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Diversity of macro-benthic invertebrates in Kasha-Ruwa Reservoir, Gusau, Nigeria

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Abstract

Kasha-Ruwa Reservoir, Gusau was the main water source for domestic uses in Gusau before construction of Yardantsi Reservoir in 1980s. Various anthropogenic activities are carried out in the reservoir and its surroundings which could adversely impact it, hence this study on the composition, abundance, and distribution pattern of macro-benthic invertebrates in the reservoir. Three stations were selected across the reservoir. Macro-benthos were collected using Surber sampler (0.1m^2, 250µm mesh) and sieved through 250µm mesh sieve. The residues were preserved in 70% ethyl alcohol and labelled for identification of macro-benthos using appropriate guides. Two hundred and forty-seven (247) macro-benthos/m^2 belonging to 21 species and three phyla (Annelida, Mollusca, and Arthropoda) were identified. Arthropoda had the highest abundance (200 individuals/m^2) while Mollusca had the least (22 individuals/m^2). *Chironomus plumosus* was the most abundant species (21.05%), while *Melanoides tuberculata*, *Nepa cineria* and *Potamonautes sidneyi* were the least abundant (1.21% each). The macro-benthos of the reservoir was dominated by pollution-tolerant species such as *Chironomus plumosus,* which shows that the reservoir was polluted, probably due to anthropogenic influence on the water quality. Anthropogenic activities need to be curtailed to improve the water condition for both aquatic biota and humans.

Introduction

Rivers during rainy season subject reservoirs to inundation; this brings about gross changes in water quality as the influent rivers increase the suspended silt and/or clay loads of reservoir (Wetzel 2001). Suspended silt and/or clay loads interferes with the filter feeding mechanism of some biotic communities, which leads to declined feeding rate, longevity and reproduction. In addition, grazing by these predators leads to decline in the abundance of benthic organisms (Twombly and Lewis 1989). The rivers transport organic/inorganic pollutants from drained riparian agricultural lands to the reservoirs during inundation; this leads to fluctuation of biological and physical processes as well as biotic community structure (Okogwu *et al* 2009). Macro-benthic fauna are useful bio-indicators that provide accurate information on aquatic conditions (Mieszkowska *et al* 2013). Macro-benthic organisms live in the sediment and water interface where contaminants accumulate; thus, are exposed throughout their entire life. Most importantly, they show differential levels of tolerance to contaminants. Their sedentary lifestyles reflect local sediment conditions (Dauer 1993). They determine the quantity of nutrients released from the sediment and as well, offer a linkage between substratum and water column predators (Gray and Elloitt 2009).

Changes in composition and taxonomic richness of benthic organisms are considered sensitive tools for detecting alterations in aquatic ecosystems (Pinder *et al* 1987). Methods based on indicator species have been developed. Most of the indices based on the presence or absence of pollution scored taxa focussed on the detection of organic pollution (Hilsenhoff 1988). Assessment of macro-benthic community structure was later used as a tool to measure level of contamination by organic matter and pollutants (Johnson and Wiederholm 1989). Kasha-Ruwa Reservoir, Gusau was the main water source for domestic uses, irrigation and fishing activities in Gusau and its environs before construction of Yardantsi Reservoir Gusau in 1980s (Jabbi 2018). The Reservoir is characterised by various human activities including washing, irrigation around the catchment areas, swimming, and fishing; hence the need to study the composition, abundance, and distribution pattern of macro-benthos as bio-indicators of pollution. This study aims to identify the macro-benthic invertebrates found in reservoir, which could be used to assess water quality and to determine the relationship between their distribution and some abiotic factors such as temperature, pH, salinity, heavy metals as well as nutrients.

Materials and methods

Study area

Kasha-Ruwa Reservoir, Gusau was the main water source for domestic uses, animals watering, irrigation, and fishing activities in Gusau and its environs in 1970s, this was later supplemented in 1980s by Yardantsi Reservoir. The reservoir is located in Gusau Local Government Area of Zamfara State, Nigeria, located between latitude 12°10'12.86"-12°17'02.40"N and longitude 6°39'50.83"-6°66'41.20"E (Figure 1), and occupies an area of 1,298.8m^2. Gusau Local Government had a population of 383,162 people; the major occupation of the populace is farming (NPC 2006).

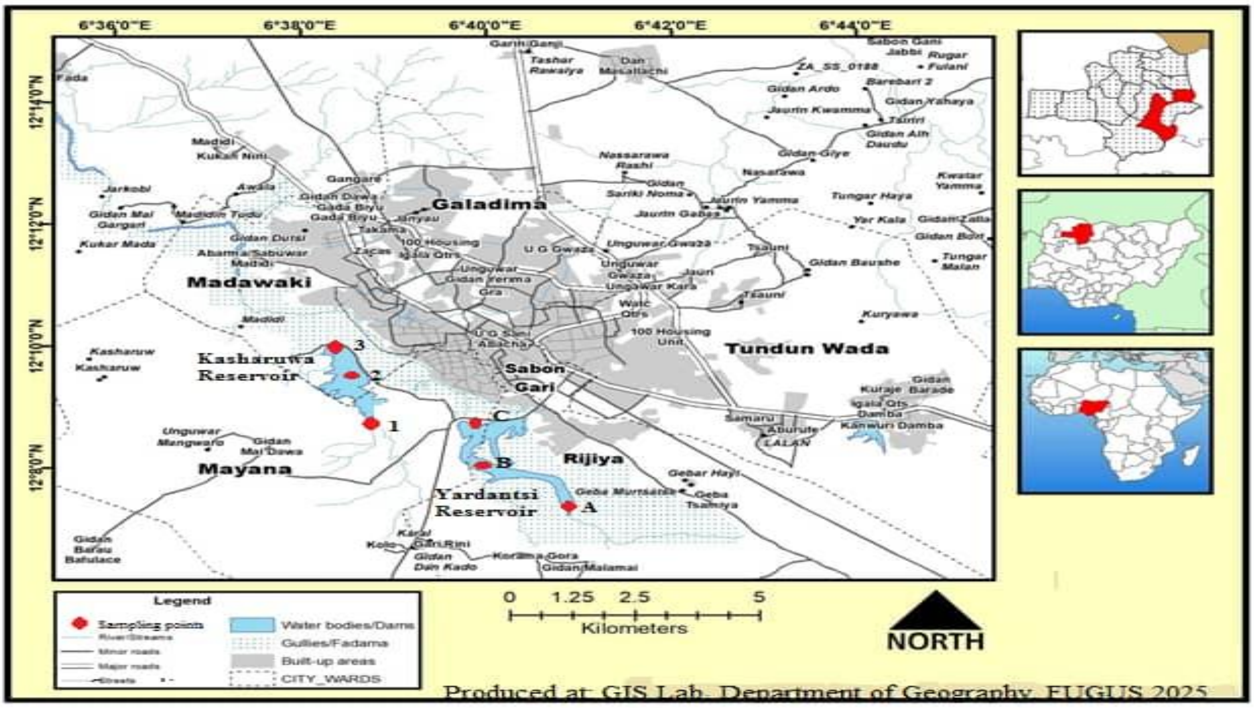

Figure 1. Map of Africa, Nigeria, Zamfara and Gusau showing Kasha Ruwa Reservoir

Sampling

Sampling was carried out monthly, between March and August, 2021. Three sampling stations (Figure 1) representing the major habitat types and basins were selected across the reservoir. Station 1 was located upstream at the reservoir's main inlet, characterised by some human activities such as washing, water pumping, irrigation, animals watering, and fetching of water for domestic use, and it was free of macrophytes. Station 2 was located at mid-basin and free of macrophytes, the only human activity here is fishing. Station 3 was located downstream at outlet of the reservoir, which was characterised by different hydrophytes and fishing was also the only human activity. Three sites were located at each sampling station and the triplicate samples were then mixed to make a composite sample representative of each sampling station. The sediment of Station 1 consisted mainly of sand while Stations 2 and 3 sediments were characterized by muddy sand.

The macro-benthic fauna were collected at the bottom of each sampling station using Surber sampler (0.1m^2, 250μm mesh) positioned against the direction of water flow and hauled over 5m. The samples were processed *in-situ* by sorting out debris from the discrete collections using 250μm mesh sieve, in order to have cleaner composite sample for analysis in the laboratory. They were preserved in 500ml plastic jar containing 70% ethyl alcohol with appropriate labelling of station number and date. Each sample collected was taken to the Zoology Laboratory of the Department of Biological Sciences, Federal University, Gusau for sorting and identification of macro-benthic invertebrates. Sub-surface water samples were also collected from the stations for determination of physico-chemical parameters.

Analysis of physico-chemical parameters

Water temperature, electrical conductivity, total dissolved solids, and pH were measured *in-situ* using portable HANNA Combo pH/EC/Temp metre Model/HI 98129. Depth was also measured *in-situ* using a rope (marked with measuring tape) tied to a heavy object (Jabbi 2018). Dissolved oxygen, alkalinity, hardness were determined by titrimetric methods, while nitrate, phosphate and sulphate were determined by colorimetry (APHA 2012).

Sorting and identification of macro-benthic invertebrates

Each composite sample was rinsed thoroughly with water to remove debris and sediment by washing through a 250μm mesh sieve to retain macro-benthic fauna. The cleaned samples were transferred on white gridded tray. Large benthos were picked out using forceps while smaller ones were pipetted out. They were then sorted with the aid of stereo dissecting microscopes to the lowest taxon (genera or species) where possible. Different species were preserved in a glass bottle with 70% ethyl alcohol and labelled for identification. The organisms were identified to genera or species levels according using standard taxonomic references/keys (Bouchard 2004; Huang and Lin 2012; Danladi *et al* 2013). Population density (PD) was calculated and expressed as individuals per m^2.

Relative abundance and diversity indices

Percentage relative abundance and diversity indices of macro-benthic invertebrates were calculated using equation (*i*) through (*vii*) (Hammer *et al* 2001; Lucy 2016).

$$\text{Relative abundance (\%)} = \frac{\text{Number of individuals of species "A"}}{\text{Total number of all species "B"}} \ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Species richness and diversity was estimated with Margalef's (*d*), Menhinick (D_{Mn}) and Shannon (*H'*) diversity indices, Pielou's evenness index (*J*) and Berger-Parker dominance index (*D*) using equation (*ii*) to (*vii*) (Hammer *et al* 2001).

$$\text{Margalef's diversity index } (d) = {S-1}/{ln(N)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Where *S* is the number of species (species richness), *N* is the total number of individuals in the sample and *ln* is the natural logarithm function.

$$\text{Menhinick's diversity index } (D_{Mn}) = {S}/{\sqrt{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

Where *S* is the number of species (species richness) and N is the total number of individuals in the sample.

$$\text{Shannon diversity index } (H') = -\sum P_i \times ln(P_i) \ldots\ldots\ldots\ldots (iv)$$

Where (P_i) is the species relative proportion and *ln* is the natural logarithm of species relative proportion.

$$\text{Species relative proportion } (Pi) = {S_i}/{S_t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (v)$$

Where S_i is the number of individuals of a particular species and S_t is the total number of individuals in the community.

$$\text{Pielou's evenness index } (J) = {H'}/{ln(S)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (vi)$$

Where *H'* is the Shannon diversity index, *N* is the total number of individuals in the sample and *ln*(*S*) is the natural logarithm of species richness. Note; a value of 1 indicates complete evenness, where all species are abundant, while a value closer to 0 signifies low evenness, meaning a few species dominate.

$$\text{Berger-Parker dominance index } (D) = {N_{max}}/{N} \ldots\ldots\ldots\ldots\ldots\ldots (vii)$$

Where N_{max} is the number of individuals in the most abundance species and N is the total number of individuals in the sample.

Data analysis

Data were analysed by descriptive statistics and Correspondence Analysis (CA) ordination using Palaeontological Statistics (PAST) software, version 4.03 (Hammer *et al* 2001).

Results

Relative abundance of macro-benthic invertebrates

A total of 247 individuals/m^2 belonging to twenty-one species and three phyla (Annelida, Mollusca and Arthropoda) were identified (Table 1). Arthropoda were the most numerous species (15) as well as individuals (200 individuals/m^2) representing 80.97% of the total abundance; while Annelida had the lowest number of species (2) but was next to Arthropoda in terms of number of individuals (25/m^2) representing 10.12 % of the total abundance. Mollusca was next to Arthropoda in terms of number of species (4) but had the lowest number of individuals (22/m^2) representing 8.91% of the total abundance. The dipteran insect larva, *Chironomus plumosus* was the most abundant species (21.05%), while the gastrod, *Melanoides tuberculata*, hemipteran insect *Nepa cineria* and the decapod crustacean, *Potamonautes sidneyi* were the least abundant (1.21%). The reservoir's inlet had the highest number of individuals 113/m^2 across the three phyla (Annelida – 16/m^2, Mollusca – 17/m^2 and Arthropoda– 80/m^2); while the rest of the stations i.e. reservoir's mid-basin and outlet had equal abundance of 67 individuals/m^2 each (Table 1). The reservoir's mid-basin had the least abundance for Arthropoda; 55 individuals/m^2 while the reservoir's outlet had the least abundance for both Annelida and Mollusca - 1individual/m^2 each (Figure 1).

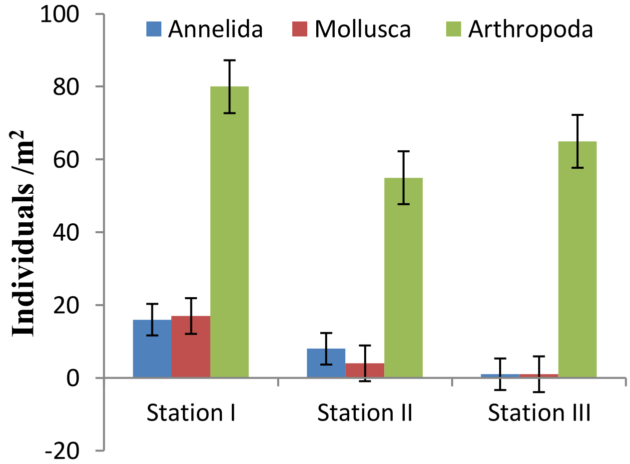

Figure 1. Population density of macro-benthic invertebrates of Kasha-Ruwa Reservoir, Gusau

Physico-chemical parameters of surface water

The results for physico-chemical parameters (mean±SE) recorded at the three sampling stations of the reservoir are shown in Table 2. Dissolved oxygen was highest in Station 1 (7.72±0.24mgl^{-1}) and lowest in Station 2 (6.93±0.32mgl^{-1}); temperature was highest in Station 2 (30.01±0.51°C) and lowest in Station 1 (27.12±0.14°C), pH was also highest in Station 2 (8.12±0.24) and lowest in Station 1 (7.26±0.41).

Relationship between environmental variables and macro-benthic invertebrate abundance

The results of Correspondence Analysis (CA) showing the relationship between environmental variables and macro-benthic invertebrates' abundance is illustrated in Figure 2. The first two axes accounted for 85.729% and 14.271% variance, respectively. The CA showed that, dissolved oxygen and hardness correlated positively with *Bulinus globosus, Nepa cineria*, *Hesperocorixa* sp.,

Table 1: Mean population density of macro-benthic invertebrates at the different stations of Kasha-Ruwa Reservoir, Gusau

Taxonomic composition						Stations PD (individuals/m²)			Total	Relative abundance (%)
Phylum	**Class**	**Order**	**Family**	**Species**	**Common name**	**1**	**2**	**3**		
Annelida	Clitellata	Tubificida	Naididae	*Limnodrilus hoffrneisteri* Claparède	Red worm	9	5	1	15	6.07
			Naididae	*Limnodrilus udekemianus* Claparède	Aquatic worm	7	3	0	10	4.05
Sub-total (ind/m²)						**16**	**8**	**1**	**25**	**10.12**
Mollusca	Gastropoda	Caenogastropoda	Thiaridae	*Melanoides tuberculata* Müller	Malayan trumpet snail	2	1	0	3	1.21
		Hygrophilia	Bulinidae	*Bulinus globosus* Morelet	Ramshorn snails	5	0	0	5	2.02
			Lymnaeidae	*Galba truncatula* Müller	Pond snail	7	2	0	9	3.64
		Cycloneritida	Neritidae	*Nerita peloronta* Linnaeus	Sea snail	3	1	1	5	2.02
Sub-total (ind/m²)						**17**	**4**	**1**	**22**	**8.91**
Arthropoda	Insecta	Coleoptera	Dystiscidae	*Dysticus* sp.	Diving beetles	0	2	4	6	2.41
	Insecta	Coleoptera	Gyrinidae	*Orectochilus* sp.	Whirligig beetles	2	2	5	9	3.64
		Diptera	Chironomidae	*Chironomus plumosus* Meigen	Midges	24	17	11	52	21.05
		Diptera	Simuliidae	*Simulium damnosum* Theobald	Black flies	11	3	0	14	5.67
		Ephemeroptera	Baetidae	*Baetis intercalaris* Leach	Mayflies	5	3	1	9	3.64
			Baetidae	*Cloeon dipterum* Leach	Mayflies	7	2	0	9	3.64
			Oligoneuriidae	*Elassoneuria candida* Eaton	Mayflies	4	4	0	8	3.21
			Leptophlebiidae	*Habrophlebia fusca* Curtis	River flies	6	3	3	12	4.86
		Hemiptera	Hesperocorixidae	*Hesperocorixa* sp.	Water boatmen	5	2	3	10	4.05
			Nepidae	*Nepa cineria* Linnaeus	Water scorpion	3	0	0	3	1.21
		Odonata	Aeshnidae	*Zosteraeschna ellioti* Kirby	Dragon flies	1	3	4	8	3.21
			Gomphidae	*Aphylla caraiba* Selys	Dragon flies	2	2	6	10	4.05
/		Plecoptera	Nemouridae	*Amphinemura sulcicollis* Stephens	River flies	7	2	2	11	4.45
/		Trichoptera	Hydroptiloidae	*Amphipsyche meridiana* Ulmer	Caddis flies	3	10	23	36	14.57
	Malacostraca	Decapoda	Potamonautidae	*Potamonautes sidneyi* Macleay	Crab	0	0	3	3	1.21
Sub-total (ind/m²)						**80**	**55**	**65**	**200**	**80.97**
Total number of individual species (ind/m²)						**113**	**67**	**67**	**247**	

Note: 1 = Reservoir's inlet; 2 = Reservoir's mid-basin; 3 = Reservoir's outlet; PD = population density; ind = individuals

Table 2: Physico-chemical parameters of surface water (mean±SE) for the different stations of Kasha-Ruwa Reservoir, Gusau

Parameters	Sampling stations 1	2	3	p-value	MPL (mg/L)
DO (mgL^{-1})	7.72±0.24	6.93±0.32	7.52±0.10	0.001	-
Temperature (°C)	27.12±0.14	30.01±0.51	29.78±0.24	0.000	Ambient
Depth (m)	1.54±0.25	2.35±0.11	2.73±0.38	0.000	-
pH	7.26±0.41	8.12±0.24	7.72±0.63	0.000	6.5-8.5
TDS (mgL^{-1})	272.10±3.21	364.53±3.01	312.19±2.58	0.000	500
EC (μScm^{-1})	366.54±1.32	426.19±1.23	357.46±2.41	0.051	1000
Alkalinity (mgL^{-1})	45.64±3.23	55.32±5.34	43.12±3.44	0.000	-
Hardness (mgL^{-1})	67.53±2.11	54.12±3.43	51.23±2.14	0.000	150
NO_3-N (mgL^{-1})	4.12±1.21	3.14±2.13	4.62±3.27	0.009	50
PO_4-P (mgL^{-1})	76.23±4.01	85.24±6.06	79.74±4.11	0.000	-
Sulphate (mgL^{-1})	37.13±4.05	43.23±2.21	39.17±3.00	0.000	100

Note; D = Dissolved oxygen; TDS = Total dissolved solids; EC = Electrical conductivity; 1 = Reservoir's inlet; 2 = Reservoir's mid-basin; 3 = Reservoir's outlet; MPL = Maximum permissible limits (Standard Organization of Nigeria, 2015)

Amphinemura sulcicollis, *Nerita peloronta*, *Habrophlebia fusca*, *Galba truncatula*, *Simulium damnosum*, *Cloeon dipterum* and *Chironomus plumosus*. A highly negative correlation existed between *Limnodrilus hoffrneisteri*, *Limnodrilus udekemianus*, *Melanoides tuberculata*, *Baetis intercalaris* and *Elassoneuria candida,* and alkalinity and electrical conductivity.

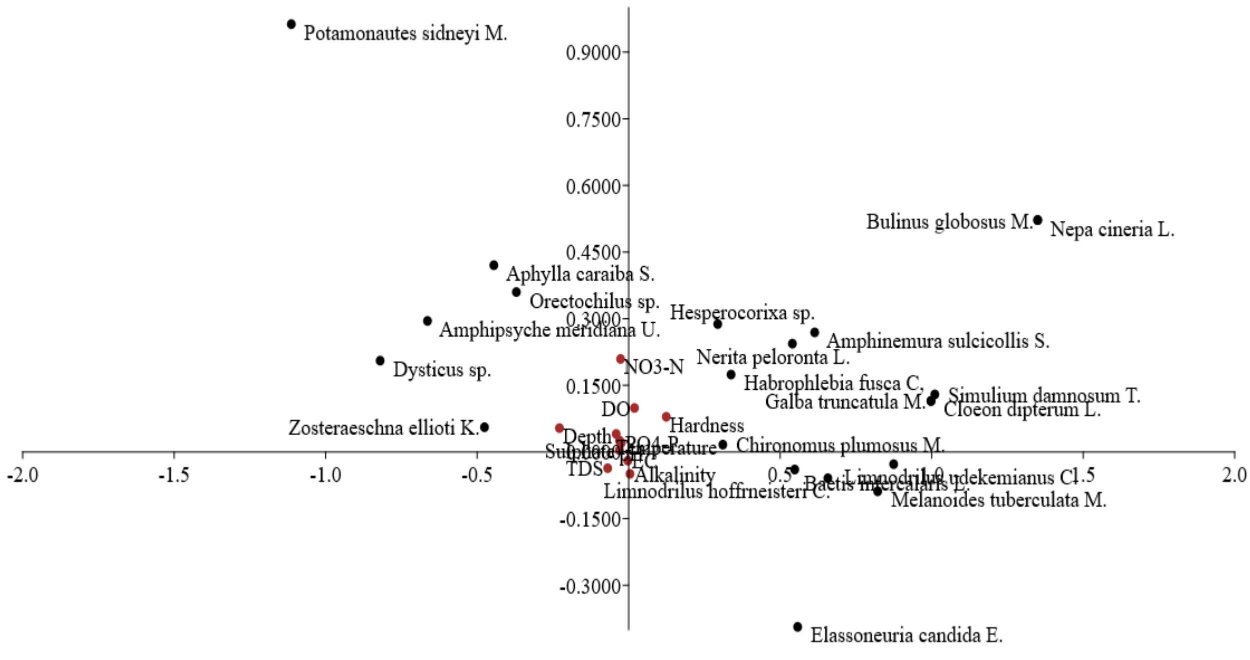

Figure 2. Biplot of Correspondence Analysis (CA) for relationship between physico-chemical parameters and macro-benthic invertebrate abundance at different stations of Kasha-Ruwa Reservoir, Gusau

Diversity indices

The results of diversity indices are presented in Table 3. Macro-benthic community structure indicated that the reservoir's inlet had the highest species richness, Margalef (d = 4.19) Menhinick (D_{Mn} = 0.94), while the reservoir's outlet had the lowest species richness, Margalef (d = 3.33) Menhinick (D_{Mn} = 0.76). The highest Shannon's diversity index (H') was recorded in inlet (H'= 2.09) while the lowest value was in mid-basin (H' = 1.85). Evenness (J) was high in the outlet (J = 0.28); whereas mid-basin had the lowest value (J = 0.22); mid-basin also had the highest Dominance (D' = 0.25) while the inlet had the lowest value (D' = 0.21).

Table 3: Macro-benthic invertebrate species diversity in the of different stations of Kasha-Ruwa Reservoir, Gusau

	Sampling stations		
Indices	**St. 1**	**St. 2**	**St. 3**
Species richness (*R*)	30	29	24
Number of individuals (*N*)	1022	1143	997
Margalef's diversity index (*d*)	4.19	4.00	3.33
Menhinick's diversity index (D_{Mn})	0.94	0.86	0.76
Shannon's diversity index (*H'*)	2.09	1.85	1.89
Pielou's evenness index (*J*)	0.27	0.22	0.28
Berger-Parker dominance index (*D*)	0.21	0.25	0.24

Note: St. 1 = Reservoir's inlet; St. 2 = Reservoir's mid-basin; St. 3 = Reservoir's outlet

Discussion

The reservoir's inlet had high population density of pollution-tolerant macrobenthos, which include; *Limnodrilus hoffrneisteri* (Red worm), *L. udekemianus* (Aquatic worm), *Melanoides tuberculata* (Malayan trumpet snail), *Bulinus globosus* (Ramshorn snail), *Galba truncatula* (Pond snail), *Nerita peloronta* (Sea snail), *Chironomus plumosus* (Midges), *Simulium damnosum* (Black flies), *Hesperocorixa* sp. (Water boatmen), *Nepa cineria* (Water scorpion), *Baetis intercalaris* (Mayflies), *Cloeon dipterum* (Mayflies), *Elassoneuria candida* E. (Mayflies), A*mphinemura sulcicollis* S. (River flies) and *Habrophlebia fusca* (River flies). The reservoir's outlet where anthropogenic activities were less had fewer macrobenthos that are tolerant to pollution, these included: *Amphipsyche meridiana*, *Potamonautes sidneyi*, *Zosteraeschna ellioti*, *Aphylla caraiba*, *Dysticus* sp. and *Orectochilus* sp. Most of the species recorded in this reservoir have also been reported by Andem *et al* (2012) in their study on composition, distribution and diversity of benthic macroinvertebrates of Ona River, South-west, Nigeria; and that of Akindele and Liadi (2014) in their study on abundance and species-richness of mayfly nymphs in pools and streams within Kibale Forest, Uganda. Enabulele and Olomukoro (2024) reported most of these species as pollution sensitive in their studies on benthic macroinvertebrates as indicators of water quality and ecological health of a tropical lake in southern Nigeria.

The present study showed that the reservoir relatively has low density of macro-benthic invertebrates 247(individuals/m^2) when compared to the studies of Avoaja *et al* (2008) that recorded a total of 1,279(ind/m^2) macrobenthic animals in water reservoir in Abia State, Nigeria and Oriabure and Ogbeibu (2024) that recorded 3,267(individuals/m^2) macro-benthic invertebrates. However, the result from the present study is higher, when compared to the studies of Magaji *et al* (2020) who recorded a total of 105(individuals/m^2) in assessment of macro-benthic invertebrates of Gubi Dam, Ganjuwa, Bauchi State.

Majority of the macro-benthic invertebrates and their larvae were found in Station 1 (inlet of the reservoir); the high abundance of the phyla (Annelida, Mollusca and Arthropoda) encountered in the present study could be attributed to high level of dissolved oxygen and low temperature. This agrees with the findings of Akindele and Malaki (2001) on the benthic macro-invertebrates of pools and streams within Kibale Forest, Uganda.

The lowest abundance of Arthropoda in reservoir's mid-basin could be attributed to the higher temperature recorded in the station; temperature is not only important as it indicates how much oxygen the water can hold, but it also has direct influence on biochemical reactions within the water's sediment. Increase in the water temperature are also linked to increased metabolic rates. Temperature affects dissolved oxygen concentration because they have an inverse relationship; as temperature increases in water, DO levels decrease; this in return affect the distribution of aquatic organism. Water that has DO concentration above 6.5-8mg/l is considered healthy (Jabbi 2018; Basira 2025). Despite different organisms having a particular tolerance range, DO levels lower than 3mg/l are a cause for concern, and levels below 1mg/l are considered hypoxic. In the present study, DO range of 6.93 to 7.72mgl^{-1} is considered healthy and indicated that the reservoir's water quality is considerably good to support aquatic life.

The phyla encountered in the present study are known to contribute greatly to freshwater macro-benthic community structure as reported by Adedeji *et al* (2012) in some fish ponds in Ife North Local Government Area, Nigeria; Arti *et al* (2015) in Ban Ganga Stream, Katra, Jammu and Kashmir, India and Olapoju and Edokpayi (2018) in Badagry Creek, South Western Nigeria.

The presence *Chironomus plumosus* (midges) indicates possible pollution as reported by Mustapha and Yakubu (2015). The significantly higher abundance of *C. plumosus* at the reservoir's inlet indicated that it is a more polluted area of the reservoir. Abundance of *C. plumosus* may be linked to their tolerance to polluted environment; they are known to possess the oxygen transport pigment, haemoglobin, conferring more efficiency to absorb dissolved oxygen in the open water. This effectively put it ahead of other species in terms of tolerance and preference to anoxic condition prevailing at the open water regions as reported by Adeogun and Fafioye (2011).

The physico-chemical parameters (such as temperature, dissolved oxygen and pH) were found to be within the minimum permissible limits impacted more on the abundance of benthos; this makes them of prime importance to the macro-benthic invertebrate distribution (Olapoju and Edokpayi 2018; Wangchuk and Dorji 2018).

The influence of anthropogenic activities that is contributing to the high number and diversity of macro-benthic invertebrates, which are indicators of pollution in this reservoir could be addressed by adopting best management practices (BMP) for the reservoirs as suggested by Mustapha and Yakubu (2015).

Conclusion

The present study established that the reservoir has relatively low macro-benthic invertebrate population when compared with some reservoirs. The taxa composition of the benthos was dominated by pollution tolerant species as shown in their abundance at reservoir's inlet. Therefore, pollution rather than types of substrate probably contributed to the distribution of macro-benthic invertebrates in the reservoir. This implies that there are some element of anthropogenic influences on the reservoir's water quality from the activities within the catchment area; this is reflected in the type of macrobenthos found in these sites. The pollution tolerant species such as *C. plumosus* could be used as potential bio-indicators of pollution in freshwater bodies.

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Conflict of interest

The authors declare no conflict of interest.

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