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Benthic Macroinvertebrates as Indicators of Water Quality in Asejire Reservoir, Southwest Nigeria

Godwin I. Asibor[1*], Israel F. Adeniyi[2]

[1]Dept. of Environmental Management and Toxicology, Federal University of Petroleum Resources Effurun, Delta State, Nigeria
[2]Dept. of Zoology, Obafemi Awolowo University, Ile-Ife, Nigeria

Correspondent Author: asibor.godwin@fupre.edu.ng, Tel. +234-802-752-3674

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***Abstract* -** The water quality assessment of Asejire reservoir was carried out using benthic macroinvertebrates. Ten sampling stations were selected based on the reaches, vegetation pattern and impact of human activities on the reservoir using a Van Veen grab sampler. Collection and identifications was done using standard identification keys. Physicochemical parameters were determined using standard methods. The mean range of physicochemical parameters studied were; electrical conductivity 108±4.01µS/cm, pH 7.78±0.26, water temperature 26.19±0.38 ^{0}C, water transparency 1.46±0.13mg/L, TDS 85.0±4.32mg/L), turbidity 11.2±0.45 NTU, dissolved oxygen 4.57±0.27mg/L, biological oxygen demand 0.77±0.29 mg/L, with low values for phosphate, nitrate, sulpgate and chloride. There was no significant difference between the sampling sites in physicochemical parameters ($p<0.05$). Thirty-six (36) species belonging to Class Insecta, Arachnida, Malacostraca, Gastropoda, Bivalvia, Hirudinea and Gordiodea were identified and accounted for 8545 individuals. Increasing dominance of benthic macroinvertebrates followed: Insecta (50%), Gastropoda (27.8%), Bivalvia (8.3%), Malacostraca (5.6%), Arachnida (2.8%), Hirudinea (2.8%) and Gordiodea (2.8%). Correlation analysis between physicochemical parameters and macroinvertebrates showed a strong positive relationship ($P<0.05$). Presence of pollution intolerant species in most of the stations and accounting for more than 20% of the recorded individuals indicates a near-pristine ecosystem. However, the presence of pollution tolerant macroinvertebrates notably *Chironomus sp. and Hirudo sp.* in the Reservoir is a cause of concern and this indicate that the reservoir may not be totally free from pollution and therefore there is the need to have a robust monitoring plan in place to control anthropogenic pollutants and put measures in place to halt the introduction of more pollutant tolerant species into the Reservoir.

***Keywords* -** reservoir, benthic macroinvertebrates, physico-chemical, pollution, water quality

I. INTRODUCTION

Physico-chemical water quality parameters indicates the condition of a water body, even though this may not show the total health of the water [1]. According to [2] and [3] a combination approach involving biological parameters such as benthic macroinvertebrates community structure and physico-chemical water quality characteristics, will provide a better evaluation of the well-being of a water body over time. Biological computation of water status have long been integrated with physical and chemical evaluation to give complete information for an effective water management [4] and [5]. Biological surveillance established on macroinvertebrates indicate more predominant pollution indicator than using only physico-chemical surveillance [6]. According to [7] water bodies can be monitored by different methods using macro invertebrates' enumerations such as diversity indices, richness measurement and similarity indices, biotic and Multimetric approach.

Domestic and industrial wastes dumped into water bodies can change the biological, physical and chemical characteristics of the aquatic system beyond their natural self-purification capacity [8]. High levels of turbidity, nutrients, suspended solids as well as dissolved solids and coliform bacteria in rivers, lakes and reservoirs are indication of compromised systems which may be attributed to increased pollutant load, resulting largely from different anthropogenic activities. According to [9] such alterations in the water quality can change the macroinvertebrates and other aquatic biota community structure.

The use of macroinvertebrates to assess the health of water bodies have been widely reviewed by many authors [10] [11][12] [13] [14] [15]. Mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), beetles (Coleoptera), crayfish (Crustaceans), aquatic snails (Mollusca), biting midges (Chironomids) and leeches (Hirudinea) are some of the macroinvertebrates utilized in aquatic pollution studies in Nigeria and other parts of the world [16]. Macroinvertebrate abundance and spread

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usually change in reaction to pollution pressure in predictable ways, therefore their application as biological benchmark for monitoring of anthropogenic effects of aquatic systems [9]. In view of the foregoing, this study was conducted in Asejire Reservoir, one of the biggest man-made lake in the Southwestern Nigeria in order to assess the physico-chemical parameters as well as the abundance and distribution of aquatic benthic macro-invertebrates. This will aid to generate data on the pollution indicator species in the reservoir.

II. MATERIALS AND METHODS

Study area

Asejire Reservoir is a manmade lake that was created in 1970 by the impoundment of River Osun. It was officially opened in 1972. The Reservoir extend from longitudes 004^0 07’017”E - 004^0 08’925”E and in length from latitudes 07^0 21’48”N and 07^0 26’84”N (Figure 1). It was primarily created to supply domestic and industrial water [17]. Other ancillary benefits such as fishing, recreation, agriculture, etc. have since emerged after the dam creation [11]. The reservoir receives the bulk of its water input from two rivers, Rivers Osun and its main tributary River Oba. The catchment area of the dam is 7,800 km^2 and the impounded area is 23.42 km^2. The surface area of the reservoir is about 24 km^2. Its gross storage capacity is approximately 7,403.4 million litres per day while its discharge capacity is 136.26 million litres per day with maximum water capacity of about 675 m^3. The reservoir supply water to more than two million inhabitants of Oyo and Osun States in the Southwestern part of Nigeria.

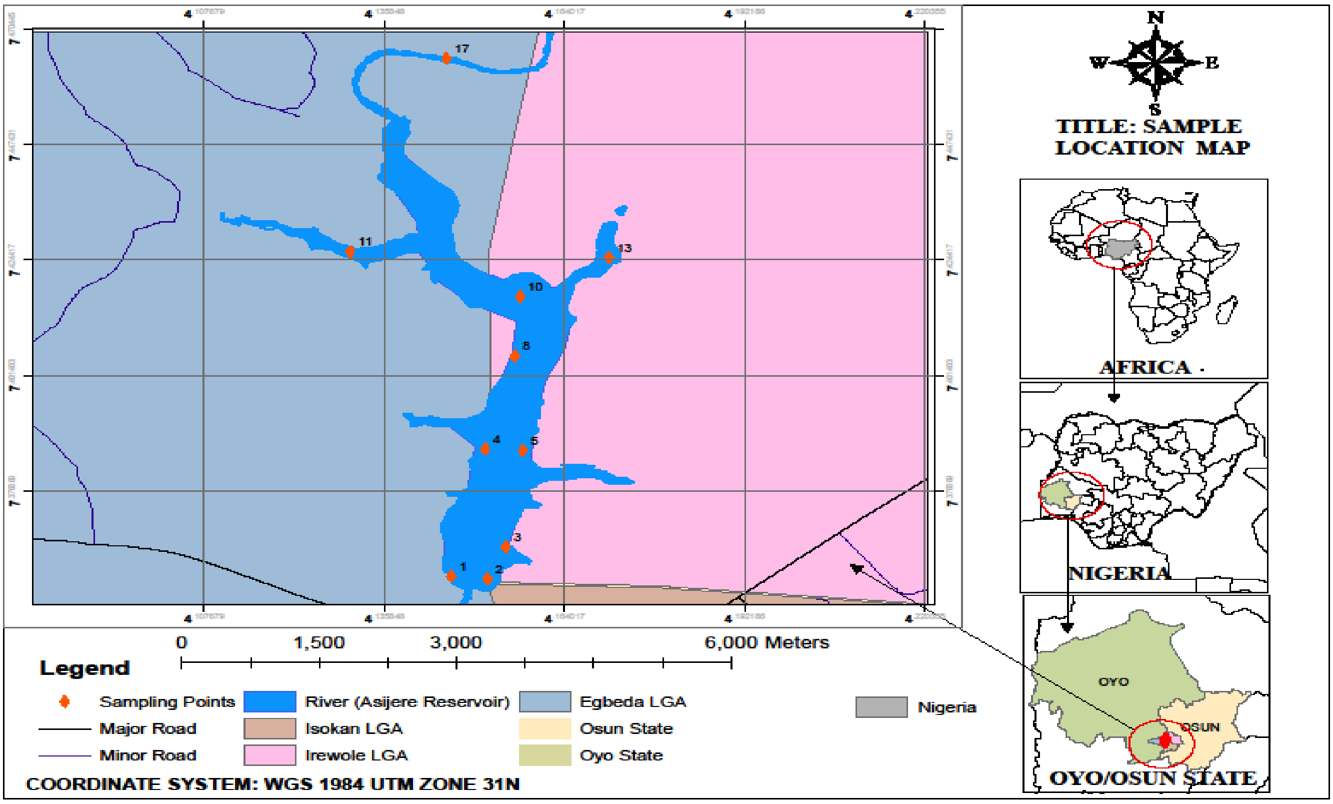

Figure 1: Map of Asejire Reservoir Showing Sampling locations.

Sampling Sites

Ten (10) sampling sites were chosen within the reservoir for the purpose of this study (Figure 1). This was based on the reservoir reaches, vegetation pattern and anthropogenic impacts.

Determination of Physico-Chemical Parameters

Water Samples were collected monthly for a period of twelve months (April 2017 – March 2018) from ten sampling stations. Conductivity, pH, water temperature, transparency, total dissolved solids (TDS), turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), sulphate, chloride, nitrate – nitrogen and phosphate – phosphorus were determined according [18].

Collection of Macroinvertebrates Samples

Sediment containing macroinvertebrates samples were collected using an improvised Van Veen grab sampler. Each sediment sample collected was washed using three set of sieves to collect the macroinvertebrates (2mm mesh size, 1mm and the 0.5mm). Macroinvertebrates were poured into a white enamel tray for proper visibility and sorting. Collected macroinvertebrates samples were sorted into different containers, labelled accordingly and preserved with 10% formalin. Identification of macroinvertebrates was carried out using keys provided by [19] [20] [21] [22] [23] [24] [25] [26]. Samples of macroinvertebrates from each site were allocated with Modified Family Biotic Index (FBI) according to their sensitivity and environmental stress

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tolerance [27] [28]. The taxa richness, diversity and evenness indices were calculated using the Shannon-Wiener index and Margalef index [29] [30].

Statistical Analyses

Relationship between physicochemical parameters and macro invertebrate was assessed using analysis of variance (ANOVA) in order to ascertain whether there is significant difference or otherwise. All the statistical analyses were carried out using the Palaeotological Statistics [31], Statistical Package for Social Sciences (SPSS) Software package for biological data analysis and Statistical Ecology [32].

III. RESULTS

Physicochemical Parameters

The results of mean physicochemical parameters are presented in Table 1. The water electrical conductivity ranged from 88.0µS/cm (July 2017) to 148 µS/cm (February 2018) with mean value of 108±4.01 µS/cm. pH ranged from 6.75 (March 2018) to 8.60 (June, July and August 2017) with a mean value of 7.78± 0.26 during the sampling period. Temperature range from 22.9 ^{0}C (January 2018) to 30.50 ^{0}C (August and September 2017) with a mean value of 26.19±0.38 ^{0}C. Transparency vary from 0.45m (August and September 2017) to 2.45m (April 2017 and February and March 2018) with a mean value of 1.46m±0.13. Total dissolved solids (TDS) was between 65.8mg/L (recorded in January and February 2018) to 106.8 mg/L (April 2017) with a mean value of 85.00 mg/L ±4.32. Turbidity values ranged from 4.80 NTU (March 2018) to 18.2 NTU (September 2017) with a mean value of 11.16±0.45 NTU. Dissolved oxygen (DO) ranged from 2.80 mg/L June 2017) to 6.65 mg/L (December 2017) with a mean value of 4.57 mg/L ± 0.27. BOD ranged from 0.08mg/L (January, February and March of 2018) to 2.25mg/L (December 2017) with a mean value of 0.77mg/L±0.29. The highest phosphate value of 2.24 was recorded in (February and March 2018), while the lowest value of 0.08mg/L was recorded in December 2017). The mean concentration was 0.54mg/L±0.25. Nitrate nitrogen values ranged 0.00 mg/L (January and March 2018) to1.22 mg/L recorded in in May and December 2017, while the mean concentration is 0.38 mg/L ± 0.16. Mean concentrations of sulphate and chloride was 4.68 mg/L ± 1.09 and 8.87 mg/L ± 1.43 respectively.

Table 1: Summary of mean monthly concentrations of physico-chemical parameters of Asejire Reservoir

Parameter	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6	Stn7	Stn8	Stn9	Stn10	Mean	Sd
Conductivity (µS/cm)	112.6	110.0	104.4	114.0	101.5	113.2	107.0	108.3	106.7	107.5	108.53	4.01
pH	8.26	7.75	8.03	7.91	7.53	7.80	7.46	7.60	7.53	7.95	7.78	0.26
Temperature (^{0}C)	26.08	26.16	26.13	25.77	25.73	27.11	26.30	26.15	26.42	26.08	26.19	0.38
Transparency (m)	1.53	1.49	1.37	1.35	1.43	1.78	1.46	1.44	1.28	1.51	1.46	0.13
TDS (mg/L)	84.09	83.87	76.65	83.59	83.23	92.50	88.08	82.26	88.75	86.96	85.00	4.32
Turbidity (NTU)	11.49	10.79	10.43	11.06	11.96	11.09	11.69	10.95	10.93	11.24	11.16	0.45
DO (mg/L)	4.39	4.44	4.06	4.63	4.73	5.00	4.48	4.82	4.35	4.75	4.57	0.27
BOD (mg/L)	0.86	1.23	0.81	0.32	0.50	0.96	0.33	0.98	0.85	0.84	0.77	0.29
PO_{4-} (mg/L)	0.33	0.41	0.72	0.29	0.48	0.49	0.42	0.48	1.17	0.60	0.54	0.25
NO_{3-} (mg/L)	0.58	0.21	0.55	0.64	0.40	0.26	0.29	0.44	0.26	0.22	0.38	0.16
SO_4^{2-} (mg/L)	6.07	3.50	4.60	4.80	4.20	3.81	3.03	4.80	5.62	6.35	4.68	1.09
Cl (mg/L)	9.04	7.43	8.89	8.26	11.43	6.68	10.86	8.57	8.31	9.19	8.87	1.43

Benthic Macroinvertebrates Composition, Distribution and Abundance

A total of 8545 benthic macroinvertebrates individuals belonging to 36 species were recorded from the ten (10) sites of the reservoir (Table 2). Among the identified taxa, Class Insecta, Gastropoda and Bivalvia were the most diverse consisting of eighteen (18), ten (10) and three species respectively. Class Gordiodea, Hirudinea and Annelidia were the least diverse, each with one species. Potadoma moerchi had the highest number of individuals of 3143, accounting for 36.8% of all the benthic macroinvertebrates. It was followed by potadoma freethi 1736 (20.3%) and Melanoides tubaculata 730 (8.5%). The least species were Sudanonautes africanus with 4 species (0.05%), Lanistes libycus with 7 species (0.08%) and Eristalis sp, Aciagrion sp and Lstinogomphus sp each with 8 individuals and accounting for 0.05 during the duration of the study. Station 2 with 1363 (16.0%) accounted for the highest individuals, followed by Stations 9 and 7 with 1025 (12.0%) and 945 (11.1%). Station 3 with 468 (5.5%) individuals accounted for the least number of macroinvertebrates. This was followed by Stations 6 and 7 with 717 and 758 individuals and accounting for 8.4% and 8.9% respectively.

Table 2: Benthic macro invertebrates Species Composition, Abundance and Distribution in Asejire Reservoir

	Taxa	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6	Stn7	Stn8	Stn9	Stn10	Total	% Prevalence
1	*Sympetrum sp*	19	31	16	12	14	26	18	16	16	31	199	2.33
2	*Acisoma panorpoides*	3	3	4	0	0	4	0	0	2	1	17	0.20
3	*Epicordulia sp*	16	24	24	0	4	16	14	20	32	56	206	2.41
4	*Enallagma deserti*	22	34	0	5	20	13	20	16	10	16	156	1.83
5	*Ishnura sp*	18	18	0	6	20	12	18	16	18	18	144	1.69
6	*Aciagrion hamoni*	0	4	0	0	0	4	0	0	0	0	8	0.09

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7	*Lestinogomphus sp*	2	2	0	0	0	4	0	0	0	0	8	0.09
8	*Cloeon dipterum*	22	34	0	16	22	18	24	19	16	16	187	2.19
9	*Baetisca sp*	22	28	0	12	24	10	24	18	20	16	174	2.04
10	*Caenis sp*	12	26	0	12	16	2	8	16	32	28	152	1.78
11	*Belostoma sp*	18	0	0	5	24	8	22	20	36	28	161	1.88
12	*Renatra sp*	18	36	0	5	22	5	20	24	22	18	170	1.99
13	*Hydrometra sp*	7	20	0	0	0	0	2	0	18	0	47	0.55
14	*Simulilium damnosum*	5	30	22	22	38	0	24	20	22	0	183	2.14
15	*Eristalis sp*	2	0	0	0	6	0	0	0	0	0	8	0.09
16	*Ablablemyia sp*	0	14	24	24	42	0	24	4	6	0	138	1.61
17	*Chaoborus sp*	3	12	20	12	26	0	24	14	4	0	115	1.35
18	*Hydracarina sp*	0	20	0	0	0	0	0	0	24	0	44	0.51
19	*Macrobrachium macrobrachium*	7	16	0	0	0	0	0	0	18	0	41	0.48
20	*Sudanonautes africanus*	2	2	0	0	0	0	0	0	0	0	4	0.05
21	*Lymnea natalensis*	3	21	0	0	0	0	0	0	18	0	42	0.49
22	*Biomphalaria pfeifferi*	34	22	0	0	44	24	24	22	40	48	258	3.02
23	*Bulinus globosus*	16	26	0	0	0	0	0	18	30	0	90	1.05
24	*Gyraulus deflectus*	3	20	0	0	0	0	0	0	18	0	41	0.48
25	*Physella gyrina*	8	20	0	0	0	0	0	0	22	0	50	0.59
26	*Physa waterlotti*	5	8	0	0	0	0	0	0	8	0	21	0.25
27	*Potadoma freethi*	122	288	48	204	104	190	252	216	136	176	1736	20.32
28	*Potadoma moerchi*	368	442	252	369	244	281	337	262	306	282	3143	36.78
29	*Melanoides tubaculata*	52	86	48	48	96	100	76	60	90	74	730	8.54
30	*Pila ovata*	22	1	0	0	0	0	0	0	24	21	68	0.80
31	*Lanistes libycus*	4	2	0	0	0	0	0	0	1	0	7	0.08
32	*Sphaerium sp*	0	7	0	0	0	0	0	0	8	0	15	0.18
33	*Tagelus plebeius*	0	24	0	0	0	0	0	23	0	0	47	0.55
34	*Hirudo sp*	4	24	0	0	0	0	0	0	24	0	52	0.61
35	*Paragodius sp*	0	10	6	4	20	0	10	2	0	0	52	0.61
36	Chironomus larvae	1	8	4	2	4	0	4	2	4	2	31	0.36
	Total sample collected	840	1363	468	758	790	717	945	808	1025	831	8545	100
	%	9.8	16.0	5.5	8.9	9.2	8.4	11.1	9.5	12.0	9.7	100	

General Diversity (H) and Equitability

The values of taxa richness, diversity and equitability are presented in Table 3. Margalef's taxa richness was highest at Station 2 (4.57) and followed by Stations 1 (4.31) and 9 (4.18). The lowest numerical value was recorded at Station 3 (1.63). Shannon diversity were highest at Station 9 (2.69) and followed by Station 2 (2.53) and Station 5 (2.39). The lowest was at Station 4 (1.62), followed by station 3 (1.64) and Station 6 (1.79), while the Equitability distribution was highest at Stations 5 (0.8127), 9 (0.7916) and 10 (0.7640). The least equitably distribution occurs in Stations 4, 6 and 1 with values of 0.5827, 0.6470 and 0.6578 respectively.

Pollution tolerant species such as *Chironomus sp. Hirudo sp. and Tubifex* sp. accounted for less than 2.0% of the total individuals, while pollution intolerant species (indicators of clean water) such as Baetidae, Baetiscidae, Caenidae, Libelludlidae, Cordulidae, Coenagrinoidae, etc. combined accounted for more than twenty percent (20%) of the benthic macroinvertebrates recorded in this study.

Table 5, shows the modified Family Biotic Index (FBI) developed by [27] and [28] for showing tolerance value to organic pollution by benthic macroinvertebrates.

Table 3: Summary of the Diversity and Faunal Indices of Macroinvertebrates at the Study Area

	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6	Stn7	Stn8	Stn9	Stn10
Taxa	30	34	11	16	19	16	19	20	30	16
Individuals	840	1363	468	758	790	717	945	808	1025	831
Dominance	0.2245	0.1608	0.3218	0.3169	0.143	0.2479	0.2112	0.1898	0.1257	0.1822
Shannon indx	2.237	2.527	1.636	1.615	2.393	1.794	2.071	2.184	2.692	2.118
Simpson indx	0.7755	0.8392	0.6782	0.6831	0.857	0.7521	0.7888	0.8102	0.8743	0.8178
Menhinick	1.035	0.9209	0.5085	0.5811	0.676	0.5975	0.6181	0.7036	0.937	0.555
Margalef	4.307	4.572	1.626	2.262	2.698	2.281	2.627	2.838	4.183	2.231
Equitability	0.6578	0.7166	0.6824	0.5827	0.8127	0.647	0.7035	0.7291	0.7916	0.764
Fisher alpha	6.078	6.322	2.018	2.867	3.504	2.902	3.369	3.712	5.789	2.811
Berger-Parker	0.4381	0.3243	0.5385	0.4868	0.3089	0.3919	0.3566	0.3243	0.2985	0.3394

Table 4: Correlations between macro-invertebrates and mean physicochemical parameters at Asejire Reservoir

	BMI	Cond	pH	Temp	Transp	TDS	Turb	DO	BOD	PO4	NO3	SO4	Cl
BMI	X												
Cond	0.1361	X											
pH	-0.345	0.4601	X										
Temp.	0.0086	0.3209	-0.103	X									
Tranp.	-0.048	0.4253	0.2128	0.6522	X								
TDS	0.3209	0.3541	-0.316	0.6713	0.5211	X							
Turb	0.0787	-0.192	-0.276	-0.236	0.1679	0.3384	X						
DO	-0.005	0.2716	-0.256	0.2755	0.5987	0.5627	0.3773	X					
BOD	0.3496	0.1480	0.2149	0.4079	0.3343	0.0094	-0.543	0.0029	X				
PO4	0.0003	-0.439	-0.285	0.2622	-0.423	0.1208	-0.353	-0.344	0.2115	X			
NO3	-0.577	0.1954	0.5116	-0.501	-0.316	-0.628	-0.065	-0.284	-0.392	-0.348	X		
SO4	-0.213	0.0844	0.5343	-0.237	-0.223	-0.088	-0.082	-0.084	0.1493	0.3094	0.2325	X	
Cl	-0.015	-0.687	-0.308	-0.577	-0.358	-0.240	0.7126	-0.141	-0.645	-0.089	0.1247	-0.055	X

Table 5: Modified family biotic index (FBI) indicating tolerance value organic pollution by benthic macro-invertebrates at Asejire Reservoir

	Taxa	FBI Value
1	*Sympetrum sp*	10
2	*Acisoma panorpoides*	9
3	*Epicordulia sp*	5
4	*Enallagma deserti*	8
5	*Ishnura sp*	9
6	*Aciagrion hamoni*	9
7	*Lestinogomphus sp*	2
8	*Cloeon dipterum*	4
9	*Baetisca sp*	5
10	*Caenis sp*	6
11	*Belostoma sp*	5
12	*Renatra sp*	5
13	*Hydrometra sp*	5
14	*Simulium damnosum*	5
15	*Eristalis sp*	10
16	*Ablablesmyia sp*	8
17	*Chaoborus sp*	8
18	*Hydracarina sp*	6
19	*Macrobrachium macrobrachium*	6
20	*Sudanonautes africanus*	8
21	*Lymnea natalensis*	6
22	*Biomphalaria pfeifferi*	7
23	*Bulinus globosus*	7
24	*Gyraulus deflectus*	8
25	*Physella gyrina*	8
26	*Potadoma freethi*	7
27	*Potadoma moerchi*	7
28	*Melanoides tubaculata*	7
29	*Pila ovate*	7
30	*Lanistes libycus*	6
31	*Sphaerium sp*	6
32	*Mutela sp*	6
33	*Tagelus plebeius*	6
34	*Hirudo sp*	10
35	*Paragordius sp*	6
36	*Chironomus larvae*	10

IV. DISCUSSION

Physicochemical Parameters

According to [33] and [34], aquatic life is governed by physicochemical and biological conditions of the water body. In Asejire Reservoir, limnological variables were observed to fluctuate slightly during the study period, across the physical parameters which include water transparency, temperature and turbidity. These parameters varied gradually from various month of the year. The temperature of the reservoir ranged from 22.9 ^{0}C to 30.50 ^{0}C. pH value recorded in this study varied from 6.75 – 8.60. The pH recorded fall within the acceptable limits of 6.5- 8.5 for fresh water bodies set by National Standard for Drinking Water Quality [35]. In the present investigation Dissolved Oxygen ranged between 2.8 – 6.65 mg/L which is quite satisfactory perhaps due to good aeration rate and photosynthetic activity as reported by [36]. The distribution of Dissolved Oxygen in water body has been reported to be governed by a balance between input from the atmosphere, rainfall, photosynthesis and losses by the chemical and biotic oxidations [37] [38]. TDS in water consist of inorganic salts and dissolved materials. High values of TDS may lead to change in water taste and deteriorate plumbing and appliances [39]. The TDS values recorded in the reservoir varied from minimum of 65.8 mg/L – 106.8 mg/L. This falls within the maximum limit of 600mg/L set by [39]. Phosphates- phosphorus and Nitrate- nitrogen values recorded were found to be low and within acceptable limits.

Benthic Macro Invertebrates

The existence or otherwise of macroinvertebrate in any given fresh water ecosystem is a function of a substrate quality, physicochemical condition and food availability [36]. Asejire Reservoir serves as critical water source for various activities such as industrial, fishing, bathing, recreation, domestic purposes among others that were ongoing during the study period. In Asejire Reservoir, the abundance and diversity of benthic macroinvertebrate have positive correlation with some of the physico-chemical characteristics of the water (Table 5). The overall benthic macro-invertebrates recorded in this study comprised of Class Insecta (50%), Gastropoda (27.8%), Bivalvia (8.3%), Malacostraca (5.6%), Arachnida (2.8%, Hirudinea (2.8%) and Gordiodea (2.8%). The 36 species recorded comprising

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of 8545 individuals in this study was high when compared with 19 taxa recorded by [40] in Okpoka Creek, 21 taxa reported by [41] in River Benue, 27 taxa recorded by [42] in River Kaduna; 33 taxa recorded by [42] in wetlands Southern Nigeria, 55 taxa reported for tropical streams; [10] and [44]. The high species diversity may be attributed to high organic matter as well as other favorable physicochemical parameters such as pH, dissolved oxygen, biological oxygen demand, TDS and electrical conductivity.The presence of pollution tolerant species such as Chrinomus sp. and Hirudo sp. in some of the sampling locations is an indication of the presence of pollution in a localized state. This can have a destructive effect not only on the aquatic flora and fauna but also on other terrestrial organisms including humans [45] if not well managed.

However, the presence of Ephemoroptera species such as Cloeon, Baetisca, Canis, etc. that are considered to be sensitive to environmental stress showed a relatively positive effect in the reservoir [24]. The abundance of these species is an indication of good quality and may be due to dilution during rains, high dissolved oxygen, low organic pollutants and availability of food [43].

V. CONCLUSION AND RECOMMENDATIONS

The benthic macro-invertebrates of Asejire Reservoir is rich in fauna composition, abundance and distribution when compared to other reservoirs of similar sizes in Nigeria and around the world. The ample presence of pollution intolerant species in appreciable number in both composition and distribution is an indication of the favourable condition of the reservoir as at the time of the study. However, the occurrence of some pollution tolerant species in the water body is an indication of the likely increase in environmental strain in the future through anthropogenic activities, which may in turn ease the biodegradation of the reservoir. Hence, the need to develop a well-structured monitoring plan for the reservoir. Therefore, there should be regular monitoring and control of the sources of pollutants into the reservoir. Biological index and their indices should be embraced for use by relevant administrative authorities as devices for monitoring the state of reservoirs at regular intervals.

Government at different levels and regulatory agencies should impose pollution abatement laws in order to conserve and preserve the reservoir biodiversity. This in turn will help to protect the health of the reservoir as well as those who make use of this invaluable resource.

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AUTHORS PROFILE

Godwin Irabor Asibor has B.Sc., M.Sc. and Ph.D. in Zoology from Obafemi Awolowo University, Ile-Ife in 1997, 2001 and 2008. He is currently working as a Senior Lecturer in the Department of Environmental Management and Toxicology, Federal University of Petroleum Resources Effurun, Delta State, Nigeria. He is a member of Zoological Society of Nigeria, Nigeria Environmental Society (NES), Freshwater Biological Association of Nigeria and Wetland Society. He has published more than 30 research manuscripts in reputed local and international journals and conferences. His main research work focuses on use of plankton and benthic macroinvertebrates as impact assessors in the environment. He has 20 years of research experience and 10 years of teaching experience in the university.

Israel Funsho Adeniyi has B.Sc. and Ph.D. in Zoology from the University of Ife (now Obafemi Awolowo University, Ile-Ife in 1972 and 1978. He is currently working as a Professor in the Department of Zoology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. He is a member of Nigeria Field Society (NFS), Zoological Society of Nigeria (ZSN), Freshwater Biological Association of Nigeria (FBAN), among others. He has published more than 70 research manuscripts in reputed local and international journals and conferences. His main research work focuses on use on planktonic and peryphyton as impact polluters in the environment. He has more than 35 years of teaching and research experience. He has supervised more than 20 Ph.D. students.

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