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Bio-assessment of Ecological Health Status of Itapaji Reservoir, Itapaji, South-Western Nigeria

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ABSTRACT

Macro-benthos communities are often threatened by environmental changes which are associated with pollution, erosion and siltation. Since paucity of information was available on Itapaji Reservoir benthic macro-invertebrates composition, a pertinent study to ascertain the quality of the water for its sustainable management becomes crucial. The reservoir was monthly sampled for benthic macro-invertebrates (BMI) from April, 2013 to March, 2015 at five purposively selected stations. Samples were collected using Van-Veen grab (surface area, $0.6m^2$), sieved (mesh size, 0.5 mm), sorted, identified using standard identification keys, and counted macroscopically. Species diversity was determined with Shannon Weiner's Index (H). Data were analysed using descriptive statistics, student's t-test, and ANOVA at $\alpha_{0.05}$. Two phyla comprise of seventeen species of BMI were recorded with moderately intolerant benthic macro-invertebrates dominating. Higher macro-benthos organisms were recorded in the rainy season with *Chaoborus* larvae dominated the assemblages in both seasons. All the encountered benthos differed significantly at $p<0.05$ across the sampling stations, while sampling station 3 recorded the highest abundance. The order of dominance coupled with Shannon Weiner's diversity index of less than 3.0 revealed that the habitat is unstable, and perturbed due to run-off of anthropogenic material from the adjourning land.

Introduction

Bio-monitoring is a tool for assessing environmental quality because biological communities integrate the effects of different stressors and, thus, provide a broad measure of their aggregate impact (Reynoldson *et al.,* 1997; Rosenberg, 1998; Barbour *et al*., 1999). The assessment of biological communities in an aquatic environment reflects the quality of the ecosystem, and the use of biological approaches to determine the ecological effects of pollution has been preferred widely for decades (Akindele and Liadi, 2014). Bio-monitoring have been a reliable method, and benthic macro-invertebrates are good and often, preferred candidates for long-term monitoring programmes relating to anthropogenic impacts because they are relatively sedentary and long lived, they occupy an important intermediate trophic position and they respond differentially to varying environmental condition as suggested by Simboura *et al*. (1995), Bamikole *et al*. (2009), and Adeogun and Fafioye (2011).

There are three major categories of environmental stress: the natural stresses (e.g. droughts and floods), imposed stresses (e.g. sewage pollution, toxic waste and pesticides) and environmental manipulation by man (e.g. reservoir construction, channel modification and the transfer of water between catchments (Hellawell, 1986). The macroinvertebrate fauna could be affected by each one of these stresses, and the fauna at any given site may be the result of more than one category of stress (Wright, 1997).

Itapaji Reservoir (the second largest reservoir in Ekiti State) is constantly used for irrigation of the adjourning farmlands, fishing and domestic activities, among other uses. The reservoir experiences at least one type of stress i.e. natural stress occasioned by drought in the dry season as a result of water abstraction for irrigation and run-off from the adjoining farming land during the rainy season. In this study, the status of Itapaji Reservoir was assessed based on the composition and diversity of the benthic macro-invertebrates.

Materials and Methods

Description of Study Area

Itapaji Reservoir is located in Itapaji, Ikole Local Government Area of Ekiti State, south western Nigeria. It lies between latitude 07° 56' and 07° 57'N, and longitude 05° 27' and 05° 28'E at an elevation of 445 m above the sea level (Figure 1). The reservoir was formed by impounding River Ele in 1972 and commissioned in 1975, with a designed capacity of 5,175m^3/day for the supply of water to 13 towns and villages in 3 local government areas of Ekiti State namely Ikole, Oye and part of Ekiti East Local Government Area.

River Ele, which took its source from the "Undifferentiated Basement Complex" hills around Osin - Ikole, is the major river in this drainage. It flows northward from source for about 20km to the dam site, 4km northwest of Itapaji. Beyond the dam site, it flows northwestward to join Rivers Osse and Kampe in Kwara State. These two rivers later join the River Niger at a point 5km north-east of Eggan. Rivers Oye and Omo are tributaries of River Ele. While River

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Omo took its source from the hills around Ikole - Ekiti and flows north westward of Ikole into River Ele, River Oye took its sources from the hills, 8km north of Itapaji and flows southwardly into River Ele (Fagbohun, 2016). The hydrographs derived from the data collected at the gauging station downstream of the dam shows that the dam does not spill any water for a period spanning 4 - 6 months (January - June) annually (Fagbohun, 2016).

Experimental/ Sampling Design and Analysis

Five sampling stations were selected on the reservoir based on the proximity to different anthropogenic activities around the reservoir. Sampling was done once monthly for 24 months (April 2013 to March 2015) between 08:00-11:00 hours on each sampling days across the five sampling stations. Temperature and transparency were measured *in situ* using mercury- in-glass thermometer and Secchi-disc, respectively (Ruttner, 1963, and Wetzel and Likens, 2000) in each sampling stations. Surface water samples for chemical parameters were collected in 2L plastic bottles and kept in a refrigerator prior its analysis.

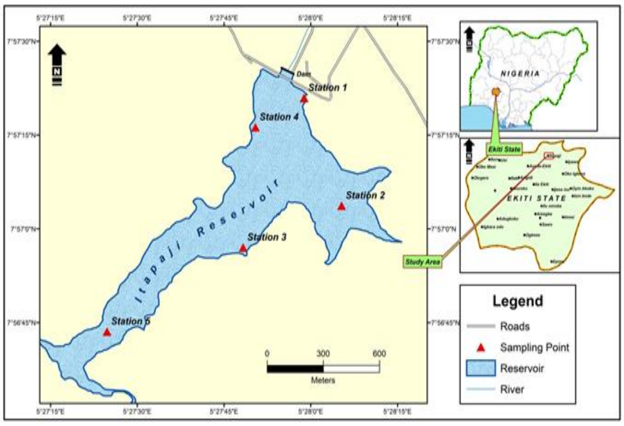

Figure 1. The Map of Itapaji Reservoir reflecting the sampling stations.

(Source: Cartographic unit, Department of Geography, University of Ibadan, Ibadan, Nigeria).

Sediment sample for benthos organisms from each sampling stations were collected using $0.6m^2$ (surface area) Van-veen grab. Three random replicate samples from each station were hauled into a pre-label sterile polythene bag and transported to the laboratory for sorting, identification and recording.

Laboratory Analysis

All the parameters were analysed in Central Laboratory, Federal University of Technology Akure, Ondo State, Nigeria using standard method (APHA, 1998).

The sediments were washed through graduated sieves of 0.5mm; sorting of the macro-invertebrates in the sediment sample was enhanced by staining the washed sediment samples with Rose Bengal solution. The macro-invertebrates were identified using identification guides of APHA/ AWWA/ WEF, (1992); Odiete (1999), and Hawkin (2000). Each identified taxon was counted and the number of individuals recorded. The samples were preserved using 10% formalin.

Statistical Analysis of Data

Bivariate and multivariate statistics as provided by the SPSS Version 22.0, and MS Excel 2010 software were used in the analysis of the data on the physico-chemical parameters and their associations with benthic macro-invertebrates. The determination of spatial variance equality (homogeneity) in the means of the physico-chemical parameters, and benthic macro-invertebrates groups was made with one-way analysis of variance (ANOVA), further mean separation was made with the Duncan Multiple Range Test (DMRT), while seasonal comparison of these variables was made with the student's t-test of significance. The analysis of the biological data was made with a combination of indices. Species diversity and evenness was determined with Shanon-Wiener's index (H), and Equitability (J) using PAST Version 3.

Results

Physico-chemical Parameters

The descriptive results of the physico-chemical parameters of the Itapaji Reservoir in Ikole LGA of Ekiti State, southwestern Nigeria measured across the sampling locations from April 2013 to March 2015 are already written in Adebayo and Ayoade (2017). Phosphate, TSS, zinc, copper, iron, lead, and chromium were observed to exceed the NESREA (2011) recommended limit for aquatic organisms (Table 1).

Benthic Macro-invertebrate Composition and Abundance

The overall benthic macro-invertebrate composition and abundance during this study period is summarized in table 2. A total of 30,854 organisms were encountered in this study between April 2013 and March 2015 sampling period. These were represented by 2 phyla, comprised of 4 classes, and 9 orders (Table 2). Class Insecta dominated the macro-benthos fauna identified (68.5%), while Arachnida was least abundant (0.5%). Gastropoda had 4 species; Bivalvia, 1 species; Insecta, 11 species and Arachnida, 1 species. *Chaoborus* larvae (Insecta) was the most abundant single species identified (6,493 organisms; 21.0%), while *Macromia magnifica* (Insecta) and *Hydracarina* sp (Insecta) species were least in abundance (143 organisms; 0.5%, each). Moderately intolerant species accounted for the highest abundance of the total recorded macro-invertebrates of the reservoir followed by very tolerant species while the sensitive/ intolerant species recorded the least overall abundance (Figure 2).

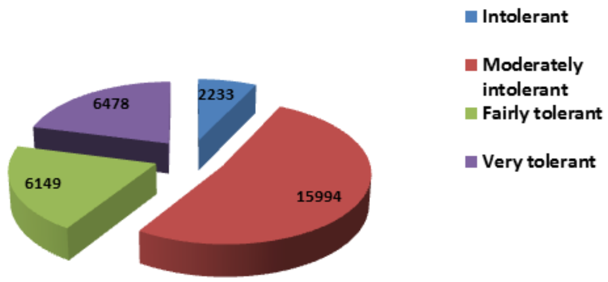

Figure 2. Percentage tolerances in the benthic macro-invertebrate fauna of Itapaji Reservoir.

Seasonal Variation in Benthic Macro-invertebrate Composition and Abundance

Higher macro-benthos organisms were recorded in the rainy (20,404 organisms; 66.1%) than dry season (10,450 organisms; 33.9%). The *Chaoborus* larvae dominated the macro-benthos assemblages in both seasons (Table 2). A pair-wise comparison of abundance of macro-benthos between the rainy and dry season revealed Gastropods and Odonata differed seasonally at $p<0.05$ (Table 3).

Spatial Variation in Benthic Macro-invertebrate Composition and Abundance

Sampling station 3 recorded the highest numerical abundance (8,672 organisms; 28.2%) while station 1 recorded the least abundance of 3,277 organisms (10.6%) (Fig 3), however, all the recorded benthos differed significantly at $p<0.05$ across the sampling stations (Table 4).

Table 1. Descriptive statistics of the Physicochemical Parameters of Itapaji Reservoir.

Parameter	Minimum	Maximum	Range	Mean ± SE	NESREA(2011)
Temperature (°C)	23.00	29.50	6.5	27.5 ± 0.125	a
Transparency (m)	0.49	2.54	2.05	1.54 ± 0.049	NS
pH	6.06	9.20	3.14	7.27 ± 0.058	6.5-8.5
Conductivity (µS/cm)	68.00	970.00	902.00	274.87 ± 20.480	NS
Total dissolved solids (mg/L)	10.54	108.50	97.96	43.52 ± 2.741	NS
Total suspended solids (mg/L)	7.67	34.81	27.14	16.64 ± 0.673	0.25
Total solid (mg/L)	19.54	123.50	103.96	59.68 ± 2.573	NS
Alkalinity (mg/L)	20.60	240.00	219.40	72.01 ± 4.647	NS
Chloride (mg/L)	18.40	168.63	150.23	57.03 ± 4.236	300
Total Hardness (mg/L)	16.00	63.00	47.00	38.57 ± 1.018	NS
Nitrate (mg/L)	2.20	10.20	8.00	5.45± 0.182	9.1
Sulphate (mg/L)	3.50	24.10	20.60	10.28 ± 0.619	100
Phosphate (mg/L)	2.50	18.60	16.10	7.23 ± 0.483	3.5
Dissolved Oxygen (mg/L)	0.50	8.50	8.00	4.88 ± 0.194	Not<6.0
BOD (mg/L)	0.40	5.00	4.60	2.42 ± 0.106	3.0
Sodium (mg/L)	5.60	16.50	10.90	11.70 ± 0.204	120.0
Potassium (mg/L)	3.40	19.80	16.40	12.36 ± 0.338	50.0
Calcium (mg/L)	8.46	24.00	15.54	15.47 ± 0.339	180.0
Magnesium (mg/L)	8.00	24.30	16.30	14.99 ± 0.370	40.0

Note: SE = standard error of mean, BOD = Biochemical Oxygen Demand, NS = Not Specified, and a = [a]except in mixing zones, temperature increase by a 7-Day Average of the Daily Maximum temperatures (7-DADMax) shall not be more than 0.3 ºC above natural background conditions.

Table 2. Relative Abundance of Macro-invertebrate taxa in Itapaji Reservoir.

Class/Order	Species	Rainy Season		Dry Season		Total	
		Abundance (No)	Percentage (%)	Abundance (No)	Percentage (%)	Abundance (No)	Percentage (%)
GASTROPODA	Melanoides tuberculata***	2,856	14.0	957	9.2	3,813	12.4
	Biomphalaria pfeifferi****	425	2.1	170	1.6	595	2.5
	Physa waterlotti****	428	2.1	149	1.4	577	1.9
	Gabiella africana****	3,135	15.4	1,067	10.2	4,202	13.6
TOTAL		6,844	33.5	2343	22.5	9,187	29.8
BIVALVIA	Margaritifera margaritifera**	287	1.4	119	1.1	406	1.3
INSECTA-Diptera	Chaoborus larvae**	4,400	21.6	2,093	20.0	6,493	21.0
	Palpomyia sp***	1,589	7.8	747	7.1	2,336	7.6
	Chironomus sp****	631	3.1	473	4.5	1,104	3.6
	Tipula sp**	1,223	6.0	558	5.3	1,781	5.8
Sub-Total		7,843	38.4	3,871	37.0	11,714	38.0
Hemiptera	Notonecta sp**	2,668	13.1	2,034	19.5	4,702	15.2
	Lethocerus americanus**	664	3.3	557	5.3	1,221	4.0
	Gerris Larvae**	417	2.0	211	2.0	628	2.0
	Sigara sp (Water boatman) **	291	1.4	186	1.8	477	1.5
Sub-Total		4,040	19.8	2,988	28.6	7,028	22.8
Ephemeroptera	Ephemerella excrucians*	1,166	5.7	877	8.4	2,043	6.6
	Caenis sp*	90	0.4	100	1.0	190	0.6
Sub-Total		1,256	6.2	977	9.3	2,233	7.2
Odonata	Macromia magnifica**	51	0.3	92	0.9	143	0.5
TOTAL		13,190	64.7	7,928	75.8	21,118	68.5
ARACHNIDA - Acarina	Hydracarina sp**	83	0.4	60	0.6	143	0.5
GRAND TOTAL		20,404	100	10,450	100	30,854	100

*=Sensitive/Intolerant species, **=ModeratelyIntolerant species, ***=fairly tolerant species, ****=Verytolerantspecies (Plotka et al, 2009)

Table 3. Seasonal variation in Benthic Macro-invertebrate taxa of Itapaji Reservoir (P<0.05).

Class/Order	Season	Mean ± SE	t	P-value
Gastropoda	**Rainy**	468.100 ± 47.137	4.003	0.003*
	Dry	250.600 ± 20.695		
Diptera	**Rainy**	509.700 ± 51.606	1.691	0.125
	Dry	398.00 ± 29.779		
Hemiptera	**Rainy**	264.600 ± 26.818	0.866	0.409
	Dry	299.00 ± 23.758		
Ephemeroptera	**Rainy**	82.200 ± 8.308	1.254	0.241
	Dry	97.700 ± 7.422		
Odonata	**Rainy**	3.500 ± 0.224	7.068	0.000*
	Dry	9.000 ± 0.699		
Acarina	**Rainy**	5.200 ± 0.772	0.706	0.498
	Dry	6.000 ± 0.715		

N.B: SE = standard error of mean, Values with superscript * differed significantly

Table 4. Spatial variation in Benthic Macro-invertebrate fauna of Itapaji Reservoir using Duncan Multiple Range Test (DMRT) (P< 0.05).

Class/Order	Sampling Stations				
	1	2	3	4	5
Gastropoda	28.17 [b]	117.83 [a]	143.50 [a]	110.33 [a]	4.50[b]
Diptera	59.00[b]	40.00[b]	122.83[a]	132.00[a]	140.83[a]
Hemiptera	36.00[b]	23.83[b]	73.83[a]	76.33[a]	82.33[a]
Ephemeroptera	11.33[b]	7.83[b]	23.17[a]	25.83[a]	26.67[a]
Odonata	0.67 [b]	0.33 [b]	1.50 [a]	1.67 [a]	2.00 [a]
Acarina	1.00 [bc]	0.50 [c]	1.33 [ab]	1.67 [a]	1.67 [a]

N.B. Values with the same superscript along same row are not significantly different at P<0.05

Table 5. Diversity index of Benthic Macro-invertebrates of Itapaji Reservoir.

Class/Order	H	J
MOLLUSCA		
Gastropoda	1.206±0.133	1.206±0.133
INSECTA		
Diptera	1.183	0.854
Hemiptera	1.053	0.759
Ephemeroptera	0.351	0.506
Mean±SE	0.862±0.26	0.706±0.10
Total Mean±SE	1.034±0.17	0.728±0.30

H = Shannon-Wiener's index, J = Equitability measure, and SE = Standard error

Table 6. Seasonal Diversity indices of Benthic Macro-invertebrate Abundance of Itapaji Reservoir.

	Rainy		Dry	
Class/Order	H	J	H	J
MOLLUSCA				
Gastropoda	1.194	0.742	1.237	0.769
ARTHROPODA				
Insecta				
Diptera	1.169	0.844	1.201	0.866
Hemiptera	1.055	0.761	1.048	0.756
Ephemeroptera	1.344	0.497	1.359	0.518
mean±SE	1.19±0.08	0.70±0.10	1.20±0.09	0.71±0.10
TOTAL mean±SE	1.191±0.00	0.72±0.02	1.211±0.02	0.74±0.03

H = Shanon-Wiener's index, J = Equitability measure, and SE = Standard error

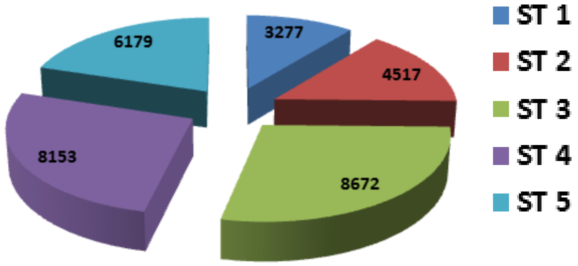

Figure 3. Spatial variations in the abundance of benthic macro-invertebrate of Itapaji Reservoir.

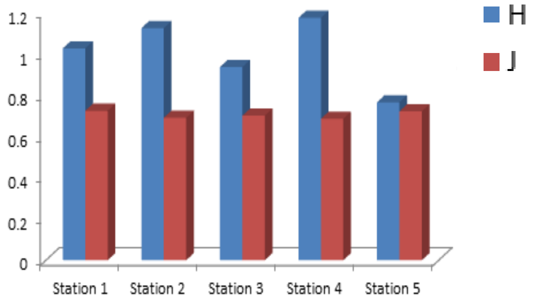

Figure 4. spatial diversity indices for the Benthic Macro-invertebrate fauna of Itapaji Reservoir.

Species Diversity of Benthic Macro-invertebrate

Shanon-Weiener's index (H) revealed the class Gastropoda to be most diverse (H= 1.206±0.133) among the macro-benthos taxa. Though class Gastropoda was revealed to be more evenly distributed (J = 0.749) than Insecta (J = 0.706), Diptera was most evenly distributed (J = 0.854) among the insects of the recorded benthos (Table 5). Higher mean diversity of 1.21±0.02 was recorded in the dry than the rainy (1.19±0.00) season for the macro-benthos of the reservoir. Also, macro-invertebrates were shown to be more evenly distributed during the dry (0.74±0.03) season than the rainy (1.19±0.00) season (Table 6). Highest diversity index of 1.17 ± 0.13 was recorded in station 4 while station 5 (0.76 ± 0.07) was the least diverse sampling station (Figure 4). Station 1 was recorded to be most evenly (J = 0.72 ± 0.11) distributed while the least spread (J = 0.68 ± 0.08) of the benthos was recorded in station 4.

Discussion

The benthic macro-invertebrate fauna composition of Itapaji Reservoir is characterized by low taxa, with least abundance of sensitive species. This was similar to Edward and Ugwumba (2010) report in Egbe Dam. They ascribed these low taxa to factors other than physico-chernical conditions of the water such as habitat preference, resource partitioning, and food availability. However in Itapaji reservoir, habitat destruction due to settling of the recorded high total suspended solid brought into the reservoir through erosion and run-off of the adjourning land might have singly influenced the overall composition and abundance of the benthic fauna of the reservoir. This probably caused disruption of life cycle, reproductive cycle, and food chain and or imposed physiological stress on even the tolerant benthic macro-invertebrates. This observation is not unusual with some earlier report by Adakole and Annune (2003) in Urban Stream, Zaria, Northern Nigeria, and Edward and Ugwumba (2010) in Egbe dam, Ekiti, South-west, Nigeria.

The higher abundance of benthic macro-invertebrates in the rainy season may be as a result of predators other than fish and aquatic invertebrates exploit invertebrate prey better in the dry season than in the rainy season. This is because in the dry season, the water level becomes reduced and clearer, and the substrate also stabilizes, thereby making available for the fish and avian predators more prey items.

The observed spatial variation reveals the differing severity of the several activities along the course of the reservoir. The highest diversity index in gastropoda could be as a result of their ability to breathe alternative oxygen source with their lungs. The low values of diversity indices recorded in this study may indicate decimating impact of impoundment on the benthic communities, as earlier reported by Emere and Nasiru (2007); George *et al.* (2009); and Adeogun and Fafioye (2011). The low values may also indicate pollution stress which is further confirmed by the low diversity at all the sampled stations for Odonata and Ephemeroptera which are clean water insects.

The Shannon-Wiener Index was found to be the most reliable in assessing water quality using macrozoo-benthos (Kalyoncu and Zeybek, 2011). According to the Water Framework Directive, the relationship between the indices and ecological level is as follows: high status: higher than 4 bits/individual, good status: 4-3 bits/individual, moderate status: 3-2 bits/individual, poor status: 2-1 bits/individual, and bad status: 1-0 bits/individual (Plotka *et al*, 2009). Thus Shannon-Weiner diversity index values above 3.0 indicate that the structure of the habitat is stable, while values less than 1.0 indicate that there are pollution and degradation of the habitat structure (Shannon, 1948; Mandaville, 2002). Shannon-Wiener Index values of macro-invertebrates in all the cases from this study showed low values with average 1.034±0.17. The low index values suggested the poor state of the aquatic health of this reservoir ecosystem with an indication to pollution.

Conclusion

Based on the values obtained in this study, the relatively dominance of the moderately intolerant, followed by tolerant benthic macro-invertebrates species and the least abundance in their sensitive species suggest that the reservoir was moderately polluted. Likewise, the recorded intermediate bio-diversity indices values, as well as the recorded dominance in the pollution indicator taxa further established the perturbation effect of anthropogenic material on the reservoir which might have being carried by run-off from the adjourning land into the reservoir. Also, the occurrence of *Biomphalaria pfeifferi* in the reservoir is of economic important that required a further research in order to prevent the future endemic of Schistosomiasis in the host community.

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