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Physicochemical Characteristics and Fish Abundance and Diversity of Mairua Reservoir Water, Funtua, Katsina State, North-Western Nigeria

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ABSTRACT: This research explores physico-chemical characteristics and fish abundance and diversity of Mairua Reservoir Water, Funtua, Katsina State, North-Western Nigeria. The duration of the study was 12 months starting from September to August, 2017, using standard methods and procedures.The result revealed that; Water temperature (25.02 ± 0.170C) pH (7.54 ± 0.03), Alkalinity (3.69±0.09), Conductivity (129.43 ± 5.15µS/cm), Total Dissolved Solids (50.54 ± 0.57mg/L) Nitrate-nitrogen (0.21 ± 0.04mg/L), Water Hardness (134.44 ± 3.06mg/LCaCO3), Dissolved Oxygen (3.98 ± 0.10mg/L),Biochemical Oxygen Demand (2.53 ± 0.08mg/L), Phosphate-phosphorus (0.19 ± 0.02mg/L),Chloride (5.09 ± 0.15mg/L),Sulphur-sulphate (0.21± 0.01) and Calcium (2.97±0.06mg/L) respectively were all varied with months and seasons. Analysis of variance indicated significant difference between seasons ($P < 0.05$).Out of the total number of fish species (8273) identified; the result indicated Fish fauna percentage composition were Coptodon zillii: 1980 (23.9%), *Clarias gariepinus*: 1560 (18.9%), *Oreochromis niloticus*: 1020 (12.3%), *Lates niloticus*: 860 (10.4%), *Bagrus. Bayad*: 632 (7.6 %), *Mormyrus senegalensis*: 973 (11.8%), *Labeo senegalensis*: 595 (7.2%) and *Synodontis clarias*: 650 (7.9%). Results also indicates most of fish species were positively correlated with the water quality parameters in all the sites studied. Hence, there were fish abundance and a sustainable livelihood amongst the fishermen. However, a careful management strategy and routine monitoring from both government and non-governmental organizations are critical for the improvement and sustenance of the fisheries resources of the reservoir.

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Keywords: Fish; Sustainable; Pollution; Abundance; Mairua reservoir.

Healthy aquatic environment and production of sufficient food in reservoir are primarily linked with successful reservoir culture operations. Various studies had been conducted on changes brought about by biotic and abiotic factors of river as a result of damming. However, responses of rivers and its ecosystem to damming are complex and varied as they depend on local sediment supplies, geomorphic constraint, climate, dam structure and operation (Lawal and Nafiu, 2020). Reservoirs constitute very important nursery and breeding grounds for a large variety of fish species, making it crucial to feeding millions of people around the globe. However, these have being over-exploited, and the environment also ecologically degraded (Singh *et al.*, 2021). The major causes of species decline in these ecosystems are anthropogenic activities such as chemical and pesticides released by agricultural activities, effluents discharged from aquaculture, solid wastes dumped from residential areas and harvesting of juvenile fishes by artisanal anglers (Li *et al.*, 2022). Environmental conditions influence fish distributions, communities and seasonal movements. In addition, decline water quality due to environmental upset threatens the stability of the biotic integrity and therefore hampers the ecosystem services and functions of the aquatic

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ecosystems (Dudgeon, 2010; Mustapha, 2011; Yusuf *et al.,* 2022). According to Kasperson *et al,* (2022) reported that there are urgent demands for comprehensive methodological approaches to evaluate the actual state of these ecosystems and to monitor their rate of changes. Physical and chemical measurements commonly form the basis of monitoring, because they provide complete spectrum of information for proper water management (Kuiwa *et al.,* 2019). However, in lotic waters, where changes in hydrology are rapid and difficult to estimate, they cannot reflect the integration of numerous environmental factors and long-term sustainability of river ecosystems for their instantaneous nature. As a result, the ability of freshwater ecosystems to provide clean and reliable sources of water, maintain the natural water cycle and the biological food web as well as provision of food and recycling of nutrients has been severely impaired (Voughn *et al.*, 2008; Hassan *et al.,* 2010; Jabbi *et al.,* 2018; Lawal *et al.,* 2020). Despite their significance to global environmental policy agendas, tropical forests and freshwater biodiversity are rapidly declining. Meanwhile, freshwater species populations have declined by 83% since 1970, and, among all vertebrates, freshwater fish had the highest extinction rate worldwide in the twentieth century (Dudgeon, 2006). Freshwater fish populations provide food security for many tropical forest-dwelling rural communities and are often one of the most important sources of protein and micronutrients (Cojocaru *et al.,* 2022). Fish contribute more than half of the protein intake for over 400 million people in the poorest countries of Africa and Asia (Obiero *et al.*, 2019). Wild capture of freshwater fish is also a vital source of income for rural livelihoods (Cojocaru *et al.,* 2022). The potential impact of an ongoing decline in forests and freshwater fish populations on human health and well-being is vast. A clear understanding of the pathways linking tropical forests and freshwater fish is therefore urgently required for designing policies that can effectively address the management of forests, the conservation of freshwater biodiversity, and the contribution of these fish to local livelihoods and food security. The objective of this research was therefore to assess the physicochemical characteristics and fish abundance and diversity of Mairua Reservoir Water, Funtua, Katsina State, North-Western Nigeria.

MATERIALS AND METHODS

Study Area: Mairuwa reservoir is located at latitude 11°34' - 11°36' N and longitude 7°14' - 7°15' E and at about 733 metres above sea level of Funtua Local Government Area of Katsina state. The reservoir cut across farmlands, residential and industrial areas with several farmlands and commercial activities taken place along its bank with both residential and munincipal wastes into the reservoir (Uba *et al.*, 2021).

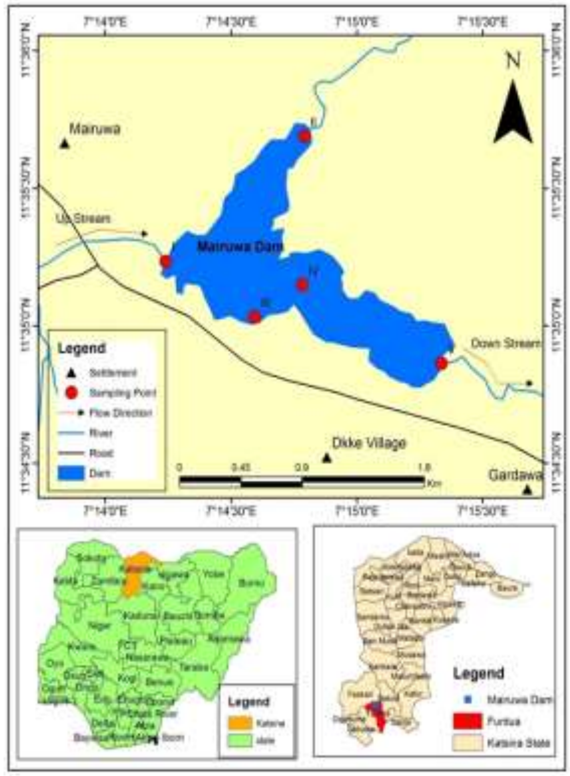

Fig 1: Map of Mairuwa Reservoir indicating Sampling Sites.

Sampling Sites: A total of five sampling sites were used within the water reservoir as follows: site I located was at the entry point of the major tributaries with many irrigated lands and animal interference; site II is at off – bank in open water of the reservoir, near the junction of the two major streams of the reservoir, with less human activities such as irrigation, farming; site III is being closer to a Bagiwa's Farm with much Typha species outgrowth and site IV is sited at the open water body with little human interference while site V; is located at 20m away from the embankment (spillway) with little or no human interference as indicated in figure 1. The distance between the sites was 20m apart. The procedural plan of this study was monthly sampling of water and fish from September to August 2017. A total of five sampling sites were used within the water reservoir as follows: site I located was at the entry point of the major tributaries with many irrigated lands and animal interference; site II is at off – bank in open water of the reservoir, near the junction of the two major streams of the reservoir, with less human activities such as irrigation, farming; site III is being closer to a Fish and Poultry Farm (Bagiwa's Farm) with much Typha species outgrowth and site IV is sited at the open water body with little human interference while site V; is located at 20m away from the embankment (spillway) with little or no human interference as indicated in figure 1. The distance between the sites was 20m apart.

Sampling Procedures: The procedural plan of this study was monthly sampling of water and fish from September to August 2017.

Water Sample collection: Water samples for physicochemical parameters were collected from Mairua Reservoir on a monthly basis from the months of August – September 2017, with months November to April marking the transitional period from the dry season to the rainy season (May to October). Five fixed sampling points per Reservoir were chosen and maintained throughout the study period. Water samples for physicochemical analyses were collected in five litre bottles by sliding them over the upper surface of water with their mouth open against the water current to permit undisturbed passage of the water into the bottle,while water samples for BOD and DO were fixed in BOD labeled sample bottles (300 mL) and fixed with manganese sulphate followed by alkali-iodide-azide reagent immediately in the field(APHA, 1999). It was then transported to hydrobiology laboratory for analysis of physicochemical parameters to determine the suitability of the water for fish survival.

Physicochemical Parameters analyses: During the collections some water quality parameters were determined in situ which include: Water temperature: Digital thermometer was used to determine the water temperature in situ each time a trip was made to the site by dipping thermometer into the water until a steady value was observed then recorded as the water temperature in degree Celsius (°C). Hydrogen Ion Concentration (pH): This was determined in situ using Hanna pH meter model HI96107. The meter was calibrated using pH buffer at 8.9 then dipped in the water sample until stead value was read, then recorded as pH values. Dissolved Oxygen (DO): The amount of dissolved oxygen was determined in situ by Winkler's methods. A 300-ml glass stopper BOD (Biological Oxygen Demand) bottle was filled with the water sample ensuring that there were no air bubbles. 2ml of manganese (II) sulphate was added to the collection bottle by inserting a calibrated pipette just below the surface of the liquid and the pipette squeezed out slowly to ensure that no bubbles were introduced into the sample through the pipette. 2ml of alkaline potassium iodide solution was added in the same manner. The bottle was carefully covered with a stop cock ensuring that air was not introduced and the sample mixed by inverting the bottle severally. The sample was checked for air bubbles and if found the sample was discarded. The presence of oxygen in the sample was noticed by the appearance of a brownish-orange cloud of precipitate. 2ml of concentrate tetraoxosulphate (VI) acid was added to the sample. The bottle was carefully covered and inverted several times to dissolve the precipitate. Then, the sample was fixed. 2 ml of the sample in glass was titrated with sodium thiosulphate (1 ml) until a pale straw colour was obtained. This was done by slowly dropping the sodium thiosulphate solution from a calibrated pipette and swirling the sample. 2ml of starch solution was added to the sample which gives a blue colour. Addition of the sodium thiosulphate (B ml) continued slowly until the sample turns clear which marks the end point of the experiment. The concentration of dissolved oxygen in the sample was equivalent to the milliliters equal of sodium thiosulphate used during the titration as 1 milliliter equal 1mg/1dissolved oxygen. That is concentration of dissolved oxygen = A ml+B ml (knowing that 1 ml of sodium thiosulphate is equal to 1mg/ dissolved oxygen. Conductivity: was determined using Hanna conductivity meter (model HI 98801). The meter was inserted in the water at each site and allowed to attain a stead value and then recorded in (µS/cm). Total Dissolved Solids (TDS) was also measured using Hanna TDS meter (Model HI 98801). The meter was inserted into the water and allowed to attain a stead value; the value was recorded as TDS (mg/L).Alkalinity was determined using exactly 100 ml of water sample transferred into a conical flask, 2 drops of bromocresol green and 2 drops of methyl red were added respectively. The mixture was swirled and titrated with solution of H_2SO_4 until color change. Total alkalinity in CaCO3 mg/l = titre value ×10 (APHA 1999).

Determination of Calcium: Exactly 50ml of sample was taken into conical flask with the help of pipette, 1ml of NaOH was added to produce pH of 13-14 and 0.2g murexide was added as indicator and stir. Color changes to pink then titrated with 0.1N EDTA solution and note the color change pink to purple. Noted the volume of EDTA used and was recorded as value of calcium (APHA 1999). Chloride Ions were determined using exactly 100 ml of water sample was transferred into a conical flask, 2-3 drops of potassium chromate was added, and content was swirled for few minutes, and then titrated against silver nitrate solution until dirty reddish precipitate was obtained. Chloride was calculated using: Cl mg//l = volume of $AgNO_3$ ×10 (APHA 1999).

Sampling of Fish Species: The fish samples were collected in an ice pack container from the fish landing sites based on previous arrangements with the fishermen. 10% formalin was used for sample preservation before been transported to fishery laboratory for proper identification to species level. However, the fish fauna total numbers collected/purchased were also based on months (September to August, 2017) and recorded as percentage abundance. The fish species were also obtained based on the type of fish species and recorded based on their relative abundance which was expressed below:

$$Relative\ Abundnce = \frac{X}{Y} x100$$

Where X= number of fish species collected in each month and Y= total number of fish species collected in each month (Lawal *et al.,* 2020).

Fish Sample Identification: Fish faunas were identified to species level using standard reference materials and websites such as Idodo-umeh (2003), Babatunde and Raji, (2004) and Pauly *et al.* (2004).

Statistical analyses: Analysis of variance (ANOVA) was performed to test the level significance at $P<0.05$ on the fish species. Barchart was used to express the Abundance Composition of fish. Duncan's Multiple Range Tests (DMRT) was used to separate means. Pearson's correlation coefficient was used on the data to determine significant relationships between the fish fauna and physico-chemical parameters.

RESULTS AND DISCUSSIONS

The results of the analysis carried out on the water and fish samples collected from Mairua reservoir showed variations in the diversity of fish species based on distribution and abundance of fish species present in the reservoir.

Fish Fauna: A total of Seven Families with Eight fish species were identified viz: Cichlidae (*Coptodon zillii* and *Oreochromis niloticus),* Claridae (*Clarias gariepinus*), Latidae (*Lates niloticus*), Machokidae- (*Synodontis clarias*), Bagaridae (*Bagrus bayad*), Mormyridae (*Mormyrus senegalensis*) and Cyprinidae (*Labeo senegalensis*). The total number of fishes identified in the five sites during the period of the study were 8273; which are *Bagrus bajad, Coptodon zillii, Clarias gariepinus, Momyrus senegalensis, Oreochromis niloticus, Synodontis clarias, Labeo senegalensis, Lates niloticus* (Fig. 2).

Coptodon zillii: Correlation revealed there was a positive correlation with DO, Cl^-, PO_4, NO_4, $S0_4$, Temperature, BOD, Calcium and Alkalinity and negative correlation with pH, Conductivity, Total Dissolve Solids (Table 2). The percentage composition of fishes (Fig. 2) indicated *Coptodon zilili* has the highest percentage with 23.9 %, abundance composition. The highest number was recorded in the months of September, Augustwhile the lowest was recorded in the months of March and April was the least.

Clarias gariepinus: Correlation revealed there was a positive correlation with chloride and hardness and negative correlation with pH, Conductivity, total dissolve solids (Table: 2).The percentage composition of fishes (Fig.2) indicated *Clarias gariepinus* has the second highest population which accounted for the 18.9% of the total number of fishes count identified during the period of the study; the highest number was recorded in the month of August while the lowest count was recorded in the month of April.

Oreochromis niloticus: Correlation revealed there was a weak positive correlation with the other physico-chemical parameters and negative correlation with pH, Electrical conductivity, and total dissolve solids (Table 2). The percentage composition of fishes (Fig.2) indicated the total number of *Oreochromis niloticus* identified was 238 which account for 12.3% of the total fishes identified, there was monthly variation of *Oreochromis niloticus* recorded during the period of study; The highest number was recorded in the months of September, Augustwhile the lowest was recorded in the months of March and April was the least.

Lates niloticus: Correlation revealed there was a weak positive correlation with DO, Cl^-, TDS, PO_4, Hardness, NO_4, SO_4, Temperature, EC, and negative correlation with Biochemical Oxygen and pH (Table 2). The percentage composition of fishes (Fig. 2) indicated the total number of *Lates niloticus* identified during the period of the study was 860, which accounted for the 10.4% of the total identified and recorded fishes during the period of the study. The highest count was recorded in wet season (i.e September) and the lowest in dry season (i.e April).

Bagrus bayad: Correlation revealed there was a positive correlation with Chloride, Sulphide and Hardness while negative correlation with pH, Conductivity and Total dissolve solids (Table 2). The percentage composition of fishes (Fig. 2) indicated the total number of *Bagrus bajad* identified during the period of the study was 632, which accounted for the 7.6 % of the total identified and recorded fishes during the period of the study. The highest record was in July of wet season and the lowest in January, March and May of dry season.

Mormyrus senegalensis: Correlation revealed there was a positive correlation with Chloride, Sulphide and Hardness while negative correlation with pH, Conductivity and Total dissolve solids, Biochemical Oxygen Demand and Calcium (Table 1). The percentage composition of fishes (Fig. 2) indicated the total number of *Mormyrus senegalensis* identified during the period of the study was 973, which accounted for the 11.8 % of the total identified and recorded fishes during the period of the study. The highest record was in September wet season and the lowest in March of dry season.

Labeo senegalensis: Correlation revealed there was a positive correlation with Chloride, Sulphide and Alkalinity while negative correlation with dissolve oxygen, conductivity, calcium and total dissolve solids (Table 2). The percentage composition of fishes (Fig. 2) indicated the total number of *Labeo senegalensis* identified during the period of the study was 595, which accounted for the 7.2 % of the total identified and recorded fishes during the period of the study. The highest number was recorded in the months of September, Augustwhile the lowest was recorded in the months of March and April was the least.

Synodontis clarias: Correlation revealed there was a weak positive correlation with other physico-chemical parameters while negative correlation with pH, Conductivity, Calcium and Total dissolve solids (Table 2). The percentage composition of fishes (Fig.2) indicated the total number of *Synodontis clarias* identified during the period of the study was 650, which accounted for the 7.9% of the total identified and recorded fishes during the period of the study. The highest record was in August wet season and the lowest in March dry season.

Fish Biodiversity Distribution and Abundance in relation to physicochemical Parameters: Fish fauna composition in Mairua reservoir was dominated by *Coptodon zillii*, and then *Clarias gariepinus*, which were followed by *Oreochromis niloticus* and *Lates niloticus*, *Bagrus bajad*, *Momyrus senegalensis*, *Synodontis clarias* and *Labeo senegalensis.* The fish fauna composition and abundance varies with months and seasons, which may be due to fluctuation of physicochemical parameters and reduction in abundance of phytoplanktons, which are the primary producers. Yaseen *et al,* (2022) reported factors such as light intensity; food availability, dissolved oxygen, and predation affect the population composition of zooplankton including fish fauna (Table: 1). Mairua reservoir had higher fish fauna composition and abundance during the rainy season which could be due to land use around riverine areas in Nigeria which is predominantly for farming (Adeyemi *et al.*, 2009); this could be a possible explanation for the high levels of PO_4^-P that may result from run-offs during rainy season as observed in this study. This observation coincides with that of Edward and Ugwumba (2010) in which they reported the increased number of zooplankton including fish fauna during the rainy season that was linked to the influx of nutrient. All the fish fauna and phytoplankton indicated high productivity in the rainy season and decrease to dry season, the mean values of 0.21 for NO_3^-N were also found to be above expected concentration range of natural unpolluted waters of 0.1 mg/l (UNESCO/WHO/UNEP, 1996). High nitrate levels (> 1mg/l) are not good for aquatic life (Gharti and Liping, 2023). This could be the reason why all the fish fauna indicated positive correlation to the most physico-chemical parameters of the reservoir with only negative correlation to Total dissolved solids, Conductivity, Calcium, pH and Alkalinity. The high level of nitrate observed is in line with the findings of Wolfhard and Reinhard (1998), who concluded that nitrate are usually built up during dry seasons and that high levels of nitrates are only observed during early rainy season which correspond to the period of the research work. This also played a vital role in the abundance of both fish and phytoplankton. *Coptodon zillii* like other fishes appears to be sensitive indicator of changes as they have a temperature tolerance range of 25°C to 30°C with less alkalinity of 16 to 20 ppt compared to ammonia in their natural waters. *Clarias gariepinus* have possessed an ability to tolerate adverse water quality and difficulty in aquaculture. *Lates niloticus* are found to be less abundant in oxygen poor condition in water quality. The positive correlation of most fishes like cladocerans with dissolved oxygen and biochemical oxygen demand was an indication the reservoir was unpolluted; Balogun *et al.* (2005) in Makwaye (Ahmadu Bello University Farm) made similar observation. Fish and phytoplankton in Mairua reservoir, also indicated monthly variation in abundance which could be due to variations of physico-chemical parameters. Food condition is still considered an important factor affecting growth and reproduction of zooplankton including fish fauna in nature, especially in closed environment such as reservoirs and lakes (Gharti andLiping, 2023).

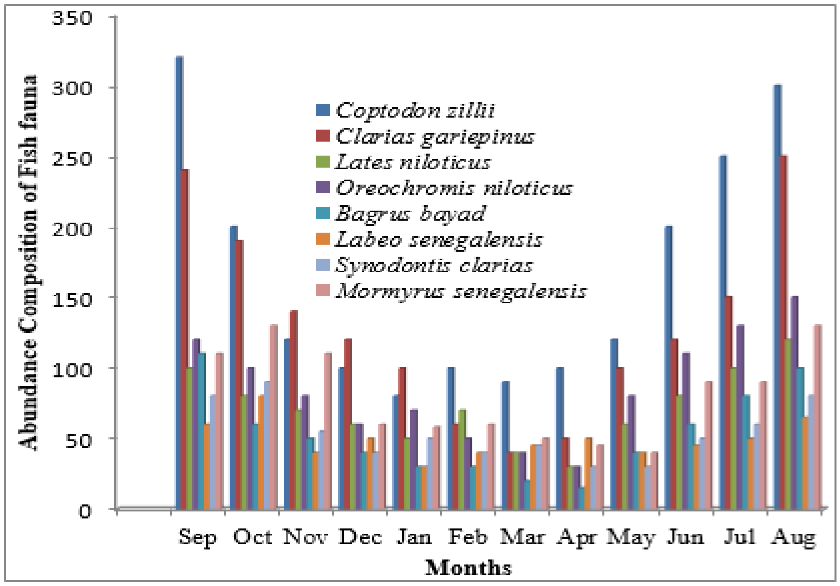

Fig 2: Fish fauna Abundance Composition of Mairua Reservoir, Funtua, Katsina State, Nigeria (2017)

Table 1: Correlation between Fish species and physico-chemical parameters of Mairua reservoir Funtua, Katsina state.

	BB	*CZ*	*CG*	*MS*	*ON*	*SC*	*L.S*	*LN*	*DO*	*Cl*	*PO*	*N*	*SO₄*	*pH*	*Temp.*	*EC*	*TDS*	*H*	*BOD*	*Ca*	*Alk*
BB	1.0																				
CZ	0.6*	1.0																			
CG	0.6*	0.6*	1.0																		
MS	0.6*	0.3	0.5*	1.0																	
ON	0.5*	0.3	0.2	0.5*	1.0																
SC	0.5*	0.6*	0.6*	0.6*	0.7*	1.0															
LS	0.2	0.0	0.0	0.3	-0.2	-0.3	1.0														
LN	-0.1	0.2	-0.2	-0.1	-0.3	-0.4	0.7*	1.0													
DO	0.1	0.2	0.3	0.1	0.2	0.5*	0.0	-0.1	1.0												
Cl	0.7*	0.4	0.6*	0.7*	0.3	0.3	0.5*	0.0	0.1	1.0											
PO_4	0.3	0.3	0.1	0.1	0.2	0.2	0.4	0.5*	0.6*	0.2	1.0										
N	0.5*	0.3	0.5*	0.3	0.2	0.2	0.2	0.0	0.5	0.6*	0.6*	1.0									
SO_4	0.6*	0.5*	0.4	0.5*	0.2	0.1	0.7*	0.4	0.1	0.9*	0.4	0.5*	1.0								
pH	-0.1	-0.2	-0.3	0.0	0.0	-0.6*	0.3	0.4	-0.7*	0.2	-0.2	-0.2	0.3	1.0							
Temp.	0.4	0.3	0.0	0.4	0.0	0.1	0.2	-0.1	-0.5*	0.4	-0.3	0.1	0.3	0.1	1.0						
EC	-0.3	-0.4	-0.3	-0.4	0.2	0.0	-0.4	-0.1	0.2	-0.7*	0.2	-0.4	-0.6*	-0.1	-0.8*	1.0					
TDS	-0.1	-0.6*	-0.3	-0.2	0.1	-0.3	-0.1	-0.3	-0.1	0.0	0.0	0.1	-0.1	0.2	-0.1	0.3	1.0				
H	0.6*	0.3	0.5*	0.5*	0.3	0.1	0.3	0.1	-0.1	0.8*	0.3	0.8*	0.7*	0.3	0.4	-0.5*	0.1	1.0			
BOD	0.1	0.1	0.3	-0.1	-0.2	0.1	0.0	-0.4	0.4	0.3	0.0	0.3	0.1	-0.5*	0.1	-0.3	0.1	-0.1	1.0		
Ca	0.1	0.2	0.3	0.0	0.4	0.2	-0.1	0.0	0.6*	0.3	0.5*	0.6*	0.4	0.0	-0.5*	0.2	0.2	0.4	0.1	1.0	
Alk	0.3	0.0	0.2	0.4	0.1	-0.2	0.5*	0.1	-0.3	0.8*	-0.1	0.4	0.8*	0.6*	0.4	-0.6*	0.3	0.7*	0.2	0.2	1.0

KEY: *BB – Bagrus bayad, CZ - Coptodon. zilili, CG – Clarias gariepinus, MS – Mormyrus senegalensis, ON – Oreochromis niloticus, SC – Synodontis clarias, LS – Labio sengalensis, LN – Lates niloticus, DO – Dissolved Oxygen, Cl – Chloride, PO4 –Phosphate, N – Nitrates, SO4, - Sulphate, pH – pH value, Temp. – Temperature, EC – Electrical Conductivity, TDS – Total Dissolved Solids, H – Hardness, BOD – Biological Oxygen Demand, Ca – Calcium, Alk – Alkalinity.*

**-strongly positive or negative correlation*

Conclusion: The observed fish faunas were *Bagrus bayad* had a total mean and percentage of: 632 (7.6), *Coptodon zillii* 1980 (23.9), *Clarias gariepinus*: 1560 (18.9), *Mormyrus senegalensis*: 973 (11.8), *Oreochromis niloticus*: 1020 (12.3), *Synodontis clarias*: 650 (7.9), *Labeo senegalensis*: 595 (7.2) and *Lates niloticus*: 860 (10.4). All the fish fauna composition and abundance were increased during rainy season due to high nutrients enrichment (NO_4,SO_4 and PO_4) and decreased with dry season with little or no agricultural activities around the reservoir. Results of the fish abundance indicates positive correlation with most of the water quality in all the sites studied. Hence, there were fish abundance and a sustainable livelihood amongst the fishermen.

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