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Plankton and Macro-benthic Invertebrate Diversity of Apodu Reservoir in Malete, Nigeria

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Abstract

The present study investigated the physicochemical, phyto- and zoo-plankton, macro-invertebrate composition and abundance in Apodu Reservoir in Malete, Ilorin, Kwara state, Nigeria. Samples were collected twice a month in duplicate using standard techniques between February and July 2021. The physicochemical parameters of water: pH, electrical conductivity, water temperature and total dissolved solids were measured *in situ* using a portable water tester, and the other parameter were measured using standard methods. A sampling net with a mesh size of 0.5 mm were used for plankton collection while benthos were sampled using an Ekma grab sampler. The species richness and diversity were calculated using PAST 4.03 software. The result of the physicochemical parameters, phyto- and zoo-plankton and benthic macro-invertebrates showed significant differences between dry and rainy seasons. Nineteen species of phytoplankton and 13 species of zooplankton were identified in the reservoir. The Simpson index (1-D) values for dry and rainy seasons were 0.7654 and 0.8595, respectively, while the Margalef index values for dry and rainy seasons were 1.82 and 2.919, respectively. The study indicated that the reservoir water was slightly alkaline (pH 7.63 – 8.63) and had a low level of dissolved oxygen (4.9–5.8 mg/l). The occurrence of pollution-resistant phytoplankton species: *Oscillatoria* spp*., Microcytis* spp*.,* and *Microthamnion* zooplankton species: *Bosmina meridinalis, Keratella tropica, Branchionus calyciflorus* and macro-invertebrates species: *Namalycastis abiuma* indicated the eutrophic status of the reservoir water indicating the reservoir is under anthropogenic pressure. Therefore, reservoir management activities such as protecting the reservoir areas and proper functioning of the reservoir to reduce, human activities are recommended.

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1. Introduction

Phytoplankton and zooplankton are the fundamental biological components from which energy is transferred to higher organisms through the food chain (Tas and Gonulal, 2007). The benthos of an aquatic ecosystem directly or indirectly relies on them. They also serve as bioindicators and are a reliable tool for determining the status of water pollution (Contreras *et al*., 2009). Plankton have a dynamic system that quickly respond to changes in the physical and chemical properties of the water as they represent the baseline of the food chain in the aquatic ecosystem (Esenowo *et al*., 2018). The assemblage of zooplankton often influences nutrient cycling and community population dynamics within a reservoir ecosystem (Mustapha, 2009). Besides, the species composition, distribution, diversity and relative abundance of zooplankton in a reservoir could have significantly impact on fisheries and public health of the reservoir and its users (Hecky and Kling, 1981).

Benthic macro-invertebrates are also important in monitoring environmental effects because they are either sessile or of limited movement and, therefore,

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cannot readily avoid pollution (Idowu and Ugwumba, 2005). Thus, their dynamics reflect the local conditions of the aquatic ecosystem (Sharma and Chowdhary, 2011). To this effect, many indices of the community structure of benthic macro-invertebrates have been used as biological indicators of the aquatic environment, including water quality status and pollution (Scotti *et al.*, 2019).

The Apodu reservoir has been serving the nearby community and other nearby settlements close to Malete town of North Central Nigeria for domestic, recreational and fishing activities (Oladipo et al., 2018; 2019). The inability of the reservoir to function appropriately has led to improper and unhygienic activities to be being carried out within and close to the reservoir. Similarly, during recreational activities the herdsmen bring their cattle near the water for feeding and to drinking water, likewise, some cattle urinate into the water during recreational activities (Oladipo *et al*., 2018).

Such problems of human-induced biotic invasions in this reservoir are accelerating changing the ecosystems making uncertainty in predicting the structure and dynamics of ecological communities present. This aspect of the reservoir's limnology has received limited attention from researchers. This study is to determine the reservoir water quality by studying the physicochemical parameters, planktons and benthic macro-invertebrate communities in Apodu reservoir, one of the major multipurpose reservoirs in Malete Town in Moro local government, Kwara State, North Central, Nigeria.

2. Materials and Methods

2.1 Study Area and Sampling Stations

Two sampling stations were chosen in the reservoir. The sampling stations were established based on ecological settings, vegetation and human activities in the area. The co-ordinates of the sampling stations were also taken using a Geographic Positioning System (GPS), and approximate distances of the stations were calculated. The sampling stations were about 403 m apart from each other.

The station 1 is characterized with fishing activities, and landing site for fishermen lies on the longitudes 8°45'16"N and latitude 4°27'39"E, while station 2 is characterized with domestic activities and minimal fishing activities lies on the longitudes 8°45'30"N and latitude 4°27'32"E (Figure 1). Generally, the location of the reservoir is characterized by dry (November to April) and rainy (May to October) seasons. Subsistence farming and commercial fishing activities were been seen in the reservoir. The fluctuation of the reservoir water level is dependent on the season, with a high volume of water during the rainy season with overflow across the dam, whereas in the dry season, the other side of the dam will be dry as a result of impounded that was created (Oladipo et al., 2018; 2019).

2.2 Sample Collection and Analysis

Samples were collected twice a month in duplicate at the designated site using standard techniques in a clean sample bottles between February, March, April and May, June, July (dry and rainy months respectively) in the year 2021. The physicochemical parameters such as pH, electrical conductivity (EC), water temperature, and total dissolved solids (TDS) were analysed *in situ* on the water surface with the aid of Hanna portable pH/ EC/ TDS/ Temperature combined waterproof tester model HI 98129. The dissolved oxygen (DO), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) was measured using Extech heavy-duty DO/Salinity/Temperature meter model 407510 A, while phosphate, nitrate and chloride was done using an Ultraviolet (UV) spectrophotometer from the water samples collected in the morning at about 8:00 am at a depth of 10 cm below the water surface before sunrises in order to observe their variation. A net with a mesh size of 0.5 mm as used for plankton collection and preserved in vials containing 4% formalin and chloroform solution, while benthos were sampled using Ekma grab sampler. The samples were taken to the laboratory in the Department of Zoology, Kwara State University, Malete, for the analysis. In the laboratory, the macrobenthos retained was poured into a white enamel tray, and organisms were identified using a hand lens/microscope, and aquatic taxonomic keys (Edmunds, 1978; Pennak, 1978).

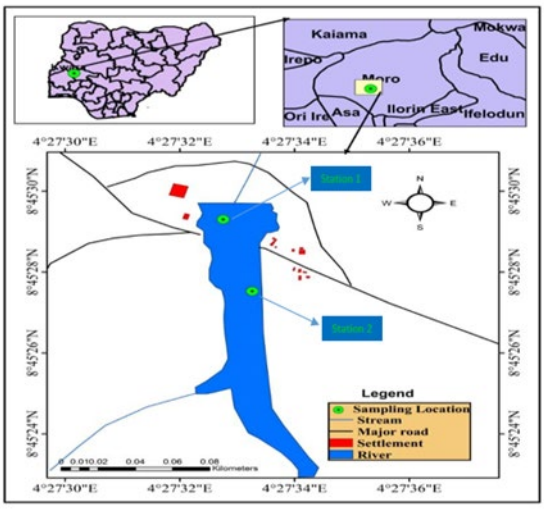

Figure 1: Map of the Study Location Indicating the Sampling Stations in Apodu Reservoir.

2.3 Statistical Analysis

The species richness and diversity of plankton and macrobenthos were calculated with Margalef and Shannon- Wiener index of diversity (H) (Shannon and Weaver, 1963) using PAST 4.03 software.

3. Results

3.1 Biological Characteristics of Phyto- and Zoo-plankton in Apodu Reservoir during Period of Sampling

Phytoplankton distribution and abundance in the dry season are presented in Table 1. A total number of 404 individuals having 52.6 cells per ml and 19 species were recorded. Dominating genera were: *Oscillatoria, Microcystes, Microthamnion, Mougeotia* and *Cosmarium* of the class Cyanophyceae and Chlorophyceae. The highest abundant species was *Oscillatoria* (12.4%) while the lowest was *Hydrodictyon* and *Planthothrix* (0.75%). The Dominance_D is 0.07573 and 0.0906 for both stations, Simpson_1-D for the dry season was 0.9243, evenness was 0.7889, Shannon Wieners' diversity index was 2.707 and Margalef was 2.999.

In the rainy season a total of 298 individuals and 28 species of phytoplankton were recorded. The dominant genera were *Oscillatoria, Anaebaena, Aphanizomenon, Flos-Aqaue*, *Mougeotia* of the class *C*yanophyceae and Chlorophyceae. The highest abundant species was *Oscillatoria* (12.8%), while the lowest was *Astrachelomon* and *Gleocapsa* (0.34%). The rainy season Dominance_D was 0.06299, Simpson_1-D was 0.937, evenness was 0.6878, Shannon Weiners diversity index 2.958 and Margalef was 4.739.

Zooplankton distribution and abundance in the dry season are presented in Table 2. A total of 196 individuals, with 13 species were recorded. The number of cells per ml of water was 26.1 cell/ml. The highest abundan zooplankton was *Calanoid* sp. (21.4% of the total zooplankton community), and the least was *Hexarthra mira* (0.5% of the total zooplankton community) and *Mesocyclops leuckarti* (0.5% of the total zooplankton community). Species dominance (D) was 0.1361, having a Simpson index of diversity (1-D) of 0.8639; Margalef index (M) was 2.274; the evenness value was 0.6823 and the Shanon-Wiener diversity index (H) was 2.183.

In the rainy season a total of 333 individuals including 23 taxa of zooplankton were recorded with *Calanoid* as the dominant genus. The highest abundant zooplankton was *Calanoid sp* (12.0% of the total zooplankton community) and the least was *Asplanchna pridonta* (0.5% of the total zooplankton community).

Table 1: Phytoplankton distribution in Apodu reservoir during sampling period

Taxon	Species	Dry Season Occurrence	% Abundance	Total number (cells/ml)	Rain Season Occurrence	% Abundance	Total number (cells/ml)
CHLOROPHYCEAE	*Microthamnion sp*	34	8.42	4.53		1	0
					4	.	.
						3	5
						5	3
	Cladophora sp	19	4.70	2.53		5	2
					1	.	.
					7	7	6
						4	7
	Hydrodictyon sp	3	0.74	0.40	-	-	-
	Spirogyra sp	17	4.21	2.27		5	
					1	.	2
					5	0	
						7	
	Ulothrix sp	22	5.45	2.93		5	2
					1	.	.
					7	7	6
						4	7
	Chodatella sp	21	5.20	2.78	-	-	-
	Microspora sp	8	1.98		-	-	-
	Volvox sp	-	-	-		0	0
					2	.	.
						6	5
						8	3
ZYGNEMATOPHYCEAE	*Desmidum sp*	27	6.68	3.60		7	2
					2	.	.
					1	0	8
						9	0
	Cosmarium sp	36	8.91	4.80		3	1
					1	.	.
					0	3	3
						8	3

	Mougeotia sp	48	11.88	6.40	24	8.11	4.73	3.20
	Zygema sp	4	0.99	0.53	16	5.41		2.13
CYANOPHYCEAE	*Rivularia sp*	4	0.99	0.53	5	1.69		0.67
	Phormidium sp	-	-	-	6	2.02		0.78
	Microcytis sp	30	7.43	4.00	26	8.78		3.47
	Chrococcus sp	16	3.96	2.13	5	1.69		0.67
	Oscillatoria sp	50	12.38	6.67	38	12.8		5.06
	Anaebaena sp	29	7.18	3.87	14	4.73		1.87
	Aphanizomenon sp	25	6.19	3.33	23	7.77		3.07
	Tolypothrix sp	-	-	-	2	0.68		0.53
	Stigonema sp	-	-	-	1	0.34		0.13
	Cylindrospermopsis sp	-	-	-	1	0.34		0.13
	Gomphosphaeria sp	-	-	-	6	2.02		0.78
	Gloeocapsa sp	-	-	-	1	0.34		0.13
	Synechocystis sp	-	-	-	14	4.73		1.87
BACILLARIOPHYCEAE	*Aulacoseira sp*	-	-	-	1	0.34		0.13
	Melosiraa sp	-	-	-	9	3.04		1.2
VAUCHERIACEAE	*Vaucheria sp*	8	1.98	1.07	10	3.38		1.33
HYPOCREACEAE	*Trichodesmidium sp*	-	-	-	6	2.02		0.78

EUGLENACEAE	*Trachelomonas sp*	-	-	-	1	0.20	0.13
BATRACHOSPERMACEAE	Batrachospermum sp	-	-	-	3	1.01	0.4
	Total number of individuals	404			296		
	Taxa_S	19			28		
	Evenness	0.79			0.69		
	Shannon Weiner's diversity index	2.71			2.96		
	Margalef	3.00			4.74		

Table 2. Zooplankton Distribution in Apodu Reservoir during the Sampling Period

Taxon	Species	Dry Season			Rainy Season		
		Occurrence	% Abundance	Total Number (cells/ml)	Occurrence	% Abundance	Total Number (cells/ml)
Copepoda	*Calanoid sp*	42	21.43	5.6	40	12.01	5.33
	Calamoecia ampulla	40	20.42	5.33	29	8.71	3.87
	Mesocyclops leuckarti	1	0.51	0.13	17	5.12	2.27
	Harpacticoid sp	-	-	-	3	0.91	0.4
Branchiopoda	*Acroperus sp*	23	11.74	3.07	23	6.91	3.07
	llyocryptus spinifer	2	1.02	0.27	19	5.71	2.53
	Daphina lumholtizi	22	11.22	2.93	22	6.61	2.93
	Bosmina meridinalis	8	4.08	1.07	13	3.90	1.73
	Karualona karua	-	-	-	13	3.90	1.73
	Macrothrix spinosa	-	-	-	17	5.11	2.27
	Coronatella rectangula	-	-	-	5	1.50	0.67
	Ceriodaphina sp	-	-	-	3	0.90	0.4
	Nauplius larva	-	-	-	2	0.60	0.27
Cyclopoida	*Lernaea cyprinacea*	12	6.12	1.6	-	-	-
	Cyclopoid sp	21	2.04	2.8	31	9.31	4.13
	Microcyclops varicans	-	-	-	12	3.60	1.6
Cladocera	*Bosminopsis deitersi*	7	3.57	0.93	15	4.51	2
Diptera	*Paratrichocladius aberrans*	7	3.57	0.93	5	1.50	0.67
Ostracoda	*Cytherella fragum*	10	5.10	1.33	29	8.71	3.87
Rotifera	*Asplanchna pridonta*	-	-	-	1	0.30	0.13
	Keratella tropica	-	-	-	4	1.20	0.53
	Trichocera pusilla	-	-	-	17	5.10	2.27
	Branchionus calyciflorus	-	-	-	3	0.90	0.4
	Hexarthra mira	1	0.51	0.13	-	-	-
Calanoida	*Acartiella sinesis*	-	-	-	10	3.00	1.33
	Total number of Individuals	196			333		
	Taxa_S	13			23		
	Margalef	2.27			3.79		
	Evenness	0.68			0.76		
	Shanon-Wiener diversity index	2.18			2.86		

3.2 Macro-invertebrate Abundance and Physicochemical Parameters in Apodu Reservoir during the Sampling Period

Benthos distribution and abundance for both dry and rainy seasons are presented in Table 3. A total of nine individuals were counted and five species during the dry season and eight species during the rainy season. The bivalves (55.5%) were the most abundant in the dry season, while Gastropoda (22.2 %) and Polychaeta (22.2%) were the least represented. Gastropoda (36.5%) and Bivalvia (36.4%) were the most abundant in the rainy season, and Polychaeta (27.3%) was the least representative. Class Polychaeta was the least representative during both seasons.

The abundance of macroinvertebrates recorded during the dry season was: *Margaritifera margaritifera* (33.3%) > *Cerithidae obtuse* (22.2%) > *Mya arenaria* (22.2%) > *Namalycastis abiuma* (11.1%) > *Pyrazuse beninus* (11.1%) while the abundance of macroinvertebrates during the rainy season was: *M. margaritifera* (18.2%) > *N. abiuma* (18.2%) >*M. arenaria* (18.2%) >*C. obtuse* (9.1%) > *Tympanotonos fuscatus* (9.1%) > *Pachymelania aurita* (9.1%) > *Pomacea bridgesii* (9.1%) > *P. beninus*(9.1%).

The dominant species was *M. margaritifera* in both seasons. The species dominance (D) for the recorded dry and rainy seasons were 0.2346 and 0.1405, respectively. Simpson index of diversity (1-D) for the dry and rainy seasons were 0.7654 and 0.8595, respectively. Margalef index (M) for the dry and rainy seasons were 1.82 and 2.919 with an evenness value of 0.9172 and 0.9421, respectively. Shanon-Wiener diversity index (H) for the dry and rainy seasons were 1.523 and 2.02, respectively.

The physicochemical data during the study period in the Apodu reservoir are presented in Table 4. The surface water temperatures of the reservoir in both seasons varied from 25.0 °C to 28.2 °C. TDSs range between 41 ppm and 45 ppm, while DO oxygen values varied between 4.9 mg/l and 5.6 mg/l. There was significant variation the fluctuation in in temperature, TDS, conductivity, phosphate, nitrate, and dissolved oxygen between seasons.

Table 3: Benthos Distribution and Abundance in Apodu Reservoir.

	Taxon	Dry season		Rainy season	
		Occurrence	% Abundance	Occurrence	% Abundance
Bivalvia	*Margaritifera margaritifera*	3	33.3	2	18.2
	Mya arenaria	2	22.2	2	18.2
Gastropoda	*Cerithidae obtuse*	2	22.2	1	9.1
	Tympanotonos fuscatus	0	0	1	9.1
	Pachymelania aurita	0	0	1	9.1
	Pomacea bridgesii	0	0	1	9.1
Polychaeta	*Namalycastis abiuma*	1	11.1	2	18.2
	Litocerus beninus	1	11.1	1	9.1
	Total number of Individuals	9		11	
	Taxa_S	5		8	
	Dominance_D	0.24		0.14	
	Margalef	1.82		2.92	
	Simpson_1-D	0.77		0.86	
	Evenness	0.92		0.94	
	Shanon-Wiener diversity index	1.52		2.02	

Table 4: The Physicochemical Parameters in Apodu Reservoir during the Sampling Period

Parameter	**Dry Season**		**Rainy Season**	
	Range	**Mean±SD**	**Range**	**Mean±SD**
Temperature (°C)	27.8-28.6	28.2 ±0.29	25.0 - 27.1	26.1 ±0.71
pH	7.84 - 9.3	8.63±0.53	7.63 - 9.20	8.18 ±0.68
TDSs (ppm)	41-45	41.7±2.22	42 – 43	42.7± 0.44
Conductivity	76-78	76.7±0.89	83 – 91	86.7 ±2.89
Phosphate (mg/l)	0.01	0.01±0.001	0.004-0.006	0.005±0.22
Nitrate (mg/l)	3.0-3.4	3.1±0.24	3.2-3.6	3.3±0.38
Cl^- (mg/l)	62-65	64±5.11	58-61	60±2.67
DO (mg/l)	4.9-5.8	5.2±0.38	5.2-5.6	5.3±0.37
BOD (mg/l)	0.27-0.32	0.3±0.01	0.2-0.4	0.3±0.24
COD (mg/l)	1.1-1.3	1.2±0.21	1.4-1.7	1.6±0.01
Ca (mg/l)	0.810-0.820	0.815±0.0053	0.820-0.8350	0.815±0.0043

Key: TDS (total dissolved solids), EC (electrical conductivity), BOD (biological oxygen demand), COD (chemical oxygen demand), Ca (calcium)

4. Discussion

The occurrence and distribution of plankton and benthos species are of great significance in freshwater habitats (Manoharan *et al*., 2011).

Jeppesen *et al.* (2002) show that the abundance and diversity of plankton vary according to limnological features such as the oligotrophication and eutrophication status of freshwater bodies. Water

quality characteristics have an enormous impact on the growth and abundance of plankton. Alexander (2012), affirmed that the occurrence of planktonic fauna depends on certain factors such as climate change, habit structure, physicochemical properties, and biotic factors. This present work shows that the cyanobacteria in the phytoplankton community are dominant in the rainy season. This could be attributed to the nutrient level resulting in high biological activities leading to toxin production in the environment (Okechukwu and Ugwumba, 2009; Senanayake and Yatigammana, 2017). The increase in the diversity of phytoplankton observed during the rainy season can also be related to the mixing of water during rainfall which result in nutrient recycling (Okogwu and Ugwumba, 2006).

Zooplankton are sensitive to changing physicochemical parameters. Additionally, the blooming of Cyanophyceae in the dry season negatively influences the feeding and development of zooplankton abundances (Goldwyn and Kowalczewska-Madura, 2008). Copepods of different stages of development have been the most abundant group of zooplankton, influenced by the abundance of phytoplankton and increased in water level (Imoobe 2011). The Copepods give indication of high pollution of Apodu reservoir with higher assemblage and dominancy in both seasons (Mukhopadhyay *et al*., 2000). Indeed, species variation, distribution and abundance of zooplankton highly depend on the chemical and physical properties of water (Patra *et al*., 2011). The spatial distribution of total zooplankton in both seasons at all studied sites showed high copepod presence in all stations but was more widespread during the dry season. The high dominance of copepod in this study corresponds with the findings of Jeje and Fernando (1986), Ikhuoriah *et al*. (2015) and Robert *et al*. (2010). These findings may bebecause Copepoda is the most abundant zooplankton found in most water bodies that are likely to be prone to pollution (Ikhuoriah *et al*., 2015).

The zooplankton species recorded from this study were common in several other rivers in Nigeria and elsewhere (Jeje and Fernando, 1986; Egborge, 1993; Imoobe and Egborge, 1997; Imoobe and Akoma, 2009; Imoobe, 2011). The seasonal difference in zooplankton species abundance, as observed in this study may be because of the chemical composition of the water. Flooding during the rainy season as a result of high rainfall whereby causing an increase in the zooplankton community during the wet season (Ravera, 1996). A higher abundance of zooplankton in the rainy season is in agreement with the reports of Okogwu and Ugwumba (2006). However, the variability in the number of zooplankton species observed in this study may be attributed to changes in environmental parameters and sampling seasons.

The spatial and seasonal distribution of zooplankton species showed that while some species were restricted to certain stations for both seasons, others were found in all the stations. Species of zooplankton, namely, *Hexarthra mira, Lernaea cyprinacea, Harpacticoid, Karualona karua, Macrothrix spinosa, Trichocera pusilla, Microcyclops varicans, Acartiella sinesis, Keratella tropica, Branchionus calyciflorus, Coronatella rectangular, Nauplius larva, Ceriodaphina sp,* and *Asplanchna pridonta,* occurred in both season show the quality of the water in Apodu reservoir. The predominant human activities in station 2 must have resulted in such high depletion in the population (Turner et al. (1990).

5. Conclusion

The values of Margalef's index, Evenness index, Dominance index, Simpson index and Shannon-Wiener index indicated a moderate diversity of zooplankton supported by the nutrient status of the water body. High level of phosphate and nitrate indicated the eutrophic status of Apodu reservoir. The occurence of pollution-tolerant organisms, such as *Oscillatoria* spp, *Microcytis* spp, and *Microthamnion*; zooplankton species: *Bosmina meridinalis, Keratella tropica, Branchionus calyciflorus* and macro-invertebrates species: *Namalycastis abiuma* confirm pollution of the reservoir due to lack of proper management of anthropogenic activities. Therefore, the reservoir is under anthropogenic pressure and reservoir management are recommended such as protection of the reservoir areas and proper functioning of the reservoir to reduced human activities.

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Author's Contribution

Oladipo SO conceived the idea; Adeshola FS and Adelodun D carried out the fieldwork and laboratory analysis; Oladipo SO, Babafemi GA and Ajiboye AO designed the methodology, analyzed the data and revised the initial draft of the manuscript. All authors contributed critically to the draft and gave final approval for publication.

Conflict of Interest Statement

The authors declare that the research was conducted without any commercial or financial relationships

that could be construed as a potential conflict of interest.

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