Spacio-temporal variation of the zooplanktonic community of Esa-Odo Reservoir, Esa-Odo, Osun State, Nigeria.

ABSTRACT

Aims: The prime objective of this study is to determine the taxonomic composition of the zooplankton fauna of Esa-Odo Reservoir in Osun State and determine the spatial (horizontal and vertical) and seasonal variations in the composition, distribution abundance and community structure of the zooplankton community in the reservoir.
Study design: sampling stations were selected horizontally and vertically to over the entire zones of the reservoir. Planktonic samples were collected at two months interval for two years.
Methodology: Samples were collected from the depth using improvised Meyer's water sampler. Net and Total plankton were sampled by filtration and sedimentation methods. Planktonic samples were preserved as 5% formalin and 1% Lugol's solution. Measurement, enumeration and scaled pictures of the recorded zooplankton were taken using a photomicrograph. The taxonomic composition of zooplankton biota was determined using identification keys.
Results: Eighty three (83) species of zooplankton recorded in this study belong to 4 groups: Rotifera, Cladocera, Copepoda, and Insecta. Rotifera was the most represented group (61.21%). Horizontally, 24 species with the highest mean abundance characterized the lacustrine; while 12 species and 10 species were unique to the transition and riverine zones, respectively. Vertically, most species had their mean abundance decreased from surface to the bottom of the reservoir. A total of nine (9), two (2) and one (1) species were peculiar to the surface, bottom and mid-depth, respectively. Zooplankton were most abundant during the dry season.
Conclusion: Esa-Odo Reservoir comprised highly diversified zooplankton fauna with great potential to support rich aquatic community and fishery production. The reservoir can be classified as fairly clean based on the abundance of rotifer group. However, the lake should be subjected to regular proper monitoring because of the presence of some pollution tolerant copepod species identified among the zooplankton fauna.

Keywords: Zooplankton, Spatial, Temporal, Abundance, Biodiversity, Reservoir

1. INTRODUCTION

This study of the biodiversity, community structure and production capacity of the zooplankton community for assessment of waterbodies status is an aspect of bio-monitoring of aquatic ecosystem. Bio-monitoring is a process of using resident biota (biological indicators) in terms of diveristy and abundance to provide information on the state of the ecosystem[1]. Biological indicators are selected according to various criteria which include sedentary life, abundance and wide distribution, simple procedure of identification and sampling, high tolerance for pollutants, population stability and high accumulating capacity[2]. Based on these categories, planktonic organisms (Phyto and Zoo plankton) are very suitable for biological assessment of waterbodies. Of these two groups, zooplankton are the most valuable indicator for they are larger and easier to identify than phytoplankton[3]. Moreover, the zooplankton community is composed of highly sensitive organisms that respond to a large number of environmental changes in relatively short periods of time[4]. Consequently, studies of the structure and population dynamics of this community in lentic aquatic systems could be very useful tools in the analysis of the environmental disturbances to which such water bodies are subjected[5].
In addition, zooplankton are microscopic aquatic animal life forms having little or no resistance to currents and therefore free floating or suspended in open or pelagic waters[6]. While some forms of zooplankton move by vertical migration, their horizontal position is mostly determined by current movements of the body of water they inhabit[7]. Furthermore, because of their short life cycles,

plankton respond quickly to environmental changes and species composition are more likely to indicate the quality of water mass in which they are found. Based on these important roles zooplankton play in aquatic ecosystem as well as open water fisheries production, it is very necessary to find out their community structure and distribution.

Only a very few studies have been conducted on the zooplankton diversity and abundance in Nigeria. Unfortunately such types of studies along Esa-Odo Reservoir are poorly known. The prime objective of this study is to determine the taxonomic composition of the zooplankton fauna of Esa-Odo Reservoir in Osun State and the spatial (horizontal and vertical) and seasonal variations in the composition, distribution abundance and community structure of the zooplankton community in the reservoir. It is hoped that the research will contribute to information for the maintainance of a sound and healthy ecosystem in Esa-Odo Reservoir thus enhance fisheries production in the reservoir.

2. MATERIAL AND METHOD

2.1 Area of Study

Esa Odo Reservoir, one of the major impoundments on Osun River (Figure 1) was impounded in 1973[8]. The reservoir is located approximately on the geographical coordinates of longitudes 07° 35' to 07° 55' North of the Equator, and latitudes 004° 30' to 004° 55'East of Greenwich Meridean on an altitude of about 350 (meters) above mean sea level in Obokun Local Government Area of Osun State, Nigeria. The reservoir's dam axis is approximately 30km East of Osogbo (Osun State capital), about 20km North-East of Ilesa, about 210 km Southwest of Lagos (the major commercial city in Nigeria) and about 330 km Northeast of Abuja (the Federal capital territory of Nigeria)[9]. The reservoir was created primarily to supply potable water to communities in Obokun Local Government Area of Osun State. The reservoir also supplies raw water for industrial use to the International Breweries, Ilesa, Nigeria. The reservoir also generates regular supply of water for industries sited around Esa-Odo and also provides potentials for fishery enterprise as well as tourism. The reservoir site is linked with motor able roads with the state capital, Osogbo.

2.1.1 Sampling Programme and Field Determinations

Sampling Stations was selected horizontally (Lacustrine, Transition and Riverine) and vertically (surface, mid-depth and close to the bottom) to cover the entire zones of the reservoir (Figure 2). At shallow Stations, only surface water sample was collected for zooplankton while water samples was collected from three levels through the water column (surface, mid-depth and close to the bottom) of the reservoir at other stations (1S 1B, 2S, 2M, 2B, 3S, 3M, 3B) using an improvised Meyer's water sampler (2.5 L capacity). Riverine station (station 1) was established at the point of inflow of River Osun into the reservoir at 200 meters away from the inflow while Transition station (station 2) was established at the open water area of the reservoir. Lacustrine station (station 3) was established close to the dam area. In addition, stations 2L1, 2L2, 3L1 and 3L2 were established at the littoral zones of the transition and lacustrine stations of the reservoir.

2.1. 2 Zooplankton Collection and Analysis

Net plankton was sampled by filtering 50 litres of water through a plankton net of 50 μm mesh size and the plankton contained strained into a 30 ml universal bottles and preserved as 5% formalin solution and Lugol's solution for examination and identification.

Total Zooplankton was determined in the laboratory by taking 500 ml of water samples into total plankton flask and Lugol's solution was added (1:100) after which the water was reduced to 30 ml, poured into universal bottle and preserved as 5% formalin solution. The preserved zooplankton samples were examined in the laboratory using a photomicrograph (AC 100-240V, 0.2/0.1A 50/60Hz). Scaled pictures of the specimen was taken and specimen was also enumerated for the abundance determination.

2.1.3 Taxa Identification

The taxonomic composition of zooplankton biota was determined using identification keys by[10, 11, 12.]

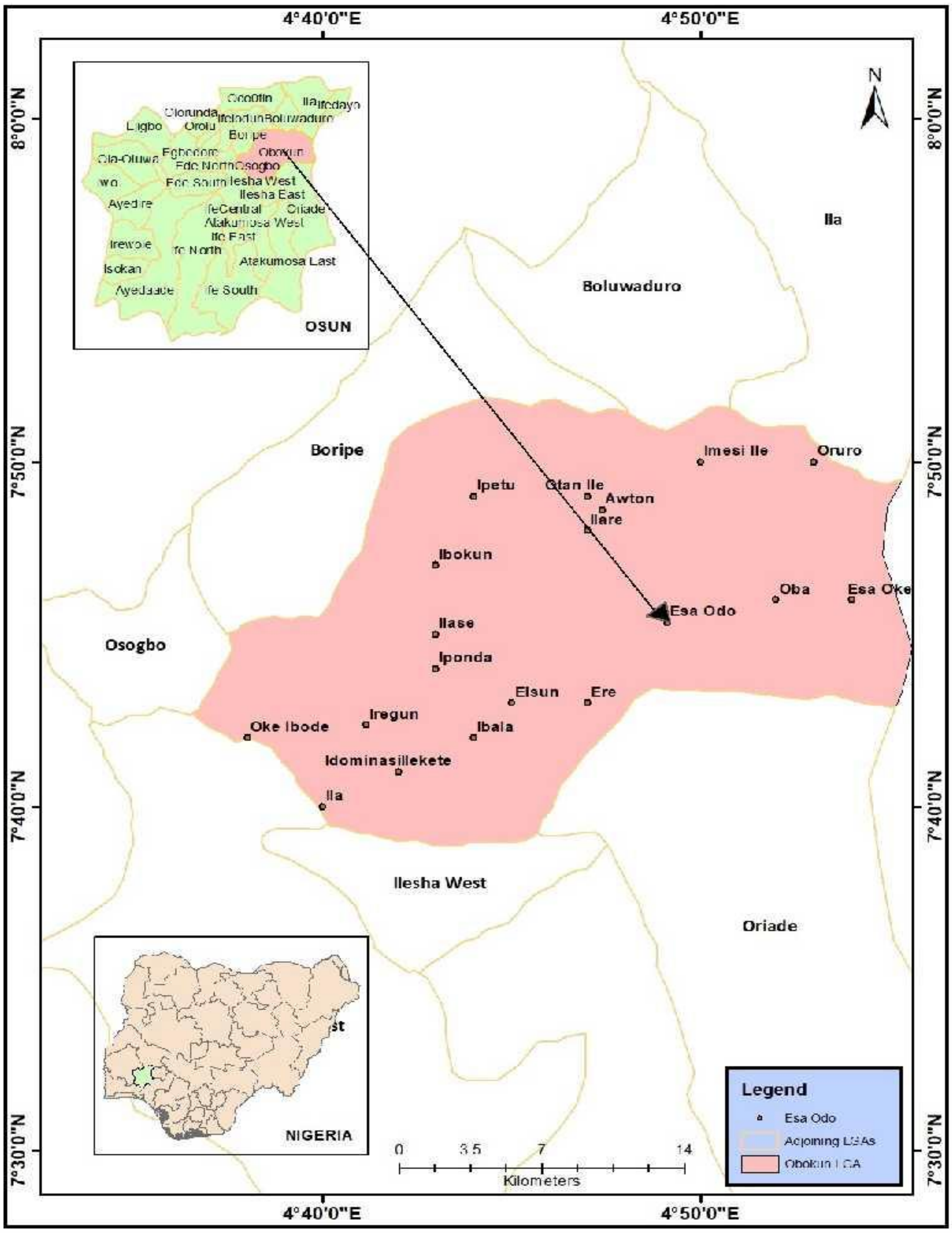

Fig. 1: Map of Obokun Local Government Area showing Esa-Odo

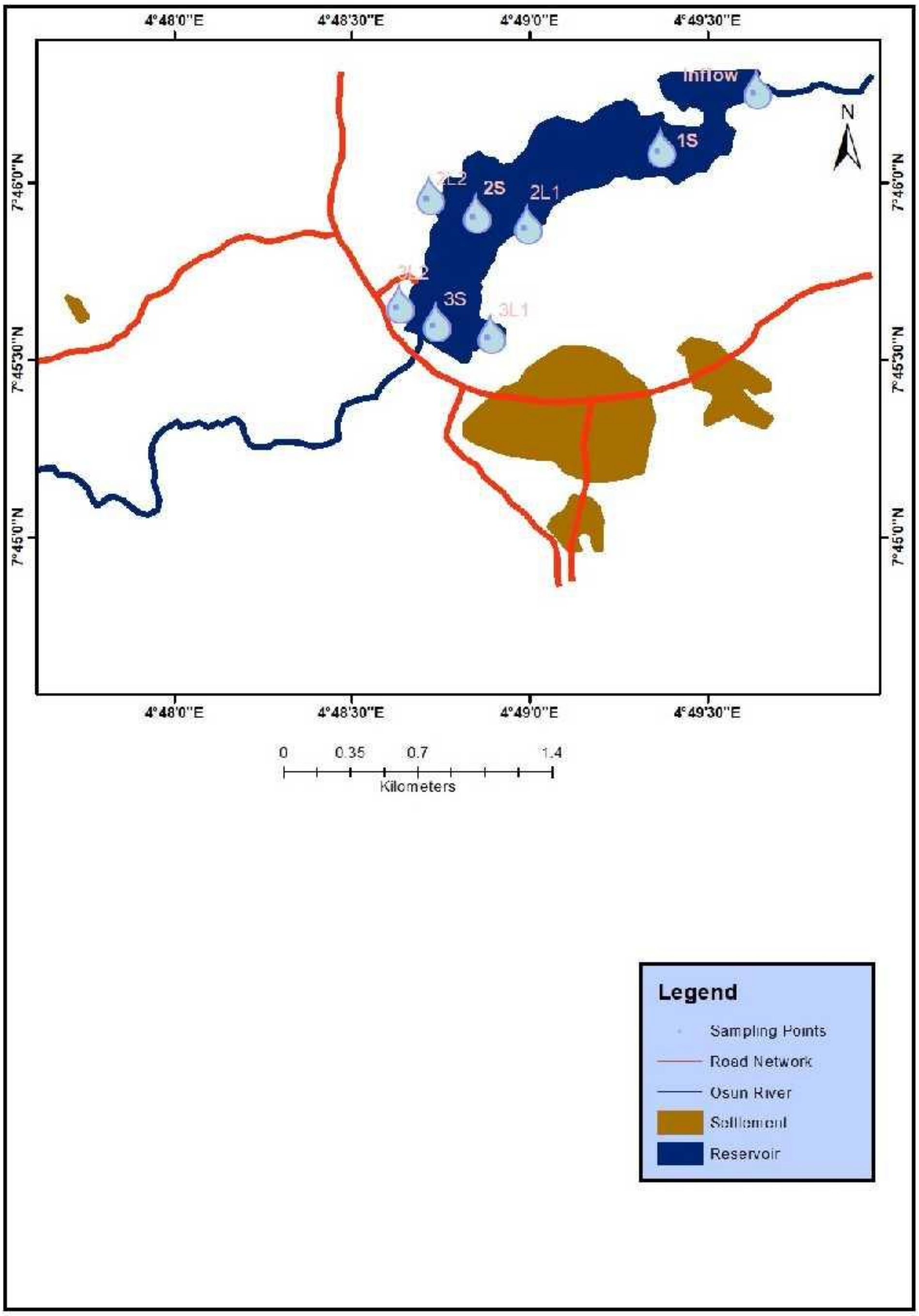

Fig. 2: Map of Esa-Odo Reservoir showing the selected sampling stations

2.1.4 Estimation of Plankton Standing Crop / Biomass

The difference species of the zooplankton observed in each plankton chamber was counted and recorded. Abundance was calculated and expressed in number of organisms per meter cube (Org/m^3) of original water sample using the formular:

$$A = \frac{ab}{c} \text{ X } 1000 \ldots\ldots 1$$

Where,
A = Abundance of specie per litre of original water sample
a = Abundance of specie in counting chamber
b = Total concentrated volume of water in counting chamber
c = Original volume of water used

3.0 RESULTS

3.1 Total zooplankton Composition, Classification, Distribution and Occurrence

From the Esa-Odo Reservoir 53 species of total zooplankton were recorded. Most of them (37) were identified to species level, while the remaining 16 were identified only to the generic level. The fauna comprised mostly rotifers and arthropods. There were about 39 species of rotifers belonging to 9 families and one order. The Arthropods comprised 8 Cladocerans, 4 Copepods, 2 Insecta species.

The fifty three (53) species identified from the investigated sampling stations through total zooplankton analysis belonged to 4 groups namely: Rotifera, Cladocera, Copepoda, and Insecta. Rotifera was the most represented group (Figure 3) with 61.21% of the species and was followed by Cladocera with 19.83% of the total composition. Protozoa and Insecta had the least percentage representation of 15.08% and 3.80% each (Figure 3). *Argonotholca foliacea, Argonotholca* sp. *Anuraeopsis fissa, Anuraeopsis navicula, Asplanchna* sp*. Brachionus falcatus, Filinia* ~~*pjeleiri,*~~*pejleri Lepadella ovalis, Polyarthra vulgaris, Polyarthra* sp*, Trichocerca tropis* were the dominant species of Rotifera while the Cladocerans comprised mostly of ~~*Simicephalus*~~ *Simocephalus* sp*, Alonella dentifera, Daphnia* sp*.* during the period of study. Copepod and Insect with the least percentage composition had Nauplius larva, *Eubranchipus* sp. and *Chironomus* sp. larvae and *Coene~~o~~agrion* respectively as their most dominant species. Most of the recorded total zooplankton species especially rotifers were found to be abundant at the surface water, littoral and riverine zone of the reservoir; among these were *Asplanchna* sp*, Brachionus* spp*, Argonotholca* spp*, Cephadella gibba, Euchlanis dilatata.* Also copepods were richly represented at this part of the reservoir (Table 1). Seasonally, more zooplankton species were recorded during the dry season through total than net zooplankton analysis.

3.2 Spatio-temporal Variation in the total Zooplankton species Abundance

The pattern of horizontal variation revealed that 24 species recorded their highest mean abundance at the lacustrine of the reservoir while only 12 species and 10 species had their maximum mean abundance at the transition and riverine zone of the reservoir respectively (Table 1). Only *Trichocerca tropis* and *Filinia teminalis* showed highly significant horizontal variation in abundance (P = .01) as their mean abundance decreased towards the riverine zone while *Brachionus havanaensis* increased towards the riverine zone with very highly significant horizontal variation (Table 1). Moreover, nine (9) of the recorded species had no horizontal variation spatially (Table 1).
Vertically*,* 13 species exhibited a similar pattern of vertical variation with their mean abundance decreasing insignificantly from surface water to the bottom of the reservoir while 7 species had non-significant increase from the surface water to the bottom of the reservoir (Table 2). *Filinia terminalis* and *Lecane monostyla bulla* revealed very highly significant vertical variation (P < .001) in mean abundance with maximum abundance at bottom and mid-depth respectively. Moreover, the variation in vertical abundance of *Cephalodella gibba*, *Euchlanis dilatata* and *Trichotria tetractis* were also significant (P =.05) though these were absent at bottom, mid-depth and surface water respectively. A total of nine (9) species, two (2) species and one (1) species were peculiar to the surface, bottom and mid-depth respectively though these did not show any significant vertical variance in abundance (Table 2). Of the recorded species, (14 species were absent from the mid-depth but occurred abundantly at the surface water and bottom of the reservoir (Table 2). Highest mean abundance at the mid depth of the reservoir were observed for eight (8) species while five (5) species had their lowest mean abundance also at the mid-depth of the reservoir (Table 2).

Formatted: Font color: Red
Formatted: Font color: Red
Formatted: Font color: Red
Formatted: Font color: Red

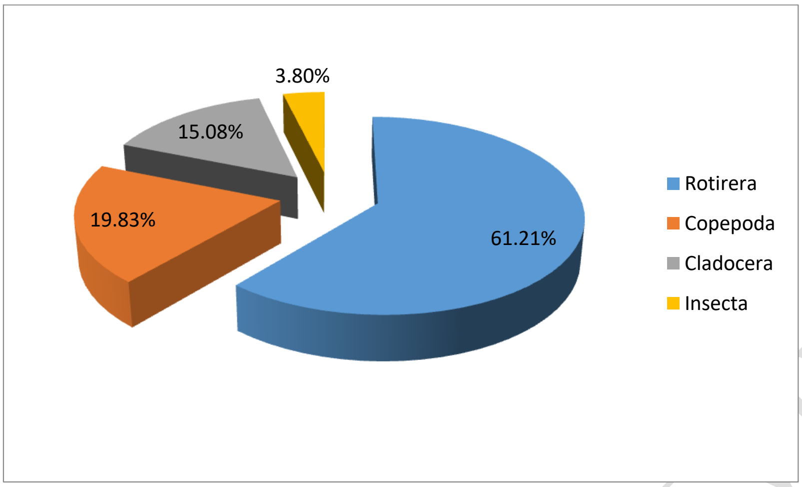

Fig. 3: Percentage abundance of zooplankton species

Table 1: ANOVA statistics of the horizontal variation in the mean abundance (Org/m^3) of total zooplankton species

Taxa	Lacustrine	Transition	Riverine	F	P
	Mean	Mean	Mean		
Anuraeopsis fissa	0.56±0.39	1.33±0.65	0.33±0.23	1.31	0.27
Anuraeopsis navicula	5.83±3.50	4.00±1.45	2.67±0.98	0.66	0.52
Asplanchna sp.	2.78±1.17	0.67±0.67	2.67±1.09	1.58	0.21
Argonotholca sp.	49.72±28.56	25.67±10.02	43.33±15.11	0.55	0.58
Argonotholca foliaceae	7.22±2.13	6.67±1.82	6.00±1.73	0.10	0.91
Brachionus angularis	2.78±1.57	0.17±0.17	1.50±0.75	2.33	0.10
Brachionus falcatus	22.50±11.40	8.50±2.42	14.50±7.17	0.92	0.40
Brachionus havanaensis	0.00±0.00	0.33±0.33	3.00±0.93	6.43	0.00***
Brachionus quadridentatus	0.00±0.00	3.17±1.69	2.00±1.06	1.23	0.30
Cephalodella gibba	0.00±0.00	0.33±0.33	1.50±1.34	0.73	0.49
Euchlanis dilatata	1.11±0.66	2.67±1.06	1.67±0.68	0.76	0.47
Euchlanis lucksiana	0.00±0.00	0.00±0.00	0.33±0.23	NV	NV
Filinia longiseta	0.00±0.00	0.00±0.00	0.17±0.17	NV	NV
Filinia pejleri	0.28±0.28	21.00±8.30	24.50±7.59	2.45	0.09
Filinia terminalis	4.72±1.80	2.17±1.04	0.00±0.00	4.90	0.01***
Elosa woralli	0.28±0.28	0.67±0.40	1.00±0.39	0.75	0.47
Keratella. tropica	1.39±0.71	3.67±1.99	0.67±0.32	1.46	0.23
Lecane bulla	7.78±3.17	3.00±0.93	5.33±1.75	1.51	0.22
Lecane closterocerca	2.78±2.78	1.50±0.75	0.67±0.40	0.63	0.54
Lecane leontina	0.28±0.28	2.50±1.57	0.67±0.67	1.09	0.34
Lecane luna	2.78±2.78	0.33±0.23	1.50±0.85	0.84	0.43
Lecane sp	0.28±0.28	0.33±0.33	0.33±0.23	0.01	0.99
Lepadella ovallis	0.28±0.28	1.83±1.10	1.67±0.98	0.60	0.55
Lepadella patella	2.22±1.06	1.17±0.48	1.17±0.59	0.68	0.51
Mytilinia mucronata	0. 00±0.00	2.00±0.78	1.00±0.52	2.28	0.11
Monostyla lunaris	0.00±0.00	0.67±0.40	0.00±0.00	NV	NV
Monostyla bulla	0. 00±0.00	0. 00±0.00	0.67±0.40	NV	NV
Notholca sp	0.00±0.00	0.00±0.00	0.67±0.31	NV	NV
Platyias sp	0.83±0.61	0.50±0.50	0.00±0.00	0.95	0.39
Macrochaetus sp.	3.89±1.51	2.50±0.97	3.50±1.82	0.22	0.80
Polyarthra vulgaris	0.83±0.83	0.00±0.00	0.00±0.00	NV	NV
Polyarthra sp.	16.11±4.90	7.00±1.63	12.67±5.47	1.08	0.34
Scaridium longicaudum	0.28±0.90	1.00±0.57	2.33±1.15	1.38	0.25
Trichocerca leontina	0.00±0.00	0.33±0.23	0. 17±0.17	0.67	0.51
Tricocerca multicrinis	0.00±0.00	0.00±0.00	0. 17±0.17	NV	NV
Trichocerca elongata	0.00±0.00	2.37±1.26	0. 33±0.23	2.33	0.10
Trichocerca weberi	0.00±0.00	0.17±0.17	0.50±0.28	1.28	0.28
Trichocerca tropis	6.11±2.33	2.67±0.85	1.33±0.60	3.72	0.03*
Trichotria sp	0.28±0.28	0.00±0.00	0.00±0.00	NV	NV
Copepod nauplius	8.61±2.56	12.83±6.57	7.83±1.72	0.37	0.69
Euclyclops agilis	0.83±0.83	1.67±0.96	2.17±1.01	0.40	0.67
Eudiaptomus gracilis	0.56±0.56	1.33±0.93	1.17±1.01	0.15	0.8
Eucyclops sp.	0.56±0.39	19.67±13.32	1.00±0.52	1.59	0.21
Diaptomus sp.	0.00±0.00	0.67±0.47	1.00±0.57	0.90	0.41
Alonella dentifera	0.83±0.47	1.33±0.84	0.00±0.00	1.50	0.23
Daphnia sp.	10.00±8.38	2.17±1.41	0.33±0.33	1.77	0.17
Diaphanosoma sp	1. 11±1.11	1.00±0.57	0.00±0.00	1.15	0.32
Eubranchipus sp	1. 67±0.85	0.17±0.17	1.00±0.62	1.75	0.18
~~*Dunhivedia*~~ *Dunhevedia crassa*	1. 11±0.87	0.00±0.00	0.00±0.00	NV	NV
~~*Pleuroxis*~~ *Pleuroxus denticulatus*	0. 56±0.56	0.50±0.28	0.00±0.00	1.15	0.32
~~*Simicephalus*~~ *Simocephalus* sp	3.61±1.74	1.17±0.72	1.00±0.39	2.20	0.12

Formatted: Font color: Red

Chironomus sp larva	1.39±1.39	3.67±2.02	1.50±0.71	0.74	0.48
Coen~~o~~agrion sp	0.56±0.39	1.33±0.73	1.50±1.06	0.27	0.76

NV = No Variance

Table 2: ANOVA statistics of the vertical variation in the mean abundance (Org/m^3) of total zooplankton species

Taxa	Surface Mean±SE	Mid-Depth Mean±SE	Bottom Mean±SE	F	P
Anuraeopsis fissa	0.93±0.38	0.42±0.42	0.42±0.42	0.35	0.71
Asplanchna sp.	2.04±0.67	1.67±1.30	1.67±1.67	0.35	0.71
Argonotholca sp.	26.02±6.92	38.75±28.02	91.25±45.39	0.35	0.71
Argonotholca foliaceae	8.15±1.37	5.00±3.01	0.83±0.83	0.35	0.71
Brachionus angularis	1.57±0.62	1.25±1.25	0.00±0.00	0.05	0.96
Brachionus falcatus	12.31±4.18	2.50±1.73	33.33±16.78	0.05	0.96
Brachionus havanaensis	0.93±0.41	4.17±1.69	0.00±0.00	0.22	0.80
Brachionus quadridentatus	1.85±0.79	1.25±1.25	3.33±3.33	0.56	0.57
Cephalodella gibba	0.83±0.75	0.83±0.83	0.00±0.00	3.01	0.05*
Euchlanis dilatata	2.50±0.70	0.00±0.00	1.25±0.92	3.17	0.04*
Euchlanis lucksiana	0.19±0.13	0.00±0.00	0.00±0.00	NV	NV
Filinia longiseta	0.09±0.09	0.00±0.00	0.0±0.00	NV	NV
Filinia pejleri	17.22±4.91	36.25±17.43	0.42±0.42	2.66	0.07
Filinia terminalis	0.74±0.45	1.67±1.15	7.50±2.84	5.54	0.001***
Elosa woralli	1.02±0.32	0.00±0.00	0.00±0.00	0.31	0.73
K.~~K.~~ tropica Keratella	2.41±1.12	0.00±0.00	2.08±1.04	0.16	0.85
Lecane bulla	6.39±1.46	2.50±1.73	1.25±0.69	1.70	0.19
Lecane closterocerca	2.04±1.03	0.42±0.42	0.00±0.00	0.58	0.56
Lecane leontina	1.67±0.94	0.00±0.00	0.83±0.58	2.02	0.14
Lecane luna	0.09±0.09	3.75±2.07	4.58±4.17	0.71	0.49
Lecane sp.	0.37±0.23	0.00±0.00	0.42±0.42	0.44	0.65
Lepadella ovallis	1.48±0.68	2.08±2.08	0.42±0.42	0.34	0.71
Lepadella patella	1.76±0.51	0.00±0.00	1.25±0.92	1.37	0.26
Manfredium eudactylotum Beauchampiella eudactylota~~Manfredium eudactylotum~~	1.39±0.69	0.00±0.00	0.00±0.00	NV	NV
Monostyla bulla.	1.20±0.49	6.67±2.53	0.00±0.00	8.34	0.00***
Monostyla lunaris	0.37±0.23	0.00±0.00	0.00±0.00	NV	NV
Notholca sp.	0.00±0.00	0.00±0.00	0.42±0.42	NV	NV
Platyias sp.	0.46±0.33	0.00±0.00	0.42±0.42	0.24	0.79
Anuraeopsis navicula	3.98±1.34	5.00±2.69	2.50±1.73	0.22	0.80
Polyarthra vulgaris	0.28±0.28	0.00±0.00	0.00±0.00	NV	NV
Polyarthra sp.	13.61±3.34	2.92±1.41	9.17±5.28	1.25	0.29
Trichotria tetractis	0.00±0.00	0.42±0.42	0.83±0.58	4.13	0.02*
Trichocerca leontina	0.28±0.16	0.00±0.00	0.00±0.00	NV	NV
Tricocerca multicrinis	0.00±0.00	0.42±0.42	0.00±0.00	NV	NV
Trichocerca elongata	1.12±0.67	0.00±0.00	1.67±1.15	0.47	0.62
Trichocerca weberi	0.37±0.18	0.00±0.00	0.00±0.00	NV	NV
Trichocerca tropis	3.15±0.83	2.50±1.73	2.50±1.73	0.10	0.91
Trichotria sp.	0.09±0.09	0.00±0.00	0.00±0.00	NV	NV
Euc~~l~~yclops agilis	1.85±0.72	0.00±0.00	2.50±1.73	0.87	0.42
Eudiaptomus gracilis	1.57±0.78	0.00±0.00	0.00±0.00	NV	NV
Eucyclops sp.	11.39±7.43	0.42±0.42	0.83±0.58	0.46	0.63
Diaptomus sp.	0.56±0.32	0.00±0.00	1.67±1.15	1.45	0.24
Alonella dentifera	0.74±0.41	1.25±1.25	0.00±0.00	0.52	0.59
Daphnia sp.	1.85±0.89	0.42±0.42	0.50±12.50	1.97	0.14
Diaphanosoma sp.	0.46±0.38	0.00±0.00	2.08±1.34	1.81	0.17
Eubranchipus sp.	0.93±0.41	0.83±0.83	0.42±0.42	0.16	0.85

Formatted: Font color: Red

Formatted: Font color: Red

Comment [KDZ1]: The full name must be entered here

Formatted: Font: Italic

Comment [KDZ2]: this is the name currently accepted

Formatted: Font color: Red

Formatted: Font color: Red

~~Dunhivedia~~ Dunhevedia crassa	0.00±0.00	0.00±0.00	1.67±1.30	NV	NV
Mytilinia mucronata	1.11±0.42	2.50±1.38	0.00±0.00	1.86	0.16
Pleuroxus denticulatus	0.28±0.16	0.00±0.00	0.83±0.83	1.02	0.36
Scaridium longicaudum	1.85±0.71	0.42±0.42	0.00±0.00	1.19	0.31
~~Simicephalus~~ Simocephalus sp.	1.76±0.63	0.00±0.00	2.92±1.75	1.28	0.28
Chironomus sp. *larva*	2.50±1.19	1.25±1.25	2.50±1.73	0.13	0.88
Coen~~o~~agrion sp.	1.57±0.71	0.00±0.00	0.83±0.58	0.67	0.51

NV = No Variance

Seasonally, 25 species out of the recorded total zooplanktonic species had higher mean abundance during dry season while only 19 species were higher in mean abundance during rainy season. Some of these species showed significant to very highly significant seasonal variation ($0.05 \geq p \leq 0.01$) in the mean abundance (3). These include *Lepadella ovalis and Filinia pej~~ei~~leri* that had higher mean abundance in rainy and dry season respectively. *Brachionus angularis* also had its maximum abundance in dry season with highly significant variation. Very highly significant variations were observed for the abundance of *Polyarthra* sp. and *Argonotholca foliacea* with higher mean abundance in dry and rainy season respectively (Table 3). Of the encountered total zooplankton species, 5 species and 4 species were recorded only in dry and rainy season respectively hence showed no variances in abundance.

3.3Time-depth abundance of zooplankton groups

Figures 4 to 7 shows the vertical distribution diagram pattern of major zooplankton groups of Esa-Odo Reservoir. The vertical distribution diagram revealed the monthly variation in abundance, rotifer were most abundant in surface to 1 m depth with a gradual decrease in density at the lower depths (Figure 4). Thus, the rotifers were very scanty at the bottom level (5m). Likewise, the bulk of copepod group population (Figure 5) was found within the 2.5 m depth with sparse population below 4m. The cladoceran population were also found to be concentrated in the surface to 2 m levels and these gradually decrease with depths. More also, the bulk of insect group generally congregated in the uppermost 2 m levels, and were relatively scanty in density at lower depth. While the lower depths were completely avoided by insecta group in February, June and October months (Figure 6). The bottom depths were also avoided by cladocerans in August 2017 as well as February and December, 2018 (Figure 7).

3.5 Diversity, Evenness and Richness of Zooplankton species

Simpson and Shannon indices showed that Riverine surface water was the most diverse station in species while transition littoral zone was the least diverse. Also, Evenness were above 0.40 in most stations of the reservoir except riverine bottom water, transition littoral and lacustrine mid-depth showing that the relative abundance of species in the area did not totally diverge from evenness and also that suggested the dominance of few abundant species in riverine bottom water, transition littoral and lacustrine mid-depth (Table 4).
Margalef value revealed that lacustrine littoral zone was richer in species than the lacustrine and transition mid-depth and inflow area. Fisher-alpha diversity index was highest at lacustrine surface water and lowest at transition mid-depth. Also, Berger-Parker value was highest at transition littoral zone and lowest at the inflow (Table 4).

Comment [KDZ3]: This species is Rotifera, not Crustacea

Comment [KDZ4]: This species is Rotifera, not Crustacea

Formatted: Font color: Red

Formatted: Font color: Red

Table 3: ANOVA statistics of the seasonal variation in the mean abundance (Org/m^3) of total zooplankton species

Taxa	Dry	Rain	F	P
	Mean±SE	Mean±SE		
Anuraeopsis fissa	1.15±0.52	0.38±0.22	1.89	0.17
Asplanchna sp.	1.79±0.81	2.05±0.78	0.05	0.82
Argonotholca sp.	53.08±15.46	22.95±11.07	2.51	0.12
Argonotholca foliaceae	2.05±0.86	11.03±1.85	19.36	0.0001***
Brachionus angularis	2.44±0.92	0.13±0.13	6.23	0.01**
Brachionus falcatus	14.62±4.69	13.46±6.31	0.02	0.88
Brachionus havanaensis	1.54±0.61	1.03±0.50	0.42	0.52
Brachionus quadridentatus	3.97±1.51	0.00±0.00	NV	NV
Cephalodella gibba	0.00±0.00	1.41±1.06	NV	NV
Euchlanis dilatata	2.82±0.89	1.03±0.47	3.17	0.08
Euchlanis lucksiana	0.00±0.00	0.26±0.18	NV	NV
Filinia longiseta	0.13±0.13	0.00±0.00	NV	NV
Filinia pejleri	27.18±6.85	7.95±5.26	4.96	0.03*
Filinia terminalis	1.79±0.75	2.05±0.92	0.05	0.83
Elosa woralli	0.64±0.33	0.77±0.30	0.08	0.78
Keratella~~.~~ tropica	2.18±0.91	1.79±1.31	0.06	0.81
Lecane bulla	3.72±1.08	6.28±1.82	1.47	0.23
Lecane closterocerca	2.82±1.41	0.13±0.13	3.60	0.06
Lecane leontina	2.44±1.31	0.13±0.13	3.09	0.08
Lecane luna	2.44±1.43	0.26±0.18	2.29	0.13
Lecane sp.	0.64±0.33	0.00±0.00	NV	NV
Lepadella ovallis	2.56±1.10	0.26±0.26	4.16	0.04*
Lepadella patella	1.54±0.52	1.28±0.56	0.11	0.74
Manfredium eudactylotum *Beauchampiella eudactylota*	1.92±0.95	0.00±0.00	NV	NV
Monostyla bulla	0.90±0.55	2.82±0.91	3.26	0.07
Monostyla lunaris	0.64±0.33	0.77±0.30	0.08	0.65
Notholca sp	1.03±0.65	2.31±0.93	1.23	0.26
Platyias sp	0.13±0.13	0.64±0.46	1.16	0.28
Anuraeopsis navicula	2.31±1.29	5.51±1.64	2.36	0.13
Polyarthra vulgaris	0.00±0.00	0.38±0.38	NV	NV
Polyarthra sp.	18.59±4.66	3.97±1.23	9.22	0.001***
Trichotria sp.	0.13±0.13	0.26±0.18	0.31	0.29
Trichocerca leontina	0.13±0.13	0.26±0.18	0.34	0.56
~~tricocerca~~ Tricocerca multicrinis	0.00±0.00	0.13±0.13	NV	NV
Trichocerca elongata	1.03±0.70	1.04±0.71	0.00	0.99
Trichocerca weberi	2.05±0.67	2.28±1.16	1.75	0.23
Trichocerca tropis	2.05±0.72	3.85±1.16	1.74	0.19
Euc~~l~~yclops agilis	1.03±0.65	2.31±0.93	1.28	0.26
Eudiaptomus gracilis	2.05±1.07	0.13±0.13	3.19	0.08
Eucyclops sp.	8.33±7.32	7.82±7.31	0.00	0.96

Comment [KDZ5]: this is the name currently accepted

Formatted: Font color: Red

Diaptomus sp.	0.26±0.26	1.03±0.50	1.86	0.17
Alonella dentifera	0.77±0.54	0.64±0.42	0.03	0.85
Daphnia sp.	6.03±3.98	0.51±0.51	1.88	0.17
Diaphanosoma sp.	0.26±0.18	1.03±0.65	1.31	0.25
Eubranchipus sp.	1.67±0.62	0.00±0.00	NV	NV
~~*Dunhivedia*~~ *Dunhevedia crassa*	0.38±0.38	0.13±0.13	0.40	0.53
Mytilinia mucronata	0.77±0.44	1.54±0.58	1.12	0.29
Pleuroxis denticulatus	0.38±0.29	0.26±0.18	0.14	0.70
Scaridium longicaudum	1.54±0.75	1.15±0.66	0.15	0.70
~~*Simicephalus*~~ *Simocephalus* sp.	2.18±0.91	1.15±0.48	1.00	0.32
Chironomus sp. larva	2.69±0.99	1.92±1.46	0.19	0.66
Coen~~o~~agrion sp.	1.28±0.76	1.15±0.66	0.02	0.90

NV = No Variance

Comment [KDZ6]: This is a rotifer species, not cladoceran

Comment [KDZ7]: This is a rotifer species, not crustacean

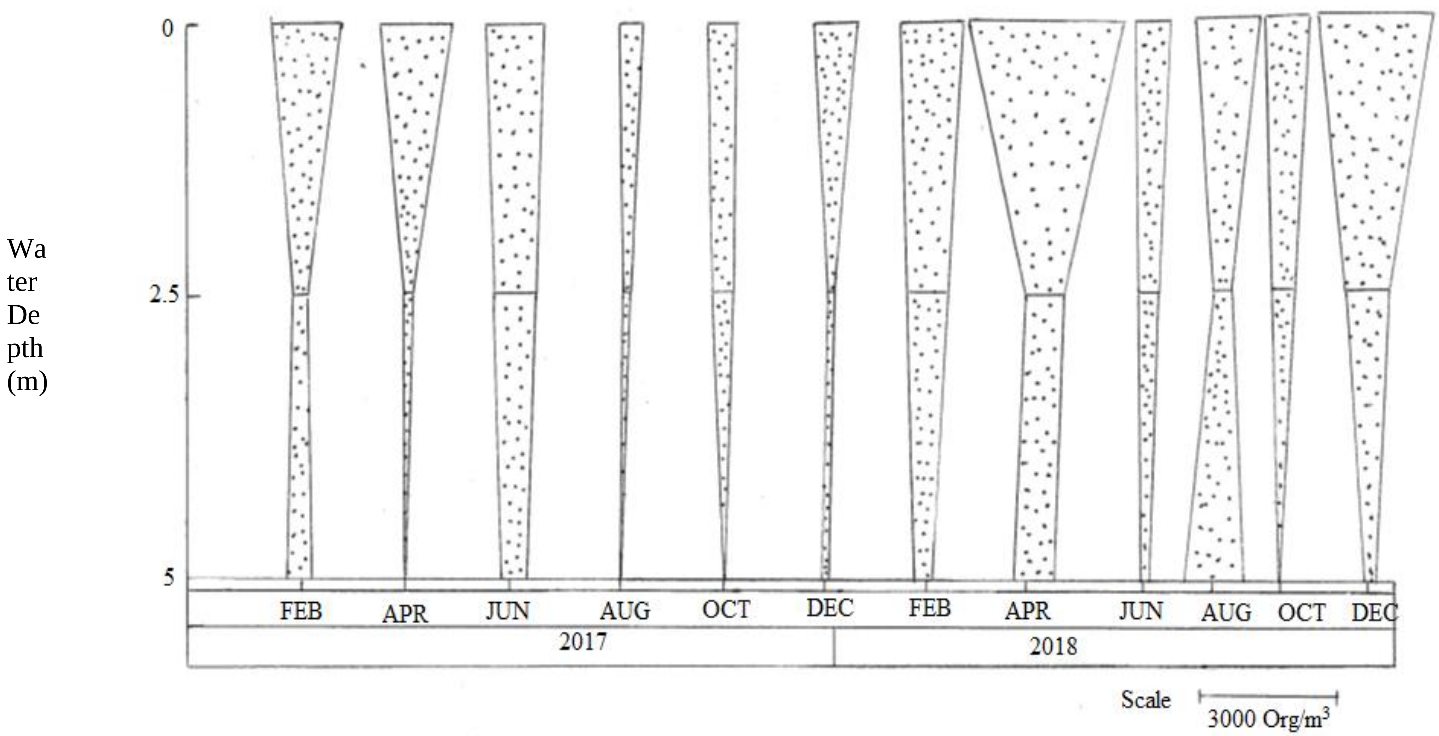

Fig. 4: Time-Depth abundance (Org/m^3) of Total Rotifera group at the lacustrine station

Comment [KDZ8]: I reco setting the scale to a smaller value, as the abundance values are a much smaller (eg. 200 Org/m3)

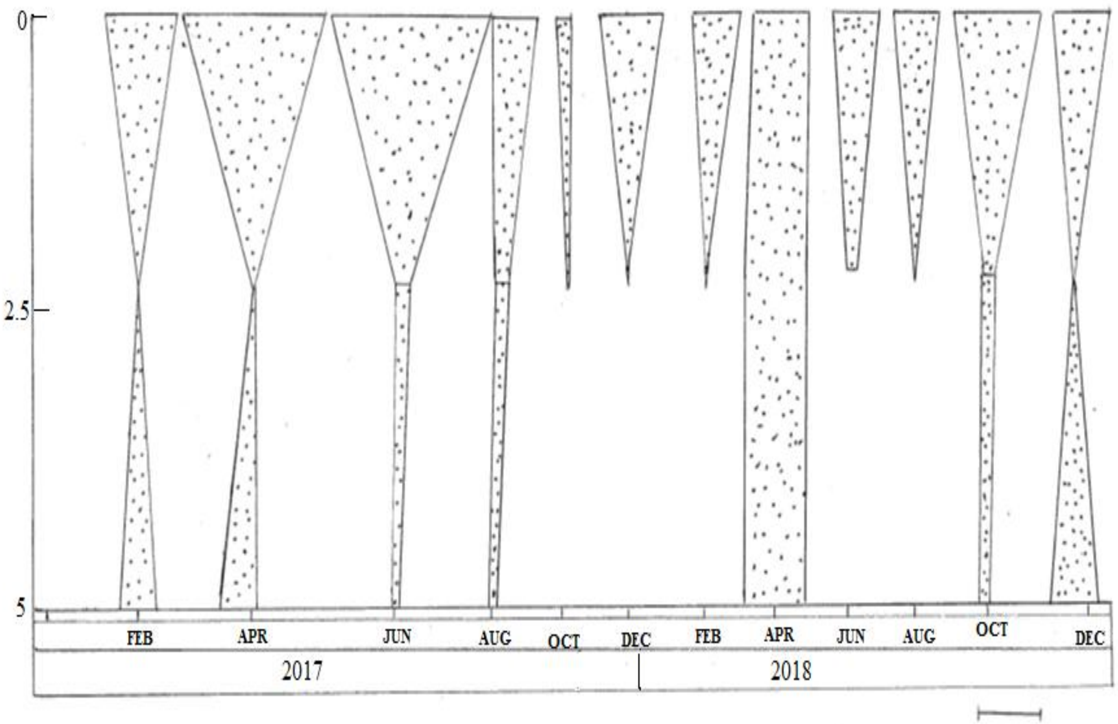

Fig. 5: Time-Depth abundance (Org/m^3) of Total Copepoda group at lacustrine

Comment [KDZ9]: the nu
value is missing
from the scales

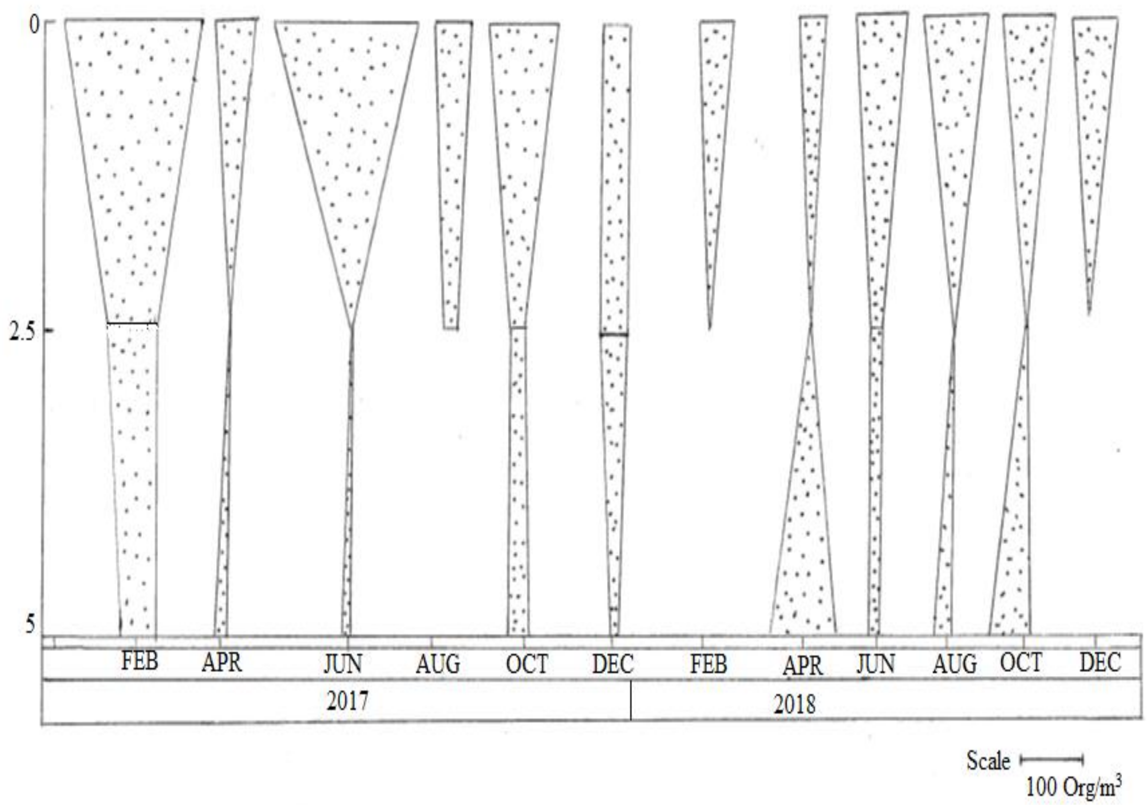

Fig. 6: Time-Depth abundance (Org/m^3) of Total Cladocera group at lacustrine

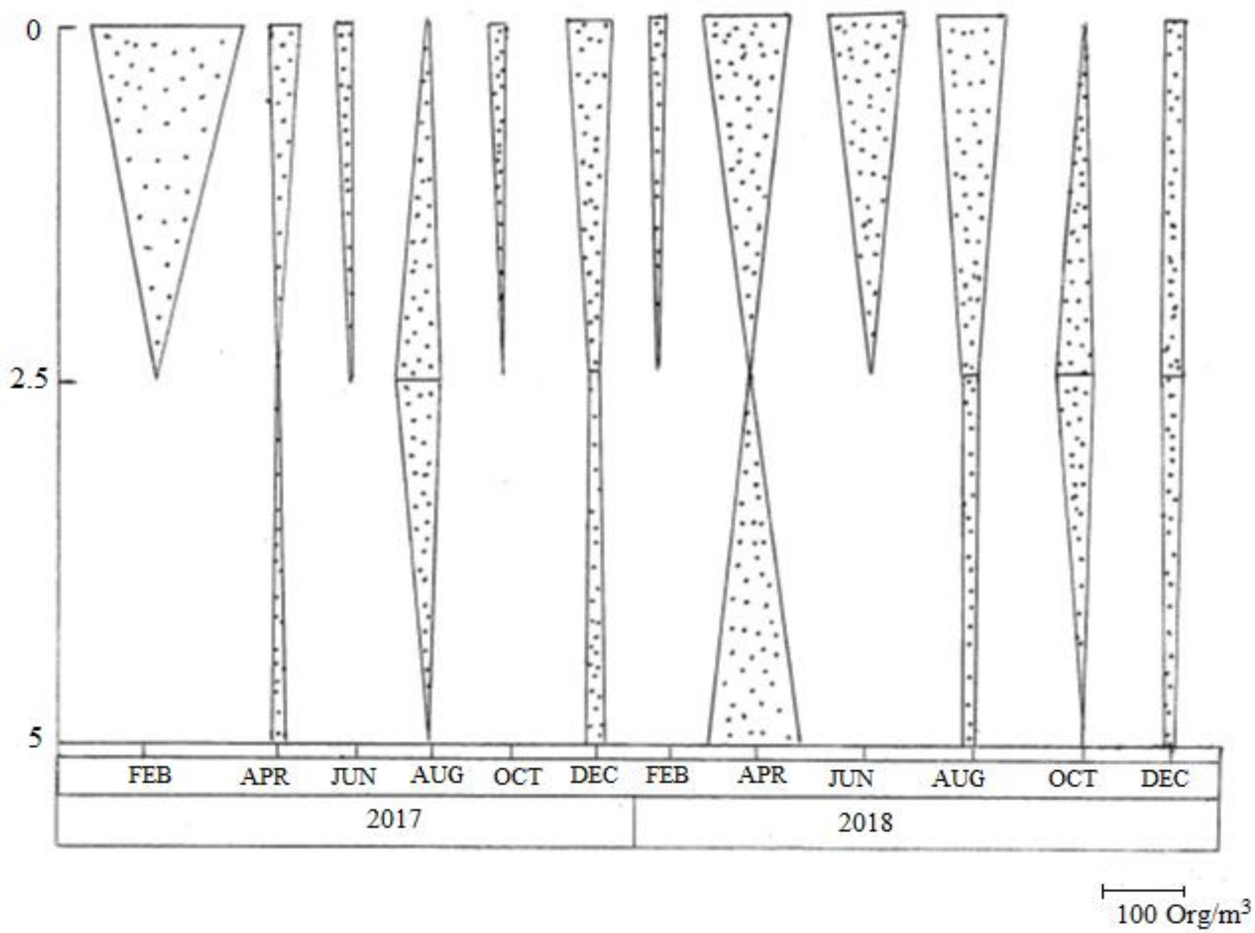

Figure 7: Time-Depth abundance (Org/m^3) of Total Insecta group at lacustrine

Table 4: Diversity, Evenness and Richness of zooplankton species

Indices	1S	1B	2S	2M	2B	2L1	2L2	3S	3M	3B	3L1	3L2	Inflow
Taxa_S	23	25	26	13	23	24	24	33	18	20	20	27	17
Individuals	1420	4840	2200	520	2130	5750	1990	4910	1440	1210	1060	2030	900
Dominance D	0.081	0.292	0.115	0.135	0.109	0.512	0.159	0.114	0.391	0.240	0.141	0.159	0.101
Simpson_1-D	0.920	0.708	0.885	0.865	0.891	0.488	0.841	0.886	0.609	0.760	0.859	0.841	0.900
Shannon H	2.781	1.851	2.634	2.240	2.649	1.372	2.364	2.709	1.636	2.120	2.386	2.497	2.503
Evenness e^H/S	0.702	0.255	0.536	0.722	0.615	0.164	0.443	0.455	0.285	0.417	0.543	0.450	0.719
Margalef	3.031	2.829	3.248	1.919	2.871	2.657	3.028	3.765	2.338	2.677	2.728	3.414	2.352
Equitability J	0.887	0.575	0.808	0.873	0.845	0.432	0.744	0.775	0.566	0.708	0.796	0.758	0.883
Fisher alpha	3.898	3.450	4.142	2.418	3.603	3.203	3.838	4.754	2.898	3.403	3.498	4.400	2.974
Berger-Parker	0.190	0.504	0.232	0.250	0.249	0.710	0.322	0.279	0.611	0.463	0.302	0.355	0.178

4 DISCUSSION

The eigthy three (53) species of total zooplankton recorded in this study are common to tropical fresh water bodies. The dominance of rotifera in the zooplankton fauna of freshwater has been documented by many workers in Africa and Nigeria as reported by Green (1960)[13], Jeje and Fernando (1986)[14], Egborge and Tawari (1987)[15], Ayodele and Adeniyi (2006)[8]. The dominance of the families Brachionidae, Trichocercidae and Lecanidae among the rotifer group has also been confirmed by many researchers in Africa and beyond [13, 16, 17, 8]. The dominance of this group may be due to the fact that most of the species are warm water adapted, occurring mostly in tropical water bodies, with high temperature. Also, it may be attributed to their low environmental requirement hence their wide geographical distribution.
The vertical variation in the mean abundance of zooplankton revealed that the highest mean abundance of zooplankton species occurred at the surface. This has been explained to be due to the fact that ~~the surface provides adequate food sources (photosynthesis) to support the zooplankton community~~[18, 19]. The diversity of species also followed the same pattern as Shannon's index recorded the higher values at the surface[20]. However, the evenness recorded was low in most of the stations of the reservoir which implies that zooplankton species were not equally abundant across the reservoir.

Comment [KDZ10]: 83

Formatted: Strikethrough

Comment [KDZ11]: that photosynthesis is most intense on the surface. This provides an adequate amount of phytoplankton as a primary food source for zooplankton. This is a better wording.

Formatted: Strikethrough

Zooplankton groups had their highest mean abundance at the lacustrine. This has been explained to result from the dam site providing a suitable environment for the species reproduction and development because of the abundance of phytoplankton which serve as zooplankton major source of food[19]. This may also be due to the stability of the reservoir's zone in the term of lower current, increased transparency and also reduced suspended particles which normally clog their body forms. Yusoff *et al.* (2002)[21] also reported more abundant zooplankton species at the lacustrine area of Kenyir Reservoir in Malaysia, which was however attributed to higher oxygen concentration, higher total suspended solids and lower transparency.

The seasonal variation of zooplankton recorded from the reservoir showed that zooplankton were most abundant during the dry season. This is in contrast to what was recorded by Aduwo, (2008)[22] on OAU. Teaching and Research Farm Lake, Yusoff *et al*. (2002)[21] for Kenyir Reservoir, Malaysia and Omoboye *et al*., (2015)[23] for Owalla Reservoir. They reported increase in zooplankton abundance with rains. High abundance during the dry season followed increase in phytoplankton abundance at this period since clearer water aids light penetration for photosynthesis. Moreover, increased temperature and solar radiation, which is associated with dry season, also contribute to production in phytoplankton groups[24].

5 CONCLUSION

In conclusion, Esa-Odo Reservoir comprised highly diversified zooplankton fauna with great potential to support rich aquatic community and fishery production. The reservoir can be classified as fairly clean based on the physico-chemical parameter ranges recorded and the abundance of rotifer group. However, the lake should be subjected to regular proper monitoring because of the presence of some pollution tolerant copepod species identified among the zooplankton fauna as well as the likely effect of some human activities (like open space defaecation, washing and bathing with detergents and soaps and grazing of cows around the water shed) observed during the study. Such activities may cause change in the zooplankton composition.

REFERENCES

1. U.S. Environmental Protection Agency (EPA). International Decontamination Research and Development Conference. U.S. Environmental Protection Agency, Washington, DC. 2016
2. Gadzala-kopciuch, R., Berecka, B., Bartoszewwicz, J.and Buszewski, B. Some considerations about bioindicators in environmental monitoring. Polish Journal of Environmental Studies, 2004:13(15): 453-460.
3. Kovalev, VA. Grigoriev, AY. and Ahn, HS. Robust Recognition of White Blood Cell Images, 13th Int. Conf. on Pattern Recognition (ICPR'96), Vienna, Austria, Aug. 25-1999:29(IV): 371-375.

4.Gazonato Neto AJ., Silva L.C., Saggio AA., Rocha O. Zooplankton communities as eutrophication bioindicators in tropical reservoirs. Biota Neotropica 2004: 14: 1–12.

5. Esinazi-Santanna, EM, Menezes, R, Costa, IS, Araújo, M, Panosso, R, Attayde, JL. Zooplankton assemblages in eutrophic reservoirs of the Brazilian semi-arid. Braz. J. Biol., 2013: 73(1): 37-52.

6. Thorpe JH, Covich, AP. Ecology and Classification of North Dakota Freshwater Invertebrates. Academic Press, New York, NY, USA. 1991: 1021pp

7. Abdulazeez, MT, Bello, AH, Alhassan, N, Wada, Y. Relationship between physicochemical parameters and zooplanktons in karidna reservoir, kaduna state. Bayero Journal of Pure and Applied Sciences, 2017: 10(1): 664 – 669.

8. Ayodele, HA, Adeniyi, IF. The zooplankton fauna of six impoundments on River Osun, Southwest, Nigeria. The Zoologist. 2006:1(4): 49-67.

9. True Knowledge. The Internet Answer Engine. www.trueknowledge.com. Accessed on 18th May, 2018.

10. Witty, LM. (2004). Practical guide to identifying freshwater crustacean zooplankton. 2nd edition, Sudbury, Ontario: Cooperative. Freshwater Zoology Unit, 2004. 50pp.

11.Fernando, CH. A Guide to Tropical Freshwater Zooplankton. Backhuys, Publishers, Leiden, Netherlands, 2002. 50-253pp.

12. Edmondson, WT. Freshwater Biology (Second Edition). John Wiley and Sons, Inc, London. 1959. 421-450p.

13. Green, J. Zooplankton of the River Sokoto. The Rotifera. Proceedings of Zoological Society London. 1960: 135: 491-523.

14. Jeje, CY, Fernado, CH. A Practical Guide to the Identification of Nigerian. Zooplankton (Cladocera, Copepoda and Rotifera). The Kanji Lake Research Institute. 1986.pp. 142.

15. Egborge, ABM, Tawari, PL. The rotifer of Warri River, Nigeria. Journal of Plankton Research, 1987: 9: 1-13.

16. Egborge, ABM. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. La Revue de Zoologic Africaine. 1981: 95:137-165.

17. Akinbuwa, O. Adeniyi, IF. (1991). The Rotifers fauna of Opa Reservoir, Ile- Ife, Nigeria. J. Afr. Zool. 1991: 105: 383-391.

18. Benfield, LA. The composition and distribution of zooplankton in the lower Waikato River, New Zealand. M. Sc. Thesis. The University of Waikato, Hamilton, New Zealand. 1990. 120pp.

19. Burger, DF, Hogg, ID, Green, JD. Distribution and abundance of zooplankton in the Waikato River, New Zealand. Hydrobiologia, 2002:479: 31-38.

20. Dash, MC. Foundamentals of Ecology. Tata McGraw Hill Publishing company limited, New Delhi. 1996. 525pp.

21. Yusoff, FM, Matias, HM, Khan, N. Changes of water quality, Chlorophyll a and zooplankton along the river-lacustrine continuum in a tropical reservoir. Verh. International Verein. Limnology, 2002:28: 295-298.

22. Aduwo, IA. The study of zooplankton fauna and physicochemical water properties of Obafemi Awolowo University Teaching and Research Farm Lake. M. Sc. Thesis, Obafemi Awolowo University, 2008: 287 pp.

23. Omoboye, HY, Adeniyi, IF. The Planktonic Community and Primary Productivity of Owalla Reservoir, Osun State, Southwest, Nigeria. M. Sc. Thesis, Obafemi Awolowo University, 2015: 263pp

24. Mitrovic, SM, Howden, CG, Bowling, LC, Buckney, RT. Unusual allometry between in situ growth of freshwater phytoplankton under static and fluctuating light environments: possible implications for dominance. Journal of Plankton Research, 2003: 25(5): 517-526.