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The Benthic Macro-Invertebrate Fauna of Owalla Reservoir, Osun State, Southwest, Nigeria

Aduwo, Adedeji Idowu and Adeniyi, Israel Funso
Limnology and Hydrobiology Laboratory, Zoology Department, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.
*anjiaduwo@gmail.com & funsoadeniyi@gmail.com

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ABSTRACT

The benthic macro-invertebrate composition of Owalla Reservoir in Southwest Nigeria was surveyed over two annual cycles (2011 – 2013). The study aimed at providing information on their taxonomic composition, abundance and distribution pattern (both in time and space) of the occurring species in the reservoir. Twenty (20) sampling stations representing the major habitat types and basins were established across the reservoir. Bottom sediments were collected using a Van Veen grab and sieved through a 0.5 mm mesh sieve using the reservoir water. The residues were preserved inside a specimen bottle in 10 % formalin and labeled appropriately for specimen analysis and identification which were carried out in the laboratory using appropriate identification keys. The benthic macro-invertebrates of Owalla Reservoir comprised 18 different species belonging to three major phyla (Arthropoda, Annelida and Mollusca), with a total abundance of 5076 individuals. *Melanoides tuberculata* was the most dominant species (90 % occurrence) and the most abundant (4128 individuals). *Enallagma* sp. was the least occurring (10 %) while *Physa acuta, Radix natalensis* and *Mutela* sp. were the least abundant (16 individuals each). Most of the organisms did not show significant ($p > 0.05$) spatial variations and none of them showed significant ($p > 0.05$) seasonal variations in the reservoir. The benthic macroinvertebrate composition of the reservoir is mainly dominated by taxonomic groups with little tolerance to water pollution. This is an indication of little or no anthropogenic influences on the reservoir's water quality from activities within the catchment basin and an indication of a healthy water condition.

INTRODUCTION

The communities of organisms that live on, and/or within, the bottom substrate of waterbodies are referred to as "benthos"; a term introduced into natural history by Ernst Haeckel (1834-1919) (Tagliapietra and Sigovini, 2010). The benthic community is complex and includes a wide range of organisms from microbes (microbenthos) to plants (phytobenthos) and animals (zoobenthos) and covers different levels of the food web (Boyd, 1995; Tagliapietra and Sigovini, 2010). Benthic organisms are classified variously including with regard to size (microbenthos, meiobenthos and macrobenthos) and habitat (epibenthos and hyperbenthos). In general, marine and estuarine zoobenthos are more diverse than freshwater zoobenthos (Encyclopaedia

Britannica, 2011; Balachandar *et al.,* 2016). The most common members of freshwater benthic communities include oligochaete worms, chironomids (dipteran larvae), numerous other insect larvae, adult insects, freshwater gastropods and bivalves (Cuomo and Zinn, 1997; Strayer, 2009; Tagliapietra and Sigovini, 2010; Zenkevich and Shchapova, 2010).

Benthic macroinvertebrates are important in monitoring environmental effects because they are either sessile or of limited movement and therefore cannot readily avoid pollution. Their dynamics thus, reflect the local conditions of the aquatic ecosystem (Sharma and Chowdhary, 2011). Their presence or absence provides an indication of water quality conditions over a period of time. In general, their lifespan is long enough relative to most short-term environmental impacts and makes them good indicators of ecological disturbance, human influences in the ecosystems. They also allow for a view of stream conditions integrated over a long period of time than the snapshot provided by traditional methods involving water chemistry analysis and as well serve as tools for assessing the effects of anthropogenic stressors on water quality (Garg *et al.,* 2009; Aura *et al.,* 2011; Sharma and Chowdhary, 2011; Swarthout and O'Reilly, 2005). To this effect, many indices of the community structure of benthic macro-invertebrates have been used as biological indicators of aquatic environment, including water quality status and pollution (McLachlan and Dickinson, 1977; Beatty *et al.,* 2006; Chi *et al.*, 2017; Scotti *et al.*, 2019).

This study is on the benthic macro-invertebrate animals of Owalla Reservoir, one of the major multipurpose reservoirs in Southwest, Nigeria. The study aimed to provide information on the taxonomic composition, abundance and distribution of the zoobenthos fauna (both in time and space) of the reservoir. This aspect of the reservoir's limnology has received limited attention from workers in the Owalla Reservoir. It is hoped that the knowledge could be useful in assessing the reservoir's water quality status including its suitability for the various purposes for which it was impounded and the influence of anthropogenic activities within the reservoir's catchment basin.

Study Area

Owalla Reservoir is the largest man-made lake in Osun State, Southwest, Nigeria. It is an impoundment on Erinle and Otin Rivers, major tributaries of the Osun River, Southwest, Nigeria. It was created by the Old Oyo State Government for the primary purpose of municipal water supplies but also for fishery development and agriculture. It lies roughly between latitudes 07^0 53.5` and $07^0$ 59.0`N and longitudes 004^0 31.5` and $004^0$ 35.0`E on an average elevation of 336±8m above mean sea level and surface area of about 14.5 square kilometres (sq.km) (Fig. 1). The reservoir's dam axis is approximately 10km North of Osogbo, Osun State capital, about 200km North-East of Lagos, the major commercial city in Nigeria and about 360km South-West of Abuja the capital city of Nigeria (True knowledge, 2012). The climate of the study area is typically tropical (Ojo, 1977). Like most parts of Nigeria, the annual cycle, is characterized by two distinct climatic seasons, namely: dry season (from late November to early March), and the rainy season (from late March to early November). The beginning and end of the rainy season are marked by torrential rains and thunderstorms. The rainy season within the area is normally characterized by two peaks (occurring in July and September/October) separated by a short dry spell in August, called the August break (Iloeje, 1978).

Geologically, the study area belongs to the migmatite-gneiss quartzite zone of the basement complex of South Western Nigeria and lies within the zone of Pan African reactivation of 600 ± 150 m.y. (Rahaman, 1976a, 1976b, 1988). The area falls within the lowland tropical rainforest vegetation (Agboola, 1979), characterized by emergent trees with multiple canopies and lianas most of which had since given way to secondary forest and derived savannah (Adediji and Ajibade, 2008). Anthropogenic activities in the area are mainly from domestic and agricultural activities within the catchment basin. The inhabitants of riparian communities of the reservoir (i.e. Ilie, Oba, Bara, Onipakiti, Kuti, Igbokiti, Idiroko, Eko-Ende, and Ore, etc.) are mostly peasant farmers, fishermen or petty traders in agricultural goods. There is no evidence of heavy industrialization in the area. Riparian vegetation of the area includes cultivated crops such as vegetables, cashew, mango, cocoa, kola nut, oranges, oil palm, cassava, yam, maize banana and plantain (Aduwo and Adeniyi, 2018)

Twenty (20) sampling stations were established on the reservoir along two habitat types comprising three sections along its major axis (upstream, mid-basin and downstream) and two zones across its width (littoral and open water). Information on the descriptions, grid locations and depth of the sampling stations are presented in Table 1 and Figure 1.

Table 1: Grid co-ordinates, morphometric characteristics and descriptions of the sampling stations

S/N	Grid co-ordinate		Elevation (m)	Distance & Direction from dam (km)	Depth range (m)	Mean depth ± S.E (m)	Description of Station	
	Latitude (N)	Longitude (E)					Reach	Region
1.	07° 58.644'	004° 32.889'	336 ± 7	9.26 (N)	0.98 – 4.24	3.04±0.57	Upper Reach	Open Water
2.	07° 57.575'	004° 33.115'	332 ± 9	7.47 (NE)	3.93 – 7.05	6.05±0.60	Upper Reach	Open Water
3.	07° 57.506'	004° 32.903'	332 ± 8	7.42 (N)	1.20 – 4.00	2.88±0.48	Upper Reach	Littoral
4.	07° 57.673'	004° 33.287'	332 ± 8	7.55 (NE)	2.00 – 5.53	3.88±0.57	Upper Reach	Littoral
5.	07° 56.515'	004° 34.361'	336 ± 7	5.98 (NE)	2.71 – 6.81	4.76±0.73	Mid-Basin	Open Water
6.	07° 56.664'	004° 33.758'	334 ± 7	5.96 (NE)	4.15 – 9.60	6.40±1.06	Mid-Basin	Open Water
7.	07° 56.867'	004° 33.741'	335 ± 7	6.29 (NE)	2.36 – 5.18	4.24±0.52	Mid-Basin	Littoral
8.	07° 56.518'	004° 33.685'	334 ± 8	5.71 (NE)	1.98 – 4.77	3.41±0.47	Mid-Basin	Littoral
9.	07° 55.611'	004° 32.699'	340 ± 7	4.98 (N)	2.31 – 5.56	4.90±0.43	Mid-Basin	Littoral
10.	07° 55.636'	004° 33.044'	334 ± 7	4.51 (NE)	4.07 – 6.73	5.58±0.47	Mid-Basin	Open Water
11.	07° 55.760'	004° 33.449'	334 ± 7	4.91 (NE)	2.25 – 5.68	4.19±0.60	Mid-Basin	Littoral
12.	07° 54.831'	004° 33.886'	338 ± 8	2.99 (NE)	6.90 – 9.12	8.06±0.44	Lower Reach	Open Water
13.	07° 55.005'	004° 33.956'	336 ± 8	3.23 (NE)	1.73 – 4.94	3.34±0.69	Lower Reach	Littoral
14.	07° 54.732'	004° 33.813'	338 ± 7	2.88 (NE)	1.00 – 3.50	2.49±0.53	Lower Reach	Littoral
15.	07° 54.206'	004° 32.147'	339 ± 7	1.94 (N)	2.65 – 5.31	3.65±0.44	Lower Reach	Littoral
16.	07° 54.089'	004° 32.403'	341 ± 7	0.87 (N)	12.70 – 17.26	14.25±0.81	Lower Reach	Open Water
17.	07° 53.905'	004° 32.689'	339 ± 7	1.56 (NE)	3.16 – 5.89	5.01±0.63	Lower Reach	Littoral
18.	07° 56.594'	004° 33.487'	333 ± 8	5.71 (NE)	0.18 – 0.25	0.21±0.01	Mid-Basin	Littoral
19.	07° 54.802'	004° 33.460'	336 ± 8	2.81 (NE)	0.15 – 0.20	0.17±0.01	Lower Reach	Littoral
20.	07° 53.669'	004° 32.792'	342 ± 10	1.10 (E)	0.16 – 0.20	0.18±0.01	Lower Reach	Littoral

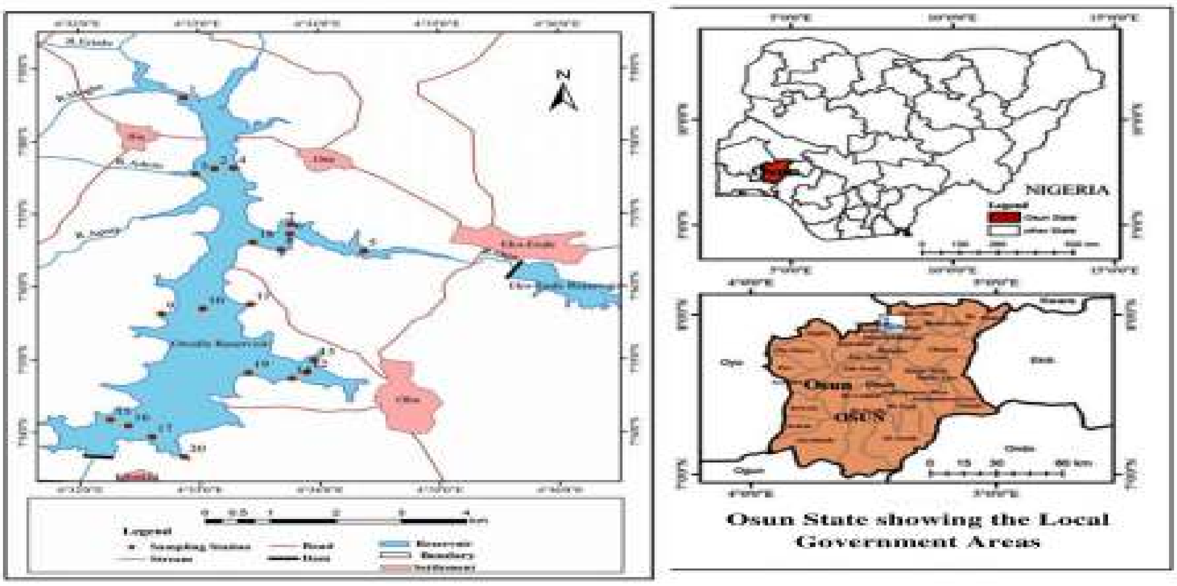

Fig. 1: The map of the area of study showing the sampling stations

MATERIALS AND METHODS

Sampling was carried out aboard a wooden boat powered by an outboard engine at every three-month intervals (covering both the dry and rainy seasons) for two annual cycles (2011 – 2013). Along the main axis of the reservoir, the stations comprised of four in the upper reach, eight in the mid reach and eight in the lower basin, while across the width they comprised seven in the open water and thirteen in the littoral zone. Samples of bottom sediment at each sampling station were collected using a Van Veen grab (Bottom sampler) of $0.04m^2$ area (0.2m X 0.2m). The grabbed samples were sieved through a 0.5mm mesh sieve using the reservoir water. The benthic macroinvertebrates found were removed using a pair of long forceps and preserved inside a specimen bottle in 10% formalin solution and labeled indicating the station's number, time and date of sampling written on the specimen bottles using a permanent marker. In the laboratory, the preserved specimens of the recorded macroinvertebrates (preserved in 10% formalin) brought from the field were transferred into a petri-dish for sorting, identification, counting and enumeration under the microscope. Identification was based mainly on the keys provided by Brown (1980); Clifford (1991); Day and de Moor (2002); Day *et al.* (2002); de Moor *et al.* (2003); Gerber and Gabriel (2002); IOWATER (2005); Madsen (1985); Umar *et al.* (2013) Stern (1990) and Verma (2006) as applicable. The abundance of recorded benthic macroinvertebrates collected was determined in relation to the surface area of the grab sampler (0.2m x 0.2m) and expressed as number of organisms per unit area (m^2). Taxa occurrence was calculated as a percentage of the number of stations where they occurred to that of all the investigated stations. Different Diversity indices were calculated and analysed using the Paleontological Statistics (PAST) software Version 3. Applicable quality assurance and quality control (QA/QC) measures were put in place both in the field and laboratory in order to ensure the integrity of the samples and specimens collected as well as the quality and reliability of the data obtained.

RESULTS

Species composition

A total of eighteen benthic macroinvertebrate species were recorded from the Owalla Reservoir over the two-year study period (March 2011 – February 2013). The fauna was made up of seven species of Arthropoda, two species of Annelida and nine species of Mollusca. These were in three phyla (Arthropoda, Annelida and Mollusca), four classes (Insecta, Clitellata, Gastropoda and Bivalvia), seven orders (Odonata, Diptera, Haplotaxida, Arhynchobdellida, Heterobranchia, Caenogastropoda and Unionida) and fourteen families (Aeshnidae, Corduliidae, Libelliludae, Coenagrionidae, Culicidae, Chironomidae, Lumbricidae, Hirudinidae, Planorbidae, Physidae, Lymnaeidae, Ampullariidae, Thiaridae and Unionidae) (Table 2). The checklist and outline classification of the species are provided in Table 2. Only six of the 18 macroinvertebrates (mostly Mollusca) were identified to the specific level.

Abundance, Occurrence and Distribution

A total of 5076 individual benthic macroinvertebrates belonging to 18 different species were recorded from the reservoir. Abundance of the individual species ranged from the lowest value of 16 individuals for *Physa acuta, Radix natalensis,* and *Mutela* sp to the highest value of 4128 individuals for *Melanoides tuberculata.*

Melanoides tuberculata was the most dominant species, occurring in 18 of the twenty stations (90% frequency of occurrence) while *Enallagma* sp. was the least, occurring in only two stations (i.e. stations 18 and 20) throughout the period of study (10% frequency of occurrence).

Gastropoda was the most abundant taxa group with 4407 individuals (87 %), followed by Insecta with a total abundance of 500 individuals (10 %), Bivalvia with a total abundance of 107 individuals (2 %), while the Clitellata was the least abundant with a total of 62 individuals (1 %). The abundance of benthic macroinvertebrates fluctuated from the lowest value of 6 Org./m^2 in Station 6 to the highest value (1078 Org./m^2) in Station 20 (Table 3). Stations 8, 19 and 20 were the richest having a total of eleven out of the recorded eighteen taxa, while Station 10 the poorest with only one recorded taxon (Table 3). Station 8 was the most diverse (Margalef Index = 1.66) of all the stations in terms of the recorded species of benthic macro-invertebrates while Station 10 was the least (Margalef Index = 0.00). The recorded species were generally evenly distributed over the sampling period in Stations 6 and 10 (Evenness_e^H/S = 1.00) and least in Station 8 (Evenness_e^H/S = 0.18). There was the dominance of a species in Station 10 (Dominance_D = 1.00) while in Station 5 dominance by a single species was lowest (Dominance_D = 0.36) (Table 3).

Spatial and temporal variation

Figure 2 is a cluster diagram showing the relationships among the investigated sampling stations based on the total abundance of the recorded benthic macroinvertebrates from the stations. Generally, the sampling stations exhibited significant correlation among themselves ($0.001 < p < 0.05$) and two clusters were formed at $p = 0.001$.

The two clusters comprised stations 10 and 12 together (Cluster 1) and the other eighteen stations (Cluster 2). The two clusters were separated by the abundance of *Chironomus* sp. which was relatively high in Stations 10 and 12 (Cluster 1) compared to the other stations (Cluster 2). Similarly, Cluster 2 can be sub-divided with regard to the abundance of *Melanoides tuberculata, Bulinus globosus* and *M. tuberculata* at the correlation coefficient (r) values of 0.72, 0.86 and 0.98 respectively. In general, the cluster analysis is based more on the open/littoral position of the stations than with regard to the reach along the reservoir main axis (upper, middle and lower reaches). This same relationship is confirmed by the Principal Component Analysis (PCA) presented in Figure 3.

In the PCA plot, two organisms, *Melanoides tuberculata* and *Chironomus* sp. stood out of the clusters, with *Melanoides tuberculata* aligning with the littoral stations and *Chironomus* sp. to the open water region. This is also corroborated with the t-tests results in Table 4 showing *Melanoides tuberculata* significantly ($p < 0.05$) higher in the littoral region than in the open water region and *Chironomus* sp. being significantly ($p < 0.05$) higher in the open water region than in the littoral region.

ANOVA statistics of the overall variations in the abundance of the benthic macroinvertebrate fauna along the major reaches of the reservoir during the period of study shows that *Bulinus globosus,* had its highest mean abundance value of 11 ± 4 Org./m^2 upstream and decreased significantly ($p < 0.05$) through the mid-basin with the lowest mean abundance value of 1 ± 1 Org./m^2 downstream. Conversely, *Ligumia recta* and class Insecta had their lowest mean abundance values of 1 ± 1 Org./m^2 and 2 ± 2 Org./m^2 upstream and increased significantly ($p < 0.05$) through the mid-basin with highest mean abundance values of 4 ± 2 Org./m^2 and 78 ± 30 Org./m^2 downstream respectively. The other major recorded taxa were not significantly different ($p > 0.05$) in their horizontal abundance (upstream-downstream) of the reservoir (Table 4).

Table 2: Checklist and outline classification of the benthic macro-invertebrates from Owalla Reservoir

S/N	PHYLUM	CLASS	ORDER	SUB-ORDER	FAMILY	GENUS	SPECIES
1	ATHROPODA	INSECTA	ODONATA	ANISOPTERA	AESHNIDAE	*Aeshna*	*Aeshna* sp.
2					CORDULIIDAE	*Epitheca*	*Aeshna* sp.
3					LIBELLILUDAE	*Sympetrum*	*Sympetrum* sp.
4				ZYGOPTERA	COENAGRIONIDAE	*Ischnura*	*Ischnura* sp.
5					COENAGRIONIDAE	*Enallagma*	*Enallagma* sp.
6			DIPTERA	NEMATOCERA	CULICIDEA	*Anopheles*	*Anopheles* sp.
7				NEMATOCERA	CHIRONOMIDAE	*Chironomus*	*Chironomus* sp.
8	ANNELIDA	CLITELLATA	HAPLOTAXIDA		LUMBRICIDAE	*Lumbricus*	*Lumbricus* sp.
9			ARHYNCHOBDELLIDA		HIRUDINIDAE	*Hirudo*	*Hirudo* sp.
10	MOLLUSCA	GASTROPODA	HETEROBRANCHIA	BASOMMATOPHORA	PLANORBIDAE	*Bulinus*	*Bulinus globosus*
11					PHYSIDAE	*Physa*	*Physa acuta*
12					LYMNAEIDAE	*Radix*	*Radix natalensis*
13			CAENOGASTROPODA	ARCHITAENIOGLOSSA	AMPULLARIIDAE	*Pila*	*Pila africana*
14				SORBEOCONCHA	THIARIDAE	*Melanoides*	*Melanoides tuberculata*
15		BIVALVIA	UNIONIDA		UNIONIDAE	*Unio*	*Unio* sp.
16						*Lamellidens*	*Lamellidens* sp.
17						*Ligumia*	*Ligumia recta*
18						*Mutela*	*Mutela* sp.

Table 3: Total abundance (Org./m^2) of benthic macro-invertebrates from Owalla reservoir.

S/N	Taxa	STATION 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total	% Freq.
1	*Aeshna* sp.	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	9	9	31	53	20.0
2	*Epitheca* sp.	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	19	34	144	200	20.0
3	*Sympetrum* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	9	9	25	15.0
4	*Ischnura* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	13	3	19	15.0
5	*Enallagma* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	25	31	10.0
6	*Anopheles* sp.	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	6	28	75	113	20.0
7	*Chironomus* sp.	0	9	0	0	3	3	0	0	6	13	0	22	0	0	0	3	0	0	0	0	59	35.0
8	*Lumbricus* sp.	3	0	0	0	3	0	6	6	0	0	0	0	0	0	0	0	0	3	0	6	28	30.0
9	*Hirudo* sp.	0	0	13	0	0	0	3	0	3	0	3	0	0	3	0	0	0	0	9	0	34	30.0
10	*Bulinus globosus*	25	3	16	0	28	0	3	13	3	0	0	3	0	9	3	0	0	0	0	0	106	50.0
11	*Physa acuta*	3	0	3	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	0	16	25.0
12	*Radix natalensis*	3	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	16	15.0
13	*Pila Africana*	28	0	6	0	28	0	6	16	6	0	19	3	3	13	3	0	6	0	3	0	141	65.0
14	*Melanoides tuberculata*	178	25	469	328	66	3	175	359	69	0	141	0	31	319	50	9	59	372	725	750	4128	90.0
15	*Unio* sp.	3	0	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	9	19	20.0
16	*Lamellidens* sp.	0	0	0	0	0	0	3	3	0	0	0	0	0	3	0	0	0	6	22	13	50	30.0
17	*Ligumia recta*	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3	0	0	13	22	20.0
18	*Mutela* sp.	3	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	3	0	3	0	16	20.0
Total Insecta		0	9	0	0	3	3	0	9	6	13	0	22	0	0	0	3	0	49	93	287	500	55.0
Total Clitellata		3	0	13	0	3	0	9	6	3	0	3	0	0	3	0	0	0	3	9	6	62	55.0
Total Gastropoda		212	28	494	331	122	3	190	394	81	0	160	6	34	341	56	9	65	372	731	750	4407	95.0
Total Bivalvia		9	0	0	0	0	0	3	9	0	0	9	0	0	3	0	0	6	6	25	35	107	45.0
Taxa No.		9	3	5	2	5	2	7	11	6	1	5	3	2	5	3	2	4	9	11	11	18	100
Total		249	37	507	331	128	6	202	418	90	13	172	28	34	347	56	12	71	430	858	1078	5076	100
Diversity Indices	Dominance_D	0.53	0.52	0.86	0.98	0.36	0.50	0.75	0.74	0.60	1.00	0.69	0.64	0.84	0.85	0.80	0.63	0.70	0.75	0.72	0.51	0.67	-
	Simpson_1-D	0.47	0.48	0.14	0.02	0.64	0.50	0.25	0.26	0.40	0.00	0.31	0.36	0.16	0.15	0.20	0.38	0.30	0.25	0.28	0.49	0.33	-
	Shannon_H	1.04	0.81	0.36	0.05	1.18	0.69	0.63	0.70	0.90	0.00	0.66	0.67	0.30	0.38	0.41	0.56	0.63	0.65	0.74	1.13	0.94	-
	Evenness_e^H/S	0.31	0.75	0.29	0.53	0.65	1.00	0.27	0.18	0.41	1.00	0.39	0.65	0.67	0.29	0.50	0.88	0.47	0.21	0.19	0.28	0.14	-
	Brillouin	0.98	0.72	0.34	0.05	1.12	0.50	0.58	0.66	0.82	0.00	0.62	0.57	0.26	0.36	0.36	0.45	0.56	0.62	0.72	1.11	0.94	-
	Menhinick	0.57	0.49	0.22	0.11	0.44	0.82	0.49	0.54	0.63	0.28	0.38	0.57	0.34	0.27	0.40	0.58	0.47	0.43	0.38	0.34	0.25	-
	Margalef	1.45	0.55	0.64	0.17	0.82	0.56	1.13	1.66	1.11	0.00	0.78	0.60	0.28	0.68	0.50	0.40	0.70	1.32	1.48	1.43	1.99	-
	Equitability_J	0.47	0.74	0.22	0.07	0.73	1.00	0.32	0.29	0.51	0.00	0.41	0.61	0.43	0.23	0.38	0.81	0.45	0.30	0.31	0.47	0.33	-
	Fisher_alpha	1.83	0.77	0.77	0.28	1.04	1.05	1.41	2.07	1.45	0.25	0.96	0.85	0.46	0.83	0.68	0.69	0.92	1.61	1.78	1.71	2.34	-
	Berger-Parker	0.71	0.68	0.93	0.99	0.52	0.50	0.87	0.86	0.77	1.00	0.82	0.79	0.91	0.92	0.89	0.75	0.83	0.87	0.85	0.70	0.81	-
	Chao-1	9	3	5	2	5	2	7	11	6	1	5	3	2	5	3	2	4	9	11	11	18	-

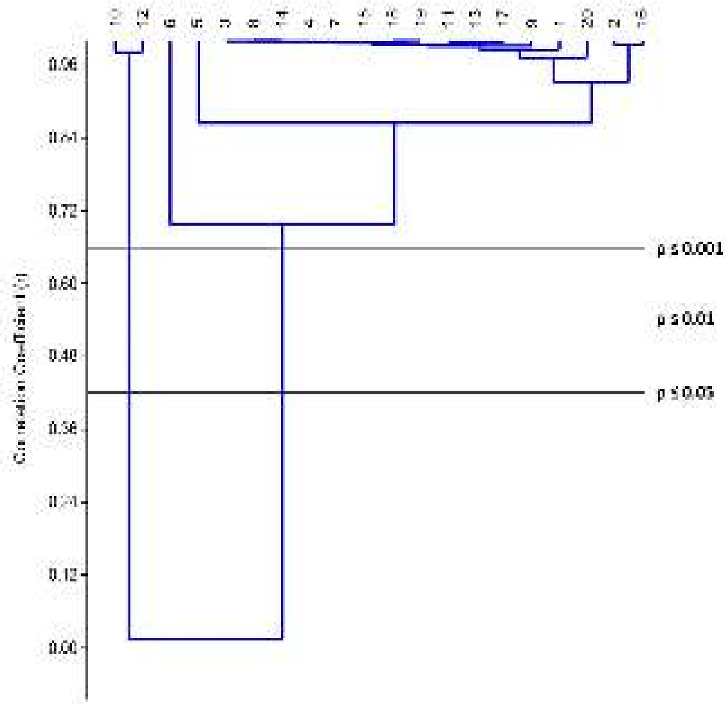

Fig. 2: Cluster diagram showing relationships among investigated sampling stations based on the total abundance of benthic macro-invertebrates.

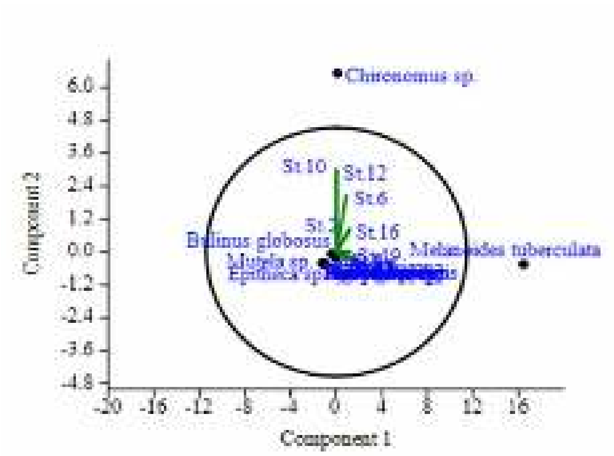

Fig. 3: Principal Component Analysis (PCA) showing relationships among the stations and the benthic macro-invertebrates

The t-tests of the variations in the abundance of the benthic macro-invertebrates across the (breadth) open water-littoral region of the reservoir showed *Melanoides tuberculata* and the classes Insecta, Clitellata, Gastropoda and Bivalvia as well as the total benthic macro-invertebrates were significantly ($p < 0.05$) higher in their mean abundance values at the littoral region than in the open water region. On the other hand, *Chironomus* sp. was significantly ($p < 0.05$) abundant at the open water than in the littoral region (Table 4). Other recorded taxa were not significant ($p > 0.05$) in their horizontal (open water – littoral regions) variations (Table 4).

However, the t-tests of the seasonal variations in the abundance of the macro-invertebrates shows that none of them were significantly different ($p > 0.05$) in their seasonal variations (Table 4).

Table 4: Spatial and temporal variations in the abundance of benthic macro-invertebrate fauna ($Org./m^2$) taxa composition from Owalla Reservoir

S/N	Horizontal variations along the major axis Taxon	Reach Upper Mean ± S.E.	 Mid-Basin Mean ± S.E.	 Lower Mean ± S.E.	ANOVA F	 P
1	*Chironomus* sp.	2±2	4±1	1±1	1.354	0.261
2	*Lumbricus* sp.	1±1	2±1	2±1	0.280	0.756
3	*Bulinus globosus*	11±4	5±1	1±1	3.994	0.020*
4	*Pila africana*	9±3	9±3	3±1	1.007	0.368
5	*Melanoides tuberculata*	250±59	201±44	232±87	0.191	0.826
6	*Unio* sp.	1±1	1±0	3±2	1.357	0.261
7	*Ligumia recta*	1±1	1±0	4±2	5.074	0.007*
8	*Mutela* sp.	1±1	1±1	1±1	0.001	0.999
9	Total Insecta	2±2	18±5	78±30	8.121	$4.493X10^{-4}$*
10	Total Clitellata	4±2	4±1	2±1	0.696	0.500
11	Total Gastropoda	273±60	216±44	235±87	0.219	0.804
12	Total Bivalvia	2±2	5±2	11±4	1.910	0.152
13	Total Organisms	281±60	243±47	325±116	0.358	0.699

	Horizontal variations across the major axis	Region Open-Water Mean ± S.E.	 Littoral Mean ± S.E.	t – tests t	 P
1	*Chironomus* sp.	8±2	1±1	3.2459	0.0045*
2	*Lumbricus* sp.	1±1	2±1	-0.7006	0.4925
3	*Bulinus globosus*	8±2	4±1	1.212	0.241
4	*Physa acuta*	1±1	1±1	-0.783	0.444
5	*Radix natalensis*	1±1	1±1	-0.540	0.596
6	*Pila africana*	8±4	7±1	0.508	0.616
7	*Melanoides tuberculata*	40±15	321±49	-2.702	0.015*
8	*Unio* sp.	1±1	1±1	-0.694	0.496
9	*Ligumia recta*	1±1	2±1	-0.724	0.479
10	*Mutela* sp.	1±1	1±1	-0.629	0.537
11	Total Insecta	8±2	37±11	-0.857	0.403
12	Total Clitellata	1±1	5±1	-2.062	0.054
13	Total Gastropoda	58±19	333±49	-2.652	0.016*
14	Total Bivalvia	1±1	8±2	-1.443	0.166
15	Total Organisms	68±18	383±56	-2.306	0.033*

	Seasonal variations	Season Dry Season Mean ± S.E.	 Rainy Season Mean ± S.E.	t – tests t	 P
1	*Aeshna* sp.	4±2	2±1	1.128	0.303
2	*Epitheca* sp.	9±4	12±6	-0.389	0.711
3	*Sympetrum* sp.	1±1	1±1	-0.234	0.823
4	*Ischnura* sp.	1±1	1±1	0.000	1.000
5	*Enallagma* sp.	2±1	2±1	0.000	1.000
6	*Anopheles* sp.	8±4	4±2	1.000	0.356
7	*Chironomus* sp.	3±1	3±1	0.129	0.901
8	*Lumbricus* sp.	2±1	1±0	3.464	0.013
9	*Hirudo* sp.	2±1	2±1	-0.277	0.791
10	*Bulinus globosus*	7±2	5±2	0.812	0.448
11	*Physa acuta*	1±1	1±0	0.655	0.537
12	*Radix natalensis*	1±1	1±1	0.000	1.000
13	*Pila africana*	7±2	8±3	-0.432	0.681
14	*Melanoides tuberculata*	243±53	191±40	0.679	0.523
15	*Unio* sp.	1±1	1±1	0.000	1.000
16	*Lamellidens* sp.	2±1	3±2	-0.211	0.840
17	*Ligumia recta*	2±1	1±0	1.555	0.171
18	*Mutela* sp.	1±1	0±0	1.477	0.190
19	Total Insecta	28±9	25±10	0.205	0.845
20	Total Clitellata	4±1	3±1	N/A	N/A
21	Total Gastropoda	258±53	206±40	0.682	0.521
22	Total Bivalvia	6±2	5±2	0.640	0.546
23	Total Organisms	296±60	238±47	0.649	0.541

NB: * = Significant difference ($p \leq 0.05$)

DISCUSSION

The benthic macroinvertebrate fauna of the Owalla Reservoir is broadly similar (in terms of abundance and species composition) to that of many other Nigerian inland waterbodies (Nathaniel, 2002; Aliu, 2006; Asibor, 2008; Olomukoro, 2008; Olomukoro and Azubuike, 2009; Adedeji, 2011; Adedeji *et al.,* 2012; Olapoju and

Edokpayi, 2018). In this study, for instance, a total of 5076 individuals were recorded from the reservoir belonging to 18 different species of benthic macroinvertebrates. These were made up of three phyla (Arthropoda, Annelida and Mollusca); Ahmad *et al.* (2002) observed that the three main phyla (Arthropoda, Annelida and Mollusca) contribute greatly to freshwater macro-benthic community; likewise, Arti Sharma *et al.* (2015) also observed a similar pattern of taxonomic composition from Ban Ganga stream, Katra, India. In comparison to the available information based on studies of inland water bodies in Nigeria, the benthic macroinvertebrate species recorded from the Owalla Reservoir can be considered as relatively poor in taxa composition but rich in the abundance of the total individuals. The benthic species diversity is controlled by productivity, habitat heterogeneity and biotic interactions; in general, invertebrates have a clumped distribution, which is assumed to be related with the mosaic of interchanging conditions in the substratum, flow conditions/velocities, depth and the type of substrate (Moretti and Callisto, 2005; Stamou *et al.,* 2018). Some physical and chemical features directly affect taxonomic composition and community structure; substratum particle size, substratum stability, substratum organic matter contents (Wangchuk and Dorji, 2018), habitat spatial heterogeneity and sediment characteristics such as; grain size, predator exposure and food availability are important factors regulating macro-invertebrates abundance, distribution and richness, and hence, habitat characterization is of prime importance to the knowledge of macro-invertebrate distribution (Moretti and Callisto, 2005; Olapoju and Edokpayi, 2018). The relatively high number of individuals (benthic macroinvertebrates) from Owalla Reservoir could be attributed to probably the high nutrients and organic matter levels in the sediments (organic matter content: range = 0.69 - 14.10 %; Mean±S.E. = 3.20 ± 0.20 %.) , as well as low water currents, low level of disturbances in the reservoir, reduced level of predation and competition as well as the presence of aquatic vegetation and high level of vegetative cover at the surroundings of the reservoir (Aduwo, 2016). Balachandar *et al.,* (2018) observed that the diversity, distribution and abundance of most macro-benthos depend on the characteristics of their environment such as pollution condition, organic matter content, soil texture and sediment.

In this study, *Melanoides tuberculata* was the most dominant taxa, occurring in almost all the twenty stations with a total occurrence of 90 % and with highest total abundance value of 4128 individuals. The high occurrence of *M. tuberculata* could be attributed to its ability to thrive well in the tropics with habitat temperature preference over the range of 21 to 25 ^{0}C. They are also known to become invasive on introduction to a new location due to their ability to reproduce parthenogenetically and even bring forth juveniles viviparously (Adedeji *et al.,* 2012). In general, members of family Thiaridae are quick colonizers, tolerant to habitat diversity and variability due to a very strong and thick shell; many forms are parthenogenetic females capable of multiplication in a short time, viviparous, operculate and have average longevity of five years (Sharma *et al.,* 2013). The dominant taxon in the reservoir was the phylum Mollusca which was the same as observed from Asejire Reservoir, the largest man-made lake in Southwest, Nigeria by Asibor (2015). The low occurrence of *Enallagma* sp. (Odonata: Zygoptera) (10 %) may be due to the fact that it was represented by its nymphal stage and the mature nymph of the insect often leaves water on emergence as aerial adults (Wetzel, 2001). *Physa acuta* had the lowest abundance with an overall total number of 16 individuals all through the period of this study. The fact that Martins-Silva and Barros (2001) found it abundantly in polluted waters is an indication that Owalla Reservoir is not highly polluted.

Bulinus globosus occurred in ten out of the twenty sampling stations (50 %) in the reservoir; *Bulinus globosus* has been noted to have a wide distribution in North and Western regions of Nigeria (Asibor, 2008) while Cowper (1963) concluded that *Bulinus globosus, Lymnaea natalensis, Lanistes libycus* and *Biomphalaria pffeiferi* are known to occur in most parts of Nigeria. Also, Oladejo and Ofoezie (2006) in an earlier study on Owalla Reservoir observed that the *Bilinus globosus* identified by a previous study as the local intermediate host species of Schistosomiasis was found to be abundant in the lake and occurred throughout the year, in contrast to the seasonal occurrence reported previously.

The spatial variation in the abundance of the benthic macroinvertebrates along the upstream-downstream axis of the reservoir had no definite pattern as different species and taxa had their highest mean abundance in the different basins of the reservoir. Olomukoro (2008) observed that species diversity of benthic macroinvertebrates and spatial distribution in abundance between study stations could be attributed to a strong preference for ecological niche or substrate type and feeding habit than the predominant set of physicochemical conditions in the ecosystem. According to Scheffer *et al.* (1984), vegetation pattern is the main factor determining the spatial distribution of macroinvertebrates in lakes; different vegetation types differed considerably in total faunal density. Also, Scotti *et al.* (2019) suggested that changes in the abiotic environment have great implications for benthic macroinvertebrate composition and that the spatial variability of the benthic macroinvertebrate fauna is usually higher than the temporal variability.

Significantly higher abundance of *Bulinus globosus* upstream than in the mid-basin and downstream sections could be due to the fact that most of the stations sited upstream were close to riparian communities (Illie and Oba-Ile) where *Bulinus globosus* had previously been found to be abundant throughout the year (Oladejo and Ofoezie, 2006). The highest mean abundance of *Ligumia recta* at the downstream of the reservoir could be due to the fact that its food consists primarily of particulate detritus, microzooplankton and phytoplankton that are mostly associated with that portion of the reservoir (Wetzel, 2001). The highest mean abundance of insects (Total Insecta) recorded at the downstream of the reservoir could be due to the fact that most insects and their developmental stages that are benthic living, burrow into sediments or live on macrophytic vegetation and plant detritus (Wetzel, 2001) as most of the stations sited downstream of the reservoir were at the littoral region.

Higher mean abundance of the benthic macroinvertebrates was recorded at the littoral region of the reservoir than in the open water region, except for *Chironomus* sp. which was significantly ($p < 0.05$) more abundant in the open water region than in the littoral region. This may be due to the great heterogeneity of substrata at the littoral regions of reservoirs, and as a result the benthic animal species abundance and diversity is greater in the littoral than in the more homogeneous profundal zone. Wetzel (2001) opined that the benthic community structure in lakes usually consists of rich fauna with high oxygen demands in the littoral zone above the metalimnion. The significantly higher mean abundance values of *Chironomus* sp. at the open water region than in the littoral region had also been reported by many workers. The report of McLachlan and McLachlan (1971) on this was that high concentrations of coarse sand in the littoral region appeared to have an adverse effect on the abundance of chironomids. *Chironomus* sp. larvae are also known to possess the oxygen transport pigment – haemoglobin, conferring a more efficient mode to absorb dissolved oxygen even at depth in the open water. This effectively put it ahead of other species in tolerance and preference to the anoxic condition prevailing at the open water region (Adeogun and Fafioye, 2011).

The effects of seasonal changes did not greatly alter the abundance and composition of the organisms in the reservoir as obvious with the non-significant ($p > 0.05$) seasonal variations in the abundance of all the recorded benthic taxa from the reservoir. It could also suggest that the reservoir had benthic macroinvertebrate taxa with similar seasonal preferences in the different stages of their life history. Temporal distributions of freshwater macro-invertebrate communities, both on the bottom and in the water column, are known to be influenced by the life histories of the various species (Sporka *et al.,* 2006).

CONCLUSION

In conclusion, the reservoir is relatively rich in benthic macroinvertebrate fauna species and composition compared to other waterbodies in Nigeria; which is an indication of a healthy water condition. Also, the taxa composition of the benthos from the reservoir is not dominated by pollution tolerant species. This is evidence of little or no anthropogenic influences on the reservoir's water quality from the activities within the catchment basin.

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CONFLICT OF INTEREST

The authors announce that there is no conflict of interests.

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