples were collected bi-monthly between February 2006 to February 2008 with a mind of capturing various seasons in the period of study (Figure 1).

Plankton samples were collected quantitatively using 55 µm Hydrobios plankton net. Samples for plankton analyses were collected by straining a known volume of water sample (30 litres) through a Hydrobios (fine meshed size) plankton net to a concentrated volume of 30 mL. Each sampling bottle was properly labelled and preserved with 5% formalin solution in specimen bottle and 3-5 drops of Lugol's solution was added to it depending on the density observed. The preserved plankton bottles were left to stand for about 10-14 days so that the plankton content could sediment. The supernatant was then decanted carefully leaving about 3 mL. The resultant 3 mL concentrated volume, which represents the plankton content of the original 30 litres of water was then examined. 1.5 mL of sample was put into the hydrobios counting chamber using a stamped pipette until the chamber was completely filled without any air bubble. This was carefully placed in the light microscope stage and allowed to settle for 10 minutes to enable the planktons to settle at the bottom of each square of the chamber. Proper identification and enumeration of plankton was carried-out using 10× and 40× objectives of an Olympus binocular microscope, according to the methods given in [19]. The plankton in each square of the chamber was identified to genus/species level based on the minute morphological details by observing them under the microscope using the taxonomic guide and standard identification key, as described in [19].

2. 3. Statistical analysis

The data were subjected to appropriate statistical analysis with SPSS version 23, PAST, using the standard Bio-Statistical method including descriptive statistics, analysis of variance (ANOVA).

3. RESULTS

A total number of 54 zooplankton species were identified in River Shasha during the period of study. Rotifera were mostly dominant group with 29 species in 10 genera, followed by Ostracoda with 8 species in 6 genera, Arthropoda with 5 species in 5 genera, Copepoda with 5 species in 5 genera, Protozoa with 4 species in 4 genera, and Cladocera with 3 species in 2 genera. The most abundant species were *Brachionus*, *Lecane* and *Keratella* which secondly dominated among the zooplankton observed during the sampling period, as presented in **Table 1**. At Ipetumodu station, total number of 155,404 Org/L was recorded for rotifera while the highest abundant individuals were recorded during the dry season (152,234 Org/L) compared with wet season (3,170 Org/L). *Brachionus patulus* had the highest abundant of individuals (87,503 Org/L) followed by *Filina pejeri* (62,567 Org/L). Arthropoda had 600 Org/L while the highest individuals were recorded in the wet season (567 Org/L) than dry season (33 org/L).

Nauplius larva had the highest abundant of individuals (433 Org/L) followed by *Euphausid* sp. (167 Org/L). Total number of 200 individuals were recorded for Cladocera group while wet season had the highest abundant of individuals (167 Org/L) compared with dry season (33 Org/L). It was dominant by *Holopedium amazonicum* and *Scapholeberis armata* (100 individuals each). Ostracoda had 33 individuals and dominant by *Heterocypris* sp. (33 Org/L). The total number of 765 individuals was recorded for Copepoda while wet season had the highest abundant of individuals (699 Org/L), higher than dry season (33 Org/L). *Ectocyclops phaleratus* had the highest abundance of individuals (633 Org/L) followed by *Paracyclops fumbriatus* (66 Org/L). 1,733 individuals of Protozoa were recorded during the period of study. Wet season had the highest abundant of individuals (1,633 Org/L), higher than dry season (100 Org/L) (Table 1).

At Edun-abon station, a total number of 11,203 individuals were recorded for rotifera while wet season had the highest number of individuals (7,832 Org/L), higher than the dry season (3,371 Org/L). *Filina pejleri* had the highest abundant of individuals (3,066 Org/L) followed by *Keratella tropica* (2,333 Org/L).

Table 1. Quantitative distribution, abundance and occurrence of zooplankton at two station of River Shasha, Nigeria

Taxon	Ipetumodu			Edun-abon		
	Dry season	Wet season	Overall	Dry season	Wet season	Overall
<i>Asplanchna priodonata</i>	233	100	333	0	0	0
<i>Asplanchna seiboidi</i>	0	200	200	0	0	0
<i>Brachionus calyciflora</i>	67	66	133	0	334	334
<i>Brachionus caudatus</i>	0	0	0	133	200	333
<i>Brachionus falcatus</i>	467	200	667	0	0	0
<i>Brachionus forficula</i>	301	67	368	0	0	0
<i>Brachionus havanaensis</i>	0	0	0	67	233	300
<i>Brachionus patulus</i>	87200	303	87503	106	1433	1539
<i>Cephalodella gibba</i>	33	0	33	0	0	0
<i>Euchlanis dilatata</i>	67	0	67	0	0	0
<i>Euchlanis luksiana</i>	200	0	200	0	0	0
<i>Filina opoliensis</i>	0	33	33	0	0	0
<i>Filinia pejleri</i>	61200	1367	62567	1533	1533	3066

<i>Keratella cochlearis</i>	0	0	0	67	300	367
<i>Keratella tecta</i>	0	0	0	166	233	399
<i>Keratella tropica</i>	0	0	0	833	1500	2333
<i>Keratella valga</i>	0	167	167	0	0	0
<i>Lecane bulla</i>	433	0	433	0	333	333
<i>Lecane closterocerca</i>	0	0	0	167	300	467
<i>Lecane leontina</i>	0	33	33	133	200	333
<i>Lecane luna</i>	1866	0	1866	133	300	433
<i>Lecane momstyla</i>	0	0	0	0	67	67
<i>Lecane stenroosi</i>	0	167	167	0	0	0
<i>Lepadella patella</i>	0	0	0	33	133	166
<i>Notholca acuminata</i>	0	0	0	0	66	66
<i>Notholca squamula</i>	100	167	267	0	167	167
<i>platyis quadridentatus</i>	0	300	300	0	0	0
<i>Trichocerca flagellate</i>	0	0	0	0	100	100
<i>Trichocerca similis grandis</i>	67	0	67	0	400	400
Total	152234	3170	155404	3371	7832	11203
Arthropoda	0	0	0	0	0	0
<i>Ceratopogonid sp.</i>	0	0	0	67	100	167
<i>Chaoborinid sp.</i>	0	0	0	67	0	67
<i>Chironomid sp.</i>	0	0	0	66	0	66
<i>Euphausid sp</i>	0	167	167	0	0	0
<i>Nauplius larva</i>	33	400	433	0	0	0
Total	33	567	600	200	100	300
Cladocera						
<i>Holopedium amazonicum</i>	33	67	100	0	0	0
<i>Scapholeberis armata</i>	0	100	100	0	0	0

<i>Scapholebris kingi</i>	0	0	0	0	67	67
Total	33	167	200	0	67	67
Ostracoda						
<i>Cypretta vavra</i>	0	0	0	0	100	100
<i>Cypris pubera</i>	0	0	0	0	67	67
<i>Cypris subglobosa</i>	0	0	0	0	133	133
<i>Hemicypris ovate</i>	0	0	0	134	33	167
<i>Heterocypris sp</i>	0	33	33	0	0	0
<i>Strandesia sp.</i>	0	0	0	0	100	100
<i>Zonocypris laevigata</i>	0	0	0	33	0	33
<i>Zonocypris ovate</i>	0	0	0	0	33	33
Total	0	33	33	167	466	633
Copepoda						
<i>Cyclops vicinus</i>	0	100	100	0	0	0
<i>Diacyclops sp.</i>	0	0	0	33	0	33
<i>Ectocyclops phaleratus</i>	33	633	666	0	0	0
<i>Microcyclops varicans</i>	0	33	33	0	0	0
<i>Paracyclops fimbriatus</i>	33	33	66	0	0	0
Total	33	699	765	33	0	33
Protozoa	0	0	0	0	0	0
<i>Centropyxis sp.</i>	100	33	133	0	33	33
<i>Diffugia sp</i>	0	0	0	0	67	67
<i>Notodromas entzi</i>	0	1600	1600	0	0	0
<i>Vorticella sp.</i>	0	0	0	33	33	66
Total	100	1633	1,733	33	133	166
Total zooplankton	152,433	6,233	158,702	3,804	8,598	12,402
Total dry	158,702		Total wet	12,402		

Arthropoda had the total number of 300 individuals while wet season had the highest number of individuals (200 Org/L), higher than dry season (100 Org/L). *Ceratopogonid* sp. (167 Org/L) was the most dominant species followed by *Chaoborinid* sp. (67 Org/L). Cladocera had a total number of 67 individuals, while the highest individual abundant was recorded in wet season and it was dominant by *Scapholeberis kingi* (67 Org/L). The total number of individuals recorded for Ostracoda was 633 individuals while wet season had the highest abundant of individuals of 466 Org/L, higher than dry season of 167 Org/L and it was dominant by *Hemicypris ovate* (167 Org/L) followed by *Cypretta vavra* and *Strandesia* sp. (100 Org/L). Copepoda had the number of 33 individuals in total and dominant by *Diacyclops* sp. (33 Org/L). 166 individuals were recorded for Protozoa while the highest individuals abundant was recorded for wet season (133 Org/L) compared with the dry season (33 Org/L) and *Diffugia* sp. (66 Org/L) was the most dominant species, followed by *Notodromas entzi* (33 Org/L).

The overall mean abundant of Arthropoda group (157.14 ± 53.29 Org/L) was recorded during the period of study (**Table 2**). The highest mean abundant was recorded at Ipetumodu station (200 ± 107.22 Org/L) compared with Edun-abon station (100 ± 25.82 Org/L) and there was a significant difference ($p < 0.05$) between the two stations (Table 2). Seasonally, dry season had the highest mean value (215.73 ± 28.24 Org/L), higher than wet season (71.29 ± 15.33 Org/L) (**Table 3**). Overall mean abundant recorded for Cladocera was (341 ± 112 Org/L) while the highest mean abundant was observed at Ipetumodu station (43.25 ± 35.93 Org/L), higher than Edun-abon (41.5 ± 8.5 Org/L). The highest mean abundant was recorded in dry season (216.75 ± 64.52 Org/L) compared with the wet season (78 ± 11 Org/L) and there was a highly significant difference ($p < 0.05$) between seasonal variations. The overall mean abundant of Copepoda (149.67 ± 104.19 Org/L) was observed at Ipetumodu station, while the highest mean abundant recorded in wet season (144.17 ± 98.88 Org/L) was greater than in dry season (29.33 ± 24.38 Org/L). The overall mean abundant for Ostracoda was higher in Edun-abon station (79.13 ± 15.42 Org/L) compared with Ipetumodu station (33.0 ± 0.1 Org/L), while there was a significant difference ($p < 0.01$) between the stations and the highest mean abundant was recorded at dry season (58.25 ± 8.42 Org/L), higher than in wet season (16.5 ± 16.5 Org/L). The overall mean abundant recorded for Protozoa was high in Edun-abon station (67.00 ± 0.10 Org/L), while the highest mean abundant for the seasonal variation was recorded during the dry season (66.5 ± 33.50 Org/L), higher than for the wet season (79.13 ± 15.42 Org/L). The overall mean abundant for rotifera was (5745.07 ± 3729.25 Org/L), while the mean abundant recorded at Ipetumodu station (3700.09 ± 2406.75 Org/L) was higher than Edun-abon station (224.06 ± 31.06 Org/L) and there was a significant difference ($p < 0.05$) between the stations. The highest mean abundant recorded during the dry season (3796.73 ± 2462.26 Org/L) was higher than for wet season (55.67 ± 40.31 Org/L), and there was significant difference ($p < 0.05$) between the seasonal variations.

The rotifera (33 to 8,8671 Org/L) constituted the largest group, making 97.84% of the total zooplankton population at Ipetumodu station, followed by Protozoa (1.09%) with organism ranging between 133 and 1,600 Org/L, and Copepoda (0.54%), having organisms between 33 and 666 Org/L. The genus *Brachionus* dominant the zooplankton genera consisting of 57.06% and was also the dominant genus among the rotifera making 55.83% in the group. The genus *Nauplis* recorded the highest number among the Arthropoda making 0.27% of the total zooplankton, while the genus *Ectocyclops* constituting 0.42% of the total zooplankton was the most genus among the class Copepoda. Both *Scapholeberis* and *Holopedium* constitute 0.02% among the zooplankton and 50% each among the Cladocera, while *Heterocypris* also

contributes 0.02% among the total zooplankton and 100% in Ostracoda class. The genus *Notodromas* constituted 1.01% of the total zooplankton group and 92.32% among the Protozoa class. The genus *Centropyxis*, a protozoan was the least abundant constituting only 0.08% among the zooplankton population (**Table 4**).

At Edun-abon, the range of rotifera recorded from 166 to 3,099 org/L, contribute 90.33% of the total zooplankton group, followed by Ostracoda (5.10%) with organisms ranging between 66 and 200 Org/L, and Cladocera are the least group constituting 0.54% of the zooplankton. The genus *Filina* dominated the zooplankton genera, constituting 20.57% and was also the dominant genus among the rotifera making 27.66% in the group. *Ceratopogonid* recorded the highest number among the arthropoda, making 1.11% of the total zooplankton, while the genus cypris constituting 1.61% of the total zooplankton was the dominant genus among the class Ostracoda with 31.59%. *Diffugia* recorded the highest percentage (40.36%) among the Protozoa and contributing 0.44% in the total zooplankton population, as presented in **Table 5**.

Table 2. Mean abundance of zooplankton of River Shasha, Southwest Nigeria

Taxa	Station				Anova		Overall	
	Ipetumodu		Edun-abon		F	P		
	Min-Max	Mean \pm S.em	Min-Max	Mean \pm S.em			Min-Max	Mean \pm S.em
Arthropoda	33-400	200 \pm 107.22	66-200	100 \pm 25.82	3.67	0.053	0-433	157.14 \pm 53.29
Cladocera	33-100	43.25 \pm 35.93	33-67	41.5 \pm 8.5	1.14	0.307	33-100	34.1 \pm 11.2
Copepoda	33-633	144.17 \pm 98.38	33-67	41.5 \pm 8.5	1.312	0.271	0-666	149.67 \pm 104.19
Ostracoda	33-33	33 \pm 0.0	33-134	79.13 \pm 15.42	13.89	0.002**	33-167	83.25 \pm 17.87
Protozoa	0-100	50 \pm 21.56	67-67	67 \pm 0.0	0.269	0.618	0-1600	379.8 \pm 306.19
Rotifera	33-86733	3700.09 \pm 2406.75	67-1000	224.06 \pm 31.06	2.021	0.018*	33-89042	5745.07 \pm 3729.25

Table 3. Overall mean abundance of seasonal variation of zooplankton group in River Shasha, Southwest Nigeria

Taxa	Dry Season		Wet Season		Anova	
	Min-Max	Mean \pm S.em	Min-Max	Mean \pm S.em	F	P
Arthropoda	33-900	215.73 \pm 28.24	33-133	71.29 \pm 15.33	5.932	0.050
Cladocera	100-400	216.75 \pm 64.52	67-100	78 \pm 11	2.631	0.002**
Copepoda	33-100	29.33 \pm 24.38	33-633	144.17 \pm 98.38	0.695	0.429

Ostracoda	33-67	58.25±8.42	0-33	16.5±16.5	0.2669	0.624
Protozoa	33-100	66.5±33.5	33-67	41.5±8.5	10.72	0.047
Rotifera	33-86733	3796.73±2464.26	0-134	55.67±40.31	3.98	0.054

Table 4. Percentage abundance and composition of zooplankton in Ipetumodu station of River Shasha, Southwestern Nigeria

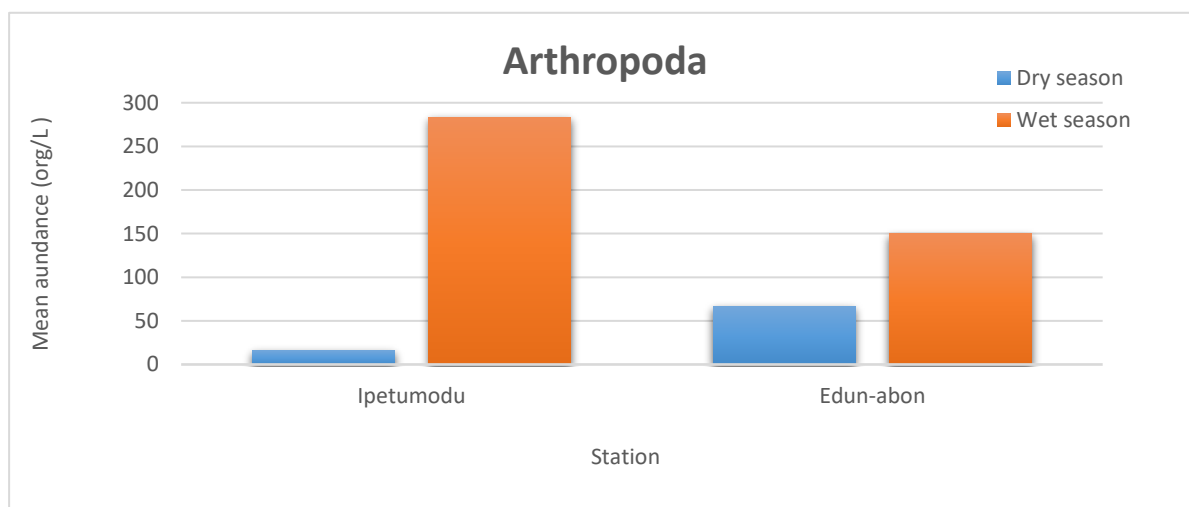
Class	Genus	Organisms/L	Species % in class	Species % in total zooplankton	Class % in total zooplankton
Rotifera	Asplanchna	533	0.34	0.34	97.84
	Brachionus	88671	57.06	55.83	
	Cephalodella	33	0.02	0.02	
	Euchlanis	267	0.17	0.17	
	Filina	62600	40.28	39.41	
	Keratella	167	0.11	0.11	
	Lecane	2499	1.61	1.57	
	Notholca	267	0.17	0.19	
	platyis	300	0.19	0.19	
	Trichocerca	67	0.04	0.04	
Total		155404	100	97.87	
Arthropoda	Euphausid	167	27.83	0.11	0.38
	Nauplius	433	72.17	0.27	
Total		600	100	0.38	
Cladocera	Scapholeberis	100	50.0	0.06	0.13
	Holopedium	100	50.0	0.06	
Total		200	100	0.12	
Ostracoda	Heterocypris	33	100	0.02	0.02

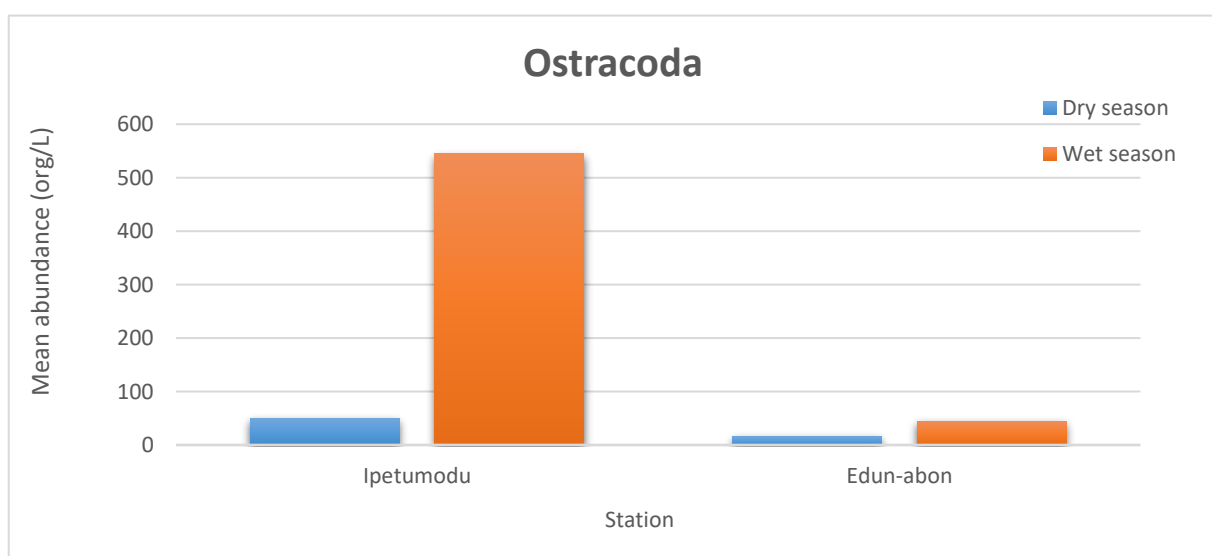
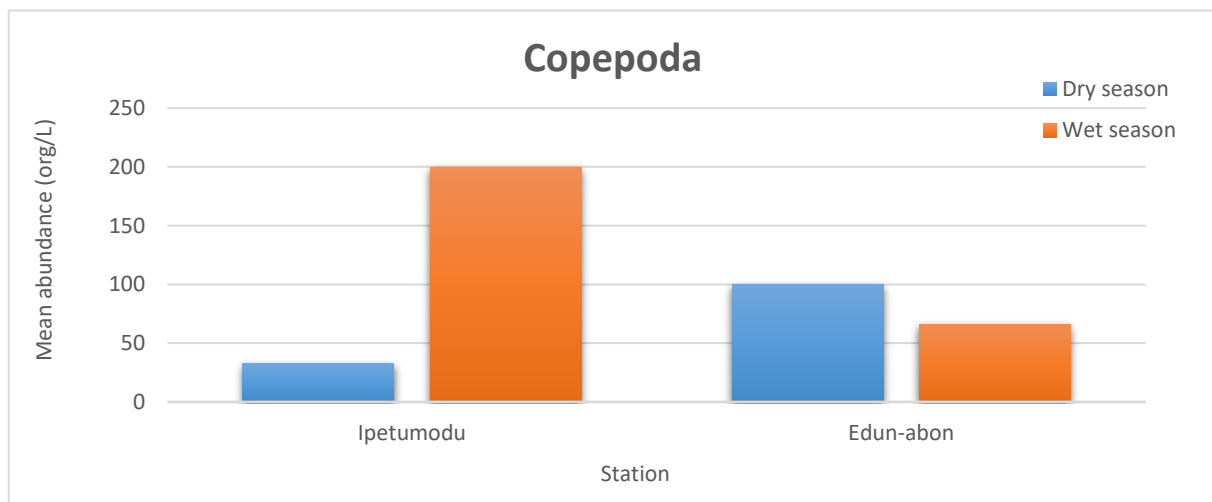
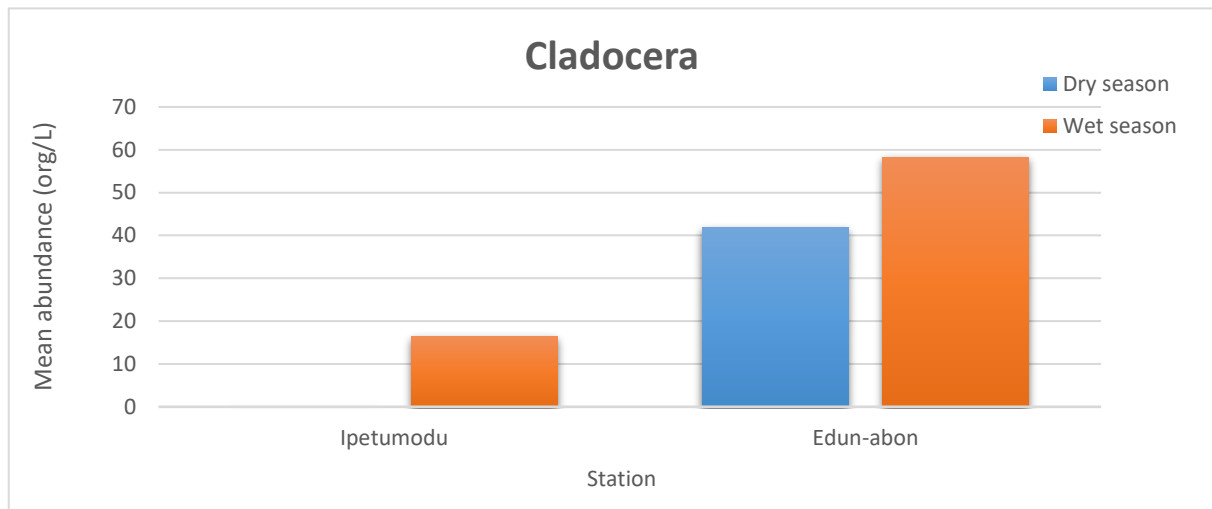
Total		33	100	0.02	
Copepoda	Cyclops	100	11.56	0.06	0.54
	Ectocyclops	666	76.99	0.42	
	Microcyclops	33	3.82	0.02	
	Paracyclops	66	7.63	0.04	
Total		865	100	1.06	
Protozoa	Centropyxis	133	7.67	0.08	1.09
	Notodromas	1600	92.32	1.01	
Total		1733	100	1.09	
Grand total		158835			100

Table 5. Percentage abundance and composition of zooplankton in Edun-abon station of River Shasha, Southwestern Nigeria

Class	Genus	Organisms/L	Species % in class	Species % in total zooplankton	Class % in total zooplankton
Rotifera	Asplanchna	2506	22.3	16.63	90.33
	Euchlanis	3066	27.37	20.35	
	Filina	3099	27.66	20.57	
	Keratella	1633	14.58	10.84	
	Lecane	166	1.48	1.10	
	Lepadella	233	2.08	1.55	
	platyis	500	4.46	3.32	
Total		11203	100	74.36	
Arthropoda	Ceratopogonid	167	55.67	1.11	2.42
	Chaoborinid	67	22.33	0.44	

	Chironomid	66	22.0	0.44	
Total		300	100	0.88	
Cladocera	Scapholeberis	67	100	0.54	0.54
Total		67	100	0.54	
Ostracoda	Cypretta	100	15.79	0.81	5.10
	Cypris	200	31.59	1.61	
	Hemicypris	167	26.38	1.35	
	Strandesia	100	15.79	0.81	
	Zonocypris	66	10.43	0.53	
Total		633	100	5.11	
Copepoda	Diacyclops	33	100	0.27	0.27
Total		33	100		
Protozoa	Centropyxis	33	19.88	0.22	1.34
	Diffugia	67	40.36	0.44	
	Vorticella	66	39.76	0.43	
Total		166	100	1.09	
Grand total		12402			100





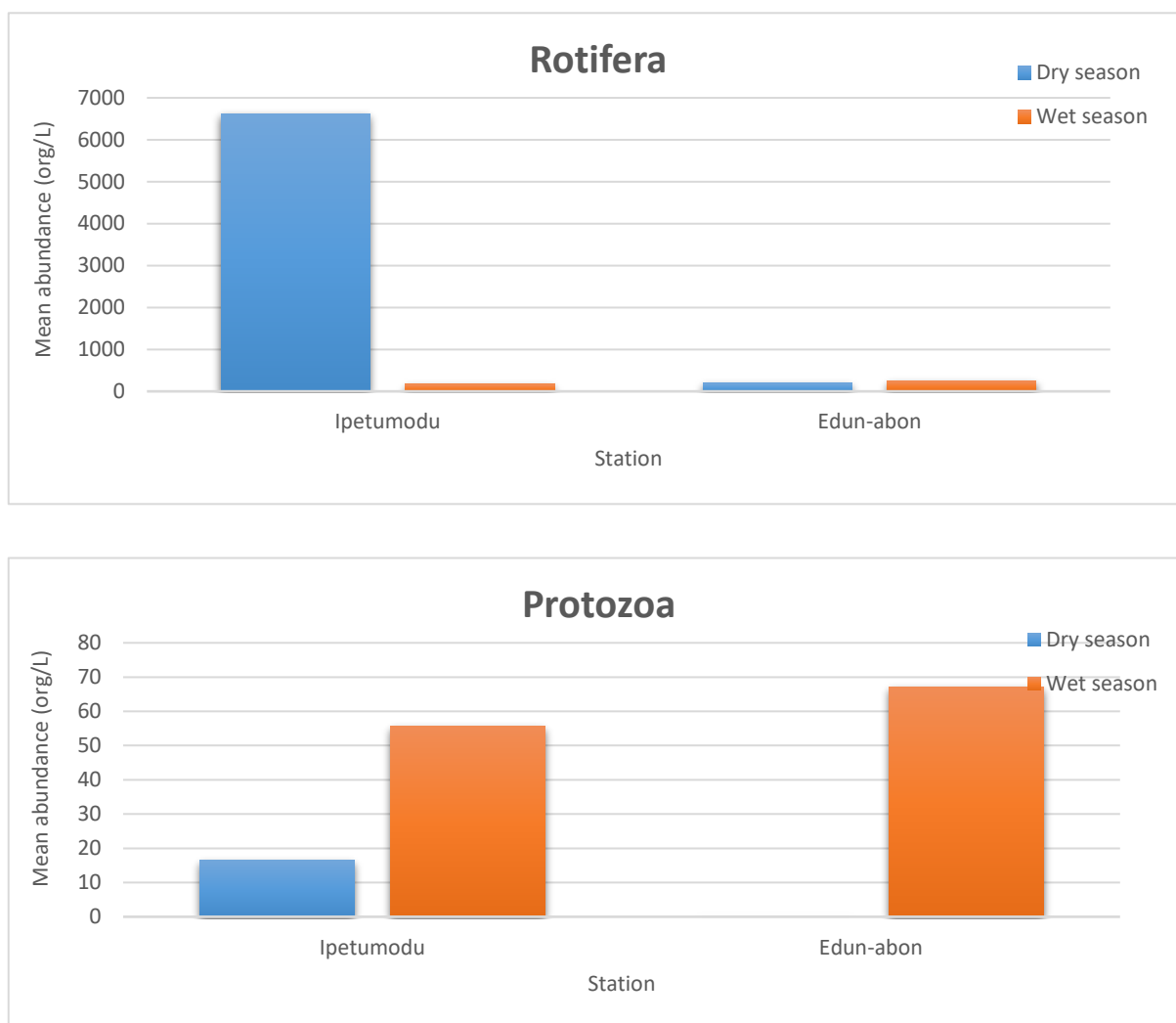


Figure 2. Seasonal variation in zooplankton groups between Ipetumodu and Edun-abon stations of River Shasha, Southwest Nigeria

Table 6. Diversity indices of zooplankton groups at Ipetumodu station in River Shasha, Southwest Nigeria

Diversity indices	Ipetumodu Station					
	Rotifera	Arthropoda	Ostracoda	Cladocera	Protozoa	Copepoda
Taxa_S	42	3	2	4	3	6
Individuals	155404	600	66	1733	200	865
Dominance_D	0.4368	0.5249	0.5	0.7562	0.3895	0.5547

Simpson_1-D	0.5632	0.4751	0.5	0.2438	0.6105	0.4453
Shannon_H	1.159	0.7858	0.6931	0.5296	1.01	0.9764
Evenness_e^H/S	0.07584	0.7314	1	0.4246	0.9154	0.4425
Brillouin	1.158	0.7759	0.6579	0.5244	0.9835	0.9605
Menhinick	0.1065	0.1225	0.2462	0.09609	0.2121	0.204
Margalef	3.43	0.3126	0.2387	0.4023	0.3775	0.7393
Equitability_J	0.31	0.7153	1	0.382	0.9196	0.5449
Fisher_alpha	3.972	0.4118	0.3891	0.4895	0.5006	0.869
Berger-Parker	0.5581	0.6667	0.5	0.8656	0.5	0.7318
Chao-1	42	3	2	4	3	6

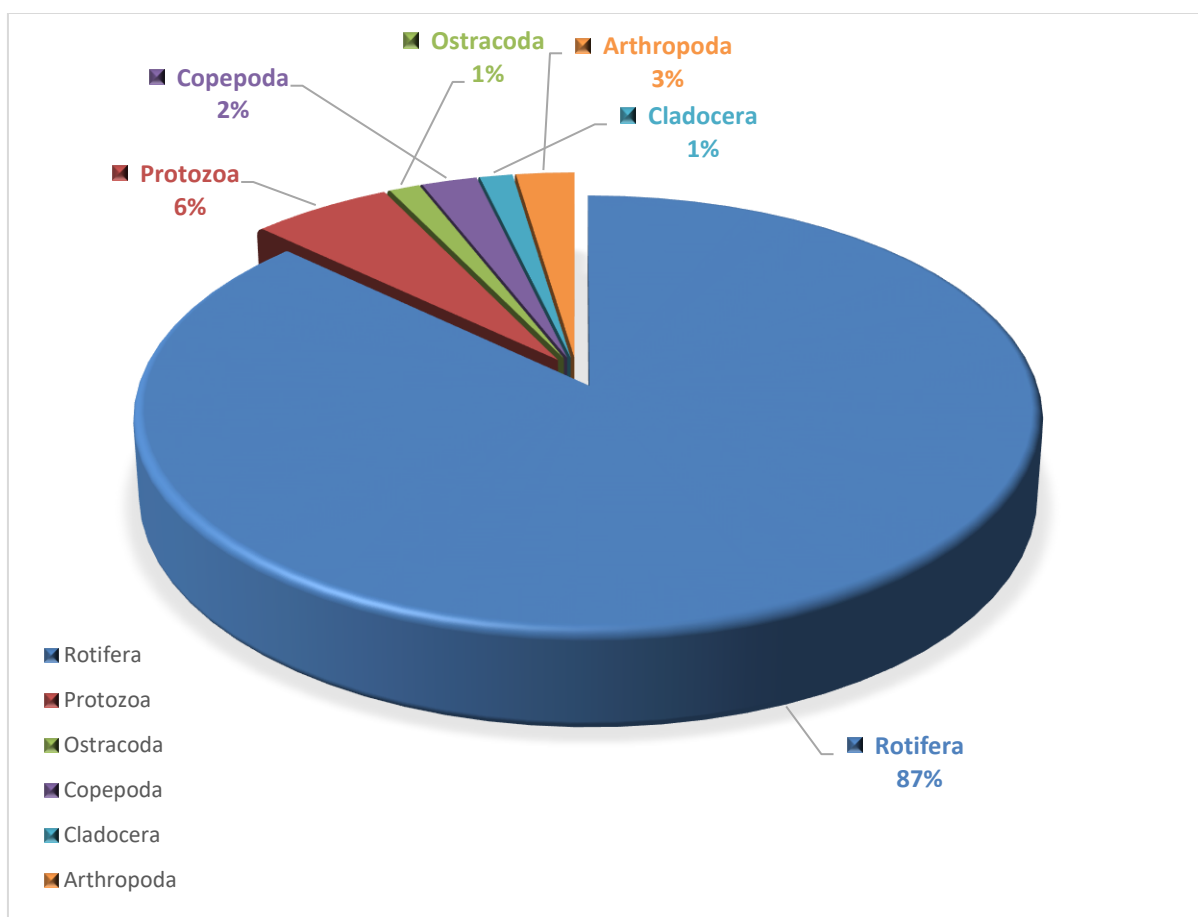


Figure 3. Pie chart showing the percentage overall mean abundance of zooplankton groups recorded in River Shasha, Southwest Nigeria

Table 7. Diversity indices of zooplankton groups at Edun-abon station in River Shasha, Southwest Nigeria

Diversity indices	Edun-abon Station					
	Rotifera	Arthropoda	Ostracoda	Cladocera	Protozoa	Copepoda
Taxa_S	50	5	8	4	2	4
Individuals	11203	500	633	166	134	166
Dominance_D	0.03884	0.2533	0.1582	0.2815	0.5	0.2815
Simpson_1-D	0.9612	0.7467	0.8418	0.7185	0.5	0.7185
Shannon_H	3.535	1.494	1.939	1.33	0.6931	1.33
Evenness_e^H/S	0.6856	0.8913	0.8692	0.9449	1	0.9449
Brillouin	3.52	1.471	1.908	1.284	0.6732	1.284
Menhinick	0.4724	0.2236	0.318	0.3105	0.1728	0.3105
Margalef	5.255	0.6436	1.085	0.5869	0.2042	0.5869
Equitability_J	0.9035	0.9285	0.9326	0.9591	1	0.9591
Fisher_alpha	6.742	0.7722	1.291	0.7379	0.3334	0.7379
Berger-Parker	0.08926	0.4	0.2117	0.4036	0.5	0.4036
Chao-1	50	5	8	4	2	4

Figure 2. The mean abundant of arthropoda was high in wet season for both stations, Edun-abon station had the highest mean abundant for Cladocera in wet season followed by dry season, while there was no occurrence of Cladocera in Ipetumodu station during the dry season. Copepoda mean abundant was with peak in wet season at Ipetumodu station and the lowest mean abundant was observed at dry season. The maximum mean abundant for Ostracoda was recorded at wet season in Ipetumodu station, while the lowest mean abundant was observed in dry season at Edun-abon station. The highest mean abundance for Protozoa was recorded at wet season for both stations and there was no occurrence of Protozoa during the dry season in Edun-abon station, while rotifera mean abundance was at peak in dry season in Ipetumodu station and the least mean abundance was recorded in wet season. Rotifera had the highest percentage with overall mean (87%) followed by Protozoa (6%), and the lowest was observed in Ostracoda and Cladocera (1%) (**Figure 3**). Indices results indicate that, among the zooplankton rotifera a high number of individuals and taxa (S) were observed for both stations, followed by Copepoda (865) in Ipetumodu station and Ostracoda (633) in Edun-abon station. The high dominance

values were showed by Cladocera (0.756), followed by Copepoda (0.555), Arthropoda (0.525) and the least for Protozoa (0.389) at Ipetumodu station, while at Edun-abon station Protozoa (0.50), Copepoda (0.282), and the least is rotifera (0.039), as presented in **Tables 6 and 7**.

4. DISCUSSION

Rotifera was the most dominant among the zooplankton genera recorded during sampling period in River Shasha which agrees with the report of [20] that rotifers are mostly dominant group of zooplankton assemblages in lentic waterbodies. Dominances of Rotifera and species like: *Brachionus* and *Lecane* were previously reported by [19-25] as the most dominant zooplankton group in Nigerian waterbodies. The high abundant of rotifers population observed in this study could be attributed to their parthenogenetic reproductive patterns and short developmental period under favourable conditions, their morphological variations or/ adaptations and their ability to feed on different food types [26, 27]. The dominance of rotifers in dry season could be due to their preference for warm waters as a result of low level of water that encourage their growth activities, as highlighted by [28]. The presence of *Brachionus species* is an indication that the river is eutrophic, and their abundance was due to the presence of high organic matter in the waterbody [29]. Rotifers are prominent group among the zooplankton of a water body irrespective of its trophic status. Among the zooplankton, rotifers respond more quickly to the environmental changes and are used as a change in water quality [30]. Rotifers are regarded as bio-indicators of water quality [31, 32] and high rotifer density has been reported to be a characteristic of eutrophic lakes.

Protozoa was secondly dominance in overall mean abundant of zooplankton population recorded in this study, while the highest mean abundance was recorded in dry season (66.5 ± 33.5 Org/L) and had 1.09% of total zooplankton composition observed in Ipetumodu station. This group of zooplankton is diversified in its morphology and physiology; in the body structure it makes them to be tolerant and survive in unfavourable condition. They are capable of forming resistant cysts around itself for protection against unfavourable conditions, while inside the cyst, it either rests or undertakes development of more spores by cell division for transmission via excystment to a new host on its return to a favourable environment [33]. Previously, [33-35] had earlier reported the predominance of Protozoa over the other groups of the zooplankton. Arthropoda group was thirdly dominance in term of overall mean abundant (157.14 ± 53.29 Individual/L) recorded during the period of study and also contribute 2.42% of the total class of zooplankton in Edun-abon station. They occur in all types of environments, from low ocean depths to very high altitudes and have various species adapted for life in marine, brackish and freshwaters, land and air; including places where other animals could not colonize. They are most capable of defending themselves against hazards or escaping from their enemies.

Copepods are considered as the most important food item for various fishes, they play a key role in the energy transformation at different trophic levels. It is reported that calanoid copepods best adapt to oligotrophic lakes, and cyclopoid copepods best adapt to eutrophic lakes [30]. A high range abundance of Copepoda (0-666 Individual/L) was recorded in the river Shasha. Copepoda group showed a high mean abundance in Ipetumodu station (144.17 ± 98.8 individual/L) compared with Edun-abon station (41.5 ± 8.8 individual/L), where a low mean abundance was recorded. Though, genus *Ectocyclops* was the dominant genus among the

copepods, its relatively low abundance in this study could be described as a good indicator of water quality.

This is because of the medical implications of large population of the genus in water bodies of Africa, where water is consumed directly from river without being treated. The low population of the genus could be due to their slow reproduction, growth and renewal rate. The absence of parthenogenetic forms of copepods might be responsible for their low population density.

The relatively low abundance of Cladocera and Ostracoda could be as a result dumping of waste materials in the waterbodies and hydrodynamics of this river, such as the low water volume, short residence time and its morphometry. The range of population of the two groups occurred at Ipetumodu station, maybe due to the presence of food (phytoplankton) on which they graze and the high transparency of the zone. The low genera abundance of cladocerans have also been documented in other water bodies like Lake Cubhu, South Africa [36], Ogun and Ona rivers [21] and Niger-Sokoto River [37]. The predominance are *Scapholeberis* and *Holopedium* among the cladocerans could have arisen due to their large bodied size which enables it to graze on large quantities and diverse forms of phytoplankton. The density and biomass of cladocerans were primarily determined by food supply. From the ecological point of view, cladocerans considered to be the most important components of zooplankton community. The group appears to prolifer more in ponds, lakes and reservoirs and prefer to live in clear waters. Ref. [38] reported that the decrease in the water level, livestock disturbances and anthropogenic activities increase the turbidity and thus inhibits the competitive abilities of *Daphnia* species. Present study findings are agreeable with earlier, report by [39] that the *Ceriodaphnia cornuta* is present only in oligotrophic lakes.

The Ostracoda are the entomostracans crustaceans having the bivalve carapace enclosing the laterally compressed body and find all kinds of fresh and marine water. The low abundances of Ostracoda species were usually affected by certain physico-chemical factors during this study. Ostracoda group was represented by *Cypris* and *Strandesia*. High individuals were noticed during the wet season and low abundance was recorded during the dry season respectively. Ref. [40] reported, that a high abundance and diversity ostracods occurred in hard water.

The high population density and biomass of zooplankton during the rains was traced to high population of phytoplankton food source which were highly abundant within the reservoir during the rains. According to [20], increase in the primary production (phytoplankton), tends to be followed by an increase in zooplankton number and biomass. Ref. [41] also corroborated the finding that zooplankton biomass usually reaches their peak during the rains in reservoirs. Apart from the food source, low predation by fish during the rains as a result of their breeding could also have encouraged the high population of the zooplankton.

High fish predation, less availability of food source, low temperature during “harmattan” period could be responsible for the decline in zooplankton during the dry season. Ref. [42] has emphasized these factors as being responsible for zooplankton biomass reduction. Food resource (bottom-up forces) [43], ability to adapt to food conditions and less predation (top-down forces) [44] may be the reasons for the significant abundance of Rotifers, Cladocera, and Copepoda in the rains. The absence of some genera, such as *Lecane*, *Sida* and *Diaptomus* in some stations could have occurred as a result of patchiness or dispersal. Dispersal has been noted to play a major role in structuring zooplankton population and communities [45].

4. 1. Diversity

Diversity indices reflect how rich and productive a waterbody is in terms of zooplankton species. The lowest abundance and species diversity observed in Ipetumodu station compared with Edun-abon station may be attributed to the relatively higher human activities, thus leading to poor water quality [21]. Shannon-wiener diversity index, Margalef's species diversity, as well as species composition were the highest for rotifera group in both stations. This observation is in line with the earlier work reported by [46], that the higher the Shannon-wiener index value, the greater the diversity. The highest Shannon-wiener diversity index of 3.535 for rotifera in Edun-abon station compared to Ipetumodu station (1.159) obtained in this study indicates a high diversity of zooplankton in Edun-abon station than Ipetumodu station, maybe due to urbanization development in Ipetumodu. Water bodies with algal Shannon-wiener diversity index <1 are classified as being heavily polluted, 1-3; moderately polluted and >3 clean [47, 48]. The Shannon-wiener diversity index in this study ranged from 0.5296-1.159 for Ipetumodu station and 0.6931-3.535 for Edun-abon station, suggesting that they are moderately polluted. Usually, the values of D for Simpson's index range between 0 and 1, where 0 represents an infinite diversity and 1 indicates no diversity. However, the Simpson's index of diversity represents the probability that two individuals randomly selected from a sample will belong to different species. This index ranges from 0 to 1 and the greater the value of Simpson's index of diversity, the greater the species diversity. The values of Simpson's reciprocal index start from 1 to represent a community with one species. The value of evenness varies between 0 and 1. The closer the value to 1, the more even the population of zooplankton species that form the community. Shannon-Weaver index (H) affects both, number of species and evenness of their population, diversity increases as both parameters increase. Diversity is maximum when all species that make up a community are equally abundant. The value of $E = 0.262$, shows that the species were unevenly distributed. The observation was similar to those of [49] in Majidun creek, Lagos, Nigeria and [50] in Ikoli creek, Niger Delta, Nigeria

5. CONCLUSIONS

Zooplankton composition observed in this study showed the river to be productive and will support a diverse species and population of fishes [51]. The assemblage was strongly influenced by the physico-chemical factors which showed the water quality to be good according to [52]. Temperature, food abundance, and nutrients were some of the factors that could limit zooplankton growth, composition and abundance in the waterbody [53]. Maintenance of good water quality in the reservoir will enhance the zooplankton community structure and population dynamics, and this will be a great advantage for fish production in the reservoir since the energetic trophic foundations for fish would have been well established.

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