UJMR, Conference Special Issue Vol. 10 No. 3. June, 2025, pp. 81 - 96

E-ISSN: 2814 – 1822; P-ISSN: 2616 – 0668

https://doi.org/10.47430/ujmr.25103.010

Received: 19 April 2025 **Accepted:** 14 June 2025

Assessment of Water Physicochemistry in Relation to Fish Diet and Biodiversity across Three Savanna Reservoirs in Katsina State, Nigeria

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Abstract

This study evaluated the effects of water quality on fish community structure and dietary patterns across three inland reservoirs in Katsina State, Nigeria: Zobe (Sudan savanna), Sabke (Sahel savanna), and Mairuwa (Guinea savanna) from October 2023 to July 2024. Seasonal sampling of water and fish was conducted, and statistical analyses were used to assess spatial variation in physicochemical parameters, fish abundance, diversity, and feeding ecology. Analysis of variance (ANOVA) revealed no significant differences in mean temperature (Zobe: 31.00 ± 0.00°C, Sabke: 28.00 ± 0.00°C, Mairuwa: 20.00 ± 0.00°C) and pH (Zobe: 6.40 ± 0.25, Sabke: 6.47 ± 0.25, Mairuwa: 6.60 ± 0.10) across reservoirs ($p > 0.05$). However, significant differences were found in electrical conductivity (Sabke: 115.86 ± 0.10, Zobe: 101.22 ± 0.05, Mairuwa: 101.65 ± 0.02), dissolved oxygen (Sabke: 10.01 ± 0.03 mg/L), and biological oxygen demand (Sabke: 41.58 ± 0.04 mg/L) ($p < 0.05$). Fish abundance varied, with Sabke reservoir recording the highest number of Oreochromis niloticus (243) and Lates niloticus (250), while Mairuwa reservoir had the highest biodiversity, reflected by a Margalef Diversity Index of 0.8142. Catch per unit effort (CPUE) highlighted the dominance of Latesniloticus in Sabke (CPUE: 3.71) and Clarias gariepinus in Mairuwa (CPUE: 1.01). Length-weight relationships for key species such as Schilbemystus, Oreochromis niloticus, Lates niloticus, and Clarias gariepinus showed negative allometric growth ($b < 3$) with high correlation coefficients (R^2 values ranging from 0.698 to 0.9132), confirming consistent growth trends across sites. Dietary analysis revealed that Schilbemystus fed primarily on insects, with occurrence rates of 56.6% (Zobe), 63.3% (Sabke), and 43.3% (Mairuwa). Clarias gariepinus showed a strong piscivorous tendency, with fish parts constituting 13.3% (Zobe), 70.0% (Sabke), and 46.6% (Mairuwa) of its diet. Latesniloticus in Sabke consumed 90.0% fish parts, confirming its role as an apex predator. In Mairuwa, Bagrusbayad relied heavily on fish (63.3%), while Synodontisclarias showed a mixed diet dominated by insects. Correlation analyses between water quality and fish abundance showed species-specific associations. In Zobe, temperature had a strong positive correlation with O. niloticus abundance, while in Mairuwa, total suspended solids (TSS) correlated positively with Schilbemystus, and chemical oxygen demand (COD) negatively with O. niloticus. Findings showed Latesniloticus as an apical predator in the Sabke reservoir, consuming 90.0% fish parts. Meanwhile, Bagrusbayad in the Mairuwa reservoir prefers fish, making up 63.3% of its diet. Further studies are needed to investigate the interactions among water quality, fish diversity, and habitat conditions in freshwater ecosystems.

Key words: Water quality, Fish community, Diet composition, Biodiversity

INTRODUCTION

Katsina State is blessed with diverse aquatic ecosystems, including reservoirs, which provide essential water resources for irrigation, domestic use, and fisheries (Muhammad, 2023). Fish communities in these reservoirs play a vital ecological role in the aquatic ecosystems of reservoirs, contribute to biodiversity, and provide valuable resources for local communities through commercial and subsistence fishing activities (Cantonati *et al.*, 2020; Chen *et al.*, 2022). Fish assemblages are an important component of aquatic ecosystems, giving significant insights into the ecological health and dynamics of these systems (Czeglédi *et al.*, 2022). The composition and structure of fish species within an aquatic ecosystem can vary depending on a variety of parameters such as habitat characteristics, water quality, temperature, flow regime, and food resource availability (Landis *et al.,* 2017; Jones *et al.,* 2018). Fish assemblages can be used to assess the health of aquatic environments using biological markers. Various biological indices have been designed to assess the condition of ecosystems by assessing features of invertebrates, and fish populations (Kim *et al.,* 2021).

Fish assemblages can be employed as indicators of water quality and ecosystem productivity (Duque *et al.,* 2020). Fish assemblages can also provide insights into the functional roles of different fish species within the ecosystem (Richardson *et al.,* 2017). Nevertheless, fish are sensitive indicators of physical and chemical habitat degradation, environmental contamination, migration barriers, and overall ecosystem productivity. However, evaluating fish assemblage has been integral to water quality assessments (VadasJr *et al.,* 2022). Environmental conditions and diet are two key factors that influence the organisational structure of fish communities in inland water. However, environmental conditions such as water quality, temperature, and habitat characteristics directly affect the availability and quality of food resources for fish (Gebrekiros, 2016).

According to Mishra *et al.* (2023), the quality of any water resource is measured in terms of physicochemical parameters. The physicochemical properties of water affect its quality and biological diversity. Changes in physicochemical parameters tend to change living conditions, especially the number, diversity, and distribution of the biota of the ecosystem (Pinheiro *et al.,* 2021). Fluctuations in physicochemical factors can adversely affect organisms by limiting their production and interfering with physiological processes that reduce their ability to compete with other populations in the environment (Suleiman *et al.,* 2021). However, variations in water temperature can influence the productivity of phytoplankton and zooplankton, which serve as the primary food sources for many fish species (Roman *et al.,* 2019). Additionally, alterations in water quality, such as increased turbidity or nutrient concentrations, can also affect the availability of prey organisms and subsequently affect the feeding patterns and composition of fish communities in selected reservoirs (Koushlesh *et al.,* 2023).

Different fish species have specific dietary requirements, and changes in environmental conditions can affect the abundance and composition of their preferred food sources (Uren Webster *et al.,* 2020). Feeding strategies and trophic plasticity can be evaluated by comparing the trophic webs and niche breadth of a species between environments that experience different levels of disturbance. Combining stomach content analyses with whole-body stable isotopes (e.g., carbon and nitrogen) can yield robust and accurate information (da Silveira *et al.,* 2020). Stomach content analysis provides detailed taxonomic information about the food items consumed and is one of the most common techniques used to evaluate fish feeding habits (Buckland *et al.* 2017).

Dietary composition of fish in reservoirs or water islands plays a significant role in shaping their community structures (Chandran *et al.,* 2021). Fish are opportunistic feeders, and their diets can vary based on the availability and accessibility of different food sources. Some fish species are specialized feeders that target specific types of feed, whereas others are more generalists, consuming a broader range of food items (de Carvalho *et al.,* 2019). Dietary preferences can affect competitive interactions among fish species within a reservoir, with dominant species having a greater ability to access and exploit preferred food resources (Grzybkowska *et al.,* 2018; Sittenthaler *et al.,* 2019). However, changes in the availability of prey organisms or alterations in food web dynamics, such as the introduction of invasive species, can affect the balance of the fish community and potentially lead to shifts in the abundance and distribution of different fish species within the reservoir (Arantes *et al.,* 2019).

The structure and composition of fish communities can be influenced by a range of factors, including environmental conditions and dietary availability (Anneville *et al., 2017; Liew et al., 2018;* Rosa *et al.,* 2023). Therefore, it is essential to investigate how the environment, diet, and fish community relate to one another in the chosen reservoirs of Katsina State, to understand the dynamics of fish communities and to advise management and conservation strategies in the selected reservoirs in Katsina State.

MATERIALS AND METHODS

Study Area

Katsina State, Nigeria, located between latitudes 11˚ to 13˚25'N and longitudes 6˚45' to 9˚E is a state of the Northwest Zone of Nigeria, with an area of 24,192 km2 (9,341 sq meters) of which 67% (about 1.6 million hectares) is devoted to cultivation. The state is an agrarian state, with agriculture, in the form of crops and livestock production, being the primary employer of labour (Muhammad and Aliyu, 2018). Several irrigation sites were distributed throughout the state (Yaradua *et al.*, 2018). Three Reservoirs were selected for this study. The Mairuwa reservoir, situated between latitude 11.587657 and longitude 7.238149 in Funtua Local Government Area, is located within a Northern Guinea savanna zone of Nigeria. Zobe reservoir is situated between latitude 12˚20' 34.62"N and longitude 7˚27' 57.12"E in Dutsinma local government area. It is located within sudan savanna zone of Nigeria. Sabke reservoir is situated between latitude 12º 57'30''- 13º 14'00 N and longitude 8º 11' 00''-8º 14'00''E in Daura local government area. It is located within sahel savanna zone of Nigeria.

Water Sampling

Water samples were collected from three different dam-sites (Zobe, Sabke and Mairuwa) reservoirs from October 2023 to July 2024 between 8 and 11 am. All samples were collected using plastic bottles of 2 L capacity during the experimental period. The sampling bottles were carefully cleaned and rinsed with water before sampling. The samples were taken from each sampling point by dipping the sample bottle approximately 20–30 cm below the water surface, allowing the container to fill up and be covered with a cap (Raji *et al.*, 2015). The samples were immediately taken to the Umaru Musa Yar'Adua University Biology laboratory for processing.

Determination of Water Quality Parameters

Water samples were analyzed for hydrogen ion concentration (pH), temperature, electrical conductivity (EC) (Nayar, 2020), total suspended solids (TSS), dissolved oxygen (DO) (Jaffar *et al.*, 2020), biological oxygen demand (BOD), chemical oxygen demand (COD) (Verma *et al.*, 2025), total dissolved solids (TDS), turbidity, chloride (Cl^-), and total hardness (TH) (Bakar *et al.*, 2020). The hydrogen ion concentration (pH) was measured using a pH meter (pH 3505 Janway), and the electrical conductivity (EC) was measured using an EC meter (EC 4510 Janway). DO and BOD were measured using a HANNA HI 9143 meter. The total dissolved solids (TDS) and total suspended solids (TSS) were determined using equations. Chemical oxygen demand (COD), chloride (Cl^-), and total hardness (TH) were measured using the titrimetric method. The analyses were carried out at the biology laboratory of Umaru Musa 'Yar'adua University, Katsina, Nigeria.

Fish Sampling and Identification

Fish sampling was conducted in accordance with standard procedures described by Kumar and Hassan (2015), with modifications to ensure gear-effort consistency across all sampling locations. A total of 450 fish specimens were collected from three reservoirs in Katsina State, Nigeria: Zobe, Sabke, and Mairuwa Reservoirs, at a sampling intensity of 150 specimens per reservoir.

Sampling was performed at three strategically selected landing sites per reservoir to ensure spatial representativeness. Two primary fish capture methods were employed: gill nets and traditional traps commonly used by artisanal fishers in the region. Gill nets of standardized mesh sizes (ranging from 25 mm to 50 mm stretched mesh) were deployed for a fixed soak time of 12 hours, typically from 6:00 pm to 6:00 am to target a broad size range of fish species and minimize bias. Traps were baited and submerged for a 24-hour soak period before retrieval.

To maintain sampling consistency and reduce variation in fishing effort, the same number and type of gear units (five gill nets and ten traps per site) were used at each sampling location. Local fishermen, trained and briefed on sampling protocols, assisted in the deployment and retrieval of gears under supervision.

Collected fish specimens were immediately placed in sterile polythene bags and transported in ice-packed coolers to the laboratory. Upon arrival, samples were rinsed under running tap water to remove debris, following the procedures of Oguntade *et al.* (2013). Each specimen was subsequently stored at −20˚C until further analysis. Prior to dissection, samples were allowed to thaw, then transferred into sterile sample containers, labelled, and prepared for stomach content analysis.

Fish species identification was conducted using dichotomous keys, taxonomic guides, and pictorial references provided by Rainboth *et al.* (2012). Post-identification, specimens were preserved in 5% buffered formalin solution for archival purposes.

Determination of Fish Abundance, Morphometric Measurement, and Species Diversity

The total length (cm) and weight (g) were taken using a graduated meter rule and weighing balance. The total number of fish caught from the Reservoirs was also recorded per species. The condition factor of fish was determined using the Fulton condition factor as described by Aryani *et al.* (2020). The length-weight relationship of all species was determined using the relationship W = aLb, where "W" is the weight of fish (g), "L" is the standard length (cm), "a" is the regression constant, and "b" is the regression coefficient.

Indices of diversity were used to describe the diversity of the fish communities in the reservoir as follows: fish diversity was determined using the Shannon-Wiener index (species richness, species evenness, Margalef species, and species dominance will be calculated). The diversity was determined using the Shannon-Wiener index (Johnson *et al.*, 2022).

Analysis of Stomach Contents

Fish were identified, counted, dissected, and their stomachs were removed and preserved in plastic containers containing 5% formalin solution. Species were selected for the analysis of stomach contents (Rosa *et al.*, 2023).

Stomach fullness was recorded using the empirical scale (full, ¾ full, ½ full, ¼ full, and empty) adapted from Zacharia (2017). The state of their stomach fullness were classified as full were extremely packed with food items, 3/4 three-quarter full stomach were nearly filled with food items, ½ half full stomach were filled with food items approximately half of its length, ¼ one-quarter full stomach have little food item in it, and digested food or empty had no trace of food.

The stomach contents were placed in a Petri dish, where the food items were separated. The contents of the stomach were then weighed, examined under a microscope, and the volume of each food item was determined using the water displacement method. The food items were identified and sorted into various taxonomic groups; the percentage of occurrence and the numerical abundance is estimated. To avoid contamination, Petri dishes, scissors, and tweezers were cleaned with distilled water and then with 70% alcohol, and disposable latex gloves were used during all analyses of the stomach contents (Rosa *et al.*, 2023).

RESULTS

During the study period, the mean temperature values recorded varied across the reservoirs, with Mairuwa reservoir exhibiting the lowest temperature at 20.00±0.00°C, followed by Dan-Nakola at 28.00±0.00°C, and the highest value recorded in Zobe reservoir at 31±0.00°C. Despite these differences in absolute values, statistical analysis showed no significant difference in temperature across the reservoirs ($p > 0.05$, Table 1), indicating relatively stable thermal regimes across the sites during the sampling period.

The pH values showed slight variation, ranging from 6.4±0.25 in Zobe, 6.47±0.25 in Sabke, to 6.60±0.10 in Mairuwa. Similarly, these values were not significantly different ($p > 0.05$, Table 1), suggesting that the three reservoirs maintained comparable pH conditions, which are slightly acidic to neutral and typical of many tropical freshwater bodies.

In contrast, electrical conductivity (EC) values displayed more pronounced differences. The highest EC was recorded in Sabke (115.86±0.10 µS/cm), followed by Mairuwa (101.65±0.02 µS/cm), and the lowest in Zobe (101.22±0.05 µS/cm). These differences were statistically significant ($p < 0.05$, Table 1), indicating varying levels of dissolved ions and possible anthropogenic or geogenic influence on water chemistry.

Dissolved Oxygen (DO) levels were also significantly different ($p < 0.05$, Table 1), with Sabke showing the highest value (10.01±0.03 mg/l), followed by Zobe (9.08±0.04 mg/l) and Mairuwa (9.02±0.03 mg/l). This shows better aeration or primary productivity in Sabke, which could support more oxygen-demanding species. Similarly, Biological Oxygen Demand (BOD) varied significantly ($p < 0.05$), with the highest in Sabke (41.58±0.04 mg/l), followed by Zobe (38.65±0.05 mg/l) and the lowest in Mairuwa (36.65±0.05 mg/l). The higher BOD in Sabke may be associated with increased organic matter and microbial activity, indicating a more eutrophic condition.

The total number of *Schilbemystus* varied from 17 to 76 across reservoirs, with the lowest CPUE in Mairuwa (0.06) and the highest in Sabke (0.29). This indicates a relatively sparse population in Mairuwa, potentially due to its lower productivity or habitat structure. In contrast, *Oreochromis niloticus* exhibited a wide abundance range (34 to 243 individuals), showing its adaptability across all sites. *Clarias gariepinus* showed a more balanced distribution (28 to 42 individuals), but its highest CPUE (1.01) occurred in Mairuwa, suggesting favorable conditions for benthic, omnivorous species in that reservoir.

Alestes nurse was only recorded in Zobe with a CPUE of 0.04, indicating a localized distribution or habitat preference. *Synodontis clarias* was observed in Zobe and Mairuwa, with CPUE ranging from 0.04 to 0.08, suggesting moderate distribution in structurally complex benthic habitats.

Latesniloticus was recorded exclusively in Sabke, with a notably high CPUE of 3.71, showing dominance and potential apex predator status in the food web. *Bagrusbayad*, on the other hand, was only found in Mairuwa with a CPUE of 0.79, reinforcing the contrast in species composition between the reservoirs.

The Margalef diversity index revealed variation in biodiversity levels across the reservoirs: Mairuwa had the highest diversity (0.8142), followed by Zobe (0.7521) and Sabke (0.6125). This indicates that Mairuwa supports a more diverse and perhaps more balanced fish community, potentially due to its environmental complexity and lower predation pressure.

Regression analysis of length-weight relationships revealed that most fish species exhibited allometric growth (a negative correlation between total length and weight) across reservoirs. Specifically, in Zobe, Schilbemystus and Oreochromis niloticus showed allometric growth, with Schilbemystus having a weaker correlation (R^2 = 0.698) compared to Oreochromis (R^2 = 0.7284).

In Sabke, Latesniloticus exhibited a strong correlation (R^2 = 0.8537) and allometric growth, consistent with fast-growing predatory behavior. *Oreochromis niloticus* in the same reservoir showed a weaker correlation (R^2 = 0.605). In Mairuwa, *Clarias gariepinus* displayed a very strong correlation (R^2 = 0.9132) with growth patterns aligning with a benthic lifestyle, while Oreochromis again showed allometric growth (R^2 = 0.704).

In Zobe reservoir, gut fullness varied across species, with *Clarias gariepinus* exhibiting the highest average weight of food items (1.69g) and total food weight (50.94g), suggesting a higher feeding rate or broader diet. *Schilbe mystus* in Zobe showed a preference for insect parts (56.6%), indicating its insectivorous habit, while *Oreochromis niloticus* consumed mostly plant parts (115 items), affirming its herbivorous tendencies. In Sabke, *Latesniloticus* fed predominantly on fish parts (90%), confirming its piscivorous nature and its dominance in that reservoir. *Oreochromis niloticus* maintained a plant-based diet (37 plant parts), consistent with observations in Zobe. In Mairuwa, *Clarias gariepinus* consumed a wide variety of food, including molluscs, fish, insects, worms, plants, and microplastics, showcasing its omnivorous and opportunistic feeding behavior. Bagrusbayad also fed heavily on fish parts, while *Synodontisclarias* consumed mainly insect parts, suggesting benthic insectivory.

Correlative analysis revealed complex interactions between environmental parameters and species abundance, as in Zobe, where temperature was positively correlated with Oreochromis niloticus and negatively with Schilbe mystus. There was a weak correlation between pH and EC.

In Dan-Nakola, temperature correlated moderately with *Clarias gariepinus*, while turbidity strongly correlated with total hardness, implying geochemical influences.

In Mairuwa, temperature and pH were strongly positively correlated, while total suspended solids (TSS) strongly influenced *Schilbemystus* abundance. A strong negative correlation was found between COD and *Oreochromis niloticus*, possibly due to organic load impacting the herbivorous fish.

PCA results (Figure 2) revealed that PC1, heavily loaded with COD, turbidity, EC, and BOD, represents a gradient of organic enrichment, whereas PC2 was structured by TSS and pH, indicating the mineral and buffering capacity. These axes differentiated the reservoirs ecologically. Sabke emerged as more productive, Mairuwa as oligotrophic, and Zobe as intermediate.

The CCA ordination (Figure 3) further illustrated reservoir-specific fish assemblages as Sabke aligned with DO and COD, supporting apex predators like Latesniloticus and Oreochromis.

Mairuwa aligned with TSS and hardness, favoring benthic feeders like *Clarias gariepinus* and *Bagrus bayad*. Zobe exhibited intermediate characteristics, supporting generalist species such as *Schilbemystus* and *Synodontis clarias*.

Table 1: Water Quality Parameters of Zobe, Sabke and Mairuwa Reservoir during the Sampling Period

Sites Parameters	Zobe	Sabke	Mairuwa
Temperature (°C)	31±0.00[a]	28.00±0.00[a]	20.00±0.00[a]
pH	6.4±0.25[a]	6.47±0.25[a]	6.60±0.10[a]
Electrical conductivity (μS)	101.22±0.05[a]	115.86±0.10[c]	101.65±0.02[b]
Dissolved oxygen(mg/l)	10.01±0.04[c]	9.08±0.03[b]	9.02±0.03[a]
Biologicaloxygen demand (mg/l)	38.65±0.05[b]	41.58±0.04[c]	36.65±0.05[a]
Chemicaloxygen demand (mg/l)	12.81±0.03[b]	15.38±0.03[c]	11.39±0.03[a]
Turbidity (ntu)	350.5±0.05[c]	300.44±0.05[b]	50.34±0.03[a]
Total hardness (mg/l)	105.72±0.03[c]	101.17±0.06[b]	100.48±0.07[a]
Total Suspended Solid (g)	2.85±0.03[b]	2.93±0.03[b]	1.29±0.05[a]
Total Dissolve Solid (g)	1.93±0.03[b]	2.16±0.05[c]	1.11±0.04[a]

Table 2: Fish Assemblage in Zobe Reservoir, Sabke and Mairuwa Reservoir

Sites	Zobe			Sabke			Mairuwa		
SPECIES	Total number	Total weight	Cpue (kg/h)	Total number	Total weight	Cpue (kg/h)	Total number	Total weight	Cpue (kg/h)
Schilblemystus	76	3.4	0.28	66	3.5	0.29	17	0.7	0.06
Oreochromisnilotus	46	8.3	0.69	243	37.6	3.13	34	9.4	0.78
Clariasgariepinus	35	11.2	0.93	28	10.1	0.84	42	12.1	1.01
Alestes nurse	24	0.5	0.04	-	-	-	-	-	-
Synodontisclarias	23	0.9	0.08	-	-	-	13	0.5	0.04
Latesniloticus	-	-	-	250	44.5	3.71	-	-	-
Petrocephalus bane	-	-	-	99	6.6	0.55	-	-	-
Bagrusbayad	-	-	-	-	-	-	30	9.5	0.79
Margalef Diversity index	0.7521			0.6125			0.8142		

Table 3: The percentage of stomach fullness of the five most abundant fish in Zobe reservoir

Species	Empty %	¼ full %	½ full %	¾ full %	Full %
Alestes nurse	30	0	16.66	20	33.33
Clariasgaripienus	6.66	0	20	30	43.33
Oreochromisniloticus	20	0	10	33.33	36.66
Schilblemystus	23.33	6.66	10	13.33	46.66
Synodontisclarias	26.66	6.66	6.66	20	40

Table 4: The percentage of stomach fullness of the five most abundant fish in Sabke reservoir

Species	Empty %	¼ full %	½ full %	¾ full %	Full %
Latesniloticus	6.66	13.33	56.66	13.33	10
Oreochromisniloticus	16.66	0	13.33	0	70
Petrocephalus bane	13.33	13.33	33.33	10	30
Schilblemystus	26.66	3.33	13.33	23.33	33.33
Clariasgaripienus	6.66	3.33	16.66	33.33	40

Table 5: The Percentage of Stomach Fullness of the Five Most Abundant Fish in Mairuwa Reservoir

Species	Empty %	¼ full %	½ full %	¾ full %	Full %
Clariasgariepinus	6.66	0	26.66	30	36.66
Orechromisniloticus	13.33	10	13.33	16.66	46.66
Bagrusbayad	6.66	0	20	26.66	46.66
Schilblemystus	36.66	0	13.33	13.33	36.66
Synodontisclarias	26.66	0	10	26.66	36.66

Table 6: The percentage of occurrence of food items in the stomach of the fish in Zobe reservoir in Katsina state, Nigeria

Site	Species	Food items	% percentage of occurrence
Zobe reservoir	*Schilblemystus*	Amphipod	10
		Water flea	16.6
		Fish egg	6.6
		Insect parts	56.6
		Digested food items	16.6
		Empty stomach	10
	Oreochromisniloticus	Plant parts	80
		Digested food items	10
		Empty stomach	10
	Clariasgariepinus	Crayfish	3.3
		Fish parts	13.3
		Fish egg	6.6
		Insect parts	3.3
		Maggot	30
		Plant parts	10
		Chlorella vulgaris	13.33
		Filamentous green algae	6.6
		Plastic	30
		Digested food items	6.6
	Alestes nurse	Insect parts	50
		Chronomid larvae	13.3
		Maggot	6.6
		Digested food items	30
	Synodontisclarias	Fish egg	6.6
		Insect parts	43.3
		Maggot	13.3
		Plant parts	26.6
		Diatom	3.3
		Filamentous green algae	3.3
		Digested food items	16.6
		Empty stomach	10

DISCUSSION

The analysis of water quality in Zobe, Sabke, and Mairuwa reservoirs revealed relatively consistent temperature and pH values across all sites. Mean temperatures of 31.00 ± 0.00°C in Zobe, 28.00 ± 0.00°C in Sabke, and 20.00 ± 0.00°C in Mairuwaalong with pH values ranging from 6.40 ± 0.25 to 6.60 ± 0.10, indicate stable physicochemical conditions that support essential biological processes in aquatic ecosystems.

In contrast, significant variations were observed in electrical conductivity (EC), dissolved oxygen (DO), and biological oxygen demand (BOD), which reflect differential environmental pressures across the reservoirs. Sabke's higher EC (115.86 ± 0.10 µS/cm) shows greater ionic input, potentially from anthropogenic sources or geological weathering, while its elevated DO (9.08 ± 0.03 mg/L) indicates favorable aerobic conditions. However, the concurrently high BOD (41.58 ± 0.04 mg/L) implies increased organic load, potentially leading to oxygen depletion in deeper strata. This pattern supports the findings of Gholikandi *et al.* (2011), who linked high BOD levels with deteriorating water quality and reduced oxygen availability for aquatic organisms. These results also corroborate the observations of Prasad *et al.* (2014) and Shawky and Al-Zubaidi (2023), who reported that excessive BOD levels impair aquatic health and reduce habitat suitability for sensitive species.

TDS and TSS also showed significant variability, with Sabke exhibiting the highest levels (TDS: 2.16 ± 0.05 mg/L; TSS: 2.93 ± 0.03 mg/L), reflecting increased runoff or sediment input. Elevated TSS reduces water transparency, thereby limiting light penetration and photosynthetic activity in primary producers. This finding aligns with Rim-Rukeh (2013) and Naveedullah *et al.* (2016), who reported that increased turbidity can compromise aquatic productivity and trophic efficiency.

Table 7: The percentage of occurrence of food items in the stomach of the fish in Sabke reservoir in Katsina state, Nigeria

Site	Species	Food items	% percentage of occurrence
Sabke reservoir	*Latesniloticus*	Fish parts	90
		Insect parts	10
		Digested food item	6.6
	Oreochromisniloticus	Plant parts	83.3
		Digested food item	16.6
	Petrocephalus bane	Water flea	33.3
		Insect parts	43.3
		Plant parts	36.6
		Digested food items	13.3
	Schilblemystus	Amphipod	10
		Fish egg	10
		Insect parts	63.3
		Plant parts	10
		Digested food items	16.6
		Empty stomach	10
	Clariasgaripinus	Crayfish	13.3
		Fish parts	70
		Fish egg	6.6
		Maggot	6.6
		Plant parts	10
		Plastic	10
		Digested food item	6.6

Fish species composition reflected these physicochemical differences. Latesniloticus and Oreochromisniloticus were most abundant in Sabke (CPUE: 3.71 and 3.13, respectively), likely due to higher DO and food availability. This abundance supports the findings of Nababa *et al.* *(2022), who observed dominance of O. niloticus in productive waters of Zobe Reservoir, and corroborates the results of* Oladipo *et al.* (2022), who found that DO and turbidity significantly influenced fish distribution in Jebba Reservoir. Conversely, *Clarias gariepinus* showed higher CPUE in Mairuwa (1.01), indicating its preference for environments with lower temperatures and variable oxygen, due to its facultative air-breathing ability.

Species-specific distributions were evident, as Alestes nurse appeared only in Zobe, while *Synodontis clarias* was absent in Sabke. These patterns suggest ecological specialization and habitat partitioning. The highest Margalef diversity index in Mairuwa (0.8142) shows a more complex habitat structure, which supports niche differentiation. This observation supports the findings of Nababa *et al.* (2022), who reported high species diversity in reservoirs with diverse microhabitats.

Length-weight relationships revealed predominantly negative allometric growth ($b < 3$) among the fish species, indicating that weight increased less proportionally with length. This may reflect environmental constraints such as limited food resources, high competition, or investment in reproductive development rather than somatic growth. For instance, Schilbemystus in Zobe showed a regression of W

$= 0.7492L^{1.0119}$ ($R^2 = 0.698$), suggesting limited energy surplus for weight gain. These findings corroborate the results of Deng *et al*. (2017) and Ahmed *et al*. (2011), who reported similar allometric trends in freshwater fish under environmental stress. Conversely, these findings are contrary to the reports of Gusau (2021), who found positive allometric growth in L. niloticus and B. bayad, likely due to differing habitat quality or resource availability.

Table 8: The percentage of occurrence of food items in the stomach of the fish in Mairuwa reservoir in Katsina state, Nigeria

Site	Species	Food items	% percentage of occurrence
Mairuwa reservoir	*Clariasgariepinus*	Blader snail	13.30
		Fish parts	46.6
		Fish egg	6.6
		Insect parts	23.3
		Maggot	13.3
		Plant parts	16.6
		Microstic	6.6
		Digested food items	6.6
	Oreochromisniloticus	Fish parts	6.6
		Fish egg	16.6
		Insect parts	16.6
		Plant parts	76.6
		Digested food items and an empty stomach	13.3
	Bagrusbayad	Fish parts	63.3
		Fish egg	23.3
		Insect parts	30
		Microplastic	10
		Digested food items	6.6
	Schilblemystus	Water flea	10
		Insect parts	43.3
		Plant parts	10
		Digested food items and an empty stomach	36.6
	Synodontisclarias	Water flea	3.3
		Fish parts	16.6
		Fish egg	3.3
		Insect parts	56.6
		Digested food items and an empty stomach	26.6

Stomach content analysis revealed species-specific feeding intensities and dietary compositions. In Zobe, S. mystus had 46.66% full stomachs with a high proportion of insects, indicating consistent carnivorous feeding and the availability of macroinvertebrate prey. Conversely, *A. nurse* showed lower stomach fullness (0–33.33%), which may be attributed to temporal scarcity of preferred food items or selective feeding behavior. These findings support Adewumi *et al*. (2014), who emphasized the influence of habitat and food availability on feeding strategies.

In Sabke, L. niloticus showed variable stomach fullness (6.66-56.66%), while O. niloticus had a higher rate (70% full), reflecting stable food supply and efficient foraging in phytoplankton-rich waters. In Mairuwa, C. gariepinus showed variable fullness (0-36.66%), consistent with its opportunistic omnivory, while O. niloticus exhibited more consistent feeding (13.33-46.66%). These findings corroborate Wakil *et al*. (2014), who classified C. gariepinus as a generalist carnivore and O. niloticus as predominantly herbivorous.

Total food weights and volumes reflected trophic positioning. In Zobe, C. gariepinus consumed the highest quantity (50.94 g, 5.4 mL), suggesting higher foraging efficiency. In Mairuwa, B. bayad recorded the highest total intake (104.2 g, 16.4 mL), supporting its role as an apex predator. This supports the reports of Malami and Magawata (2010), who described B. bayad as a top carnivore with a high dietary intake.

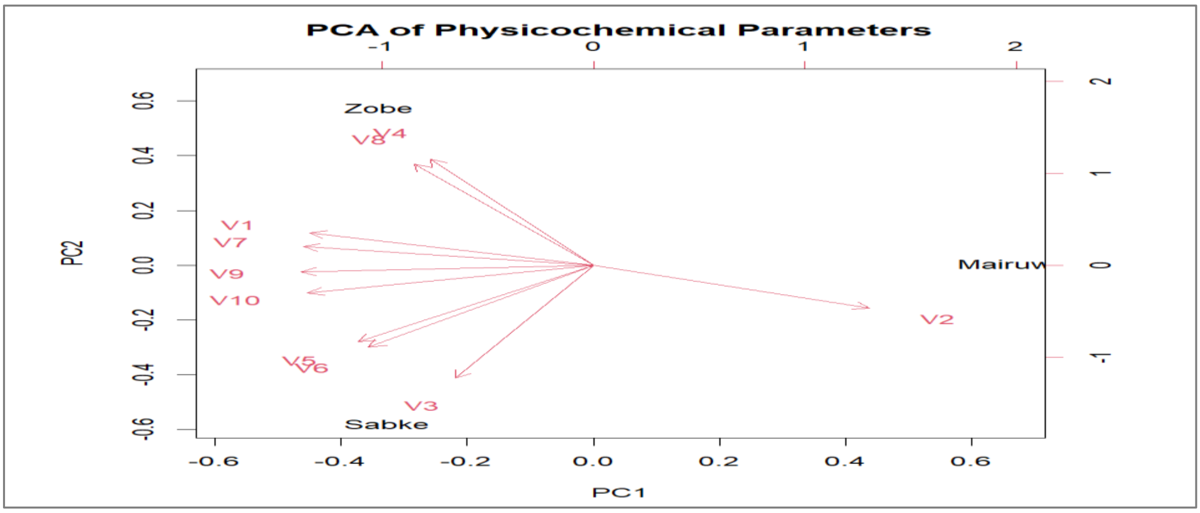

Figure 2: PCA loading plot showing vectors of environmental variables.

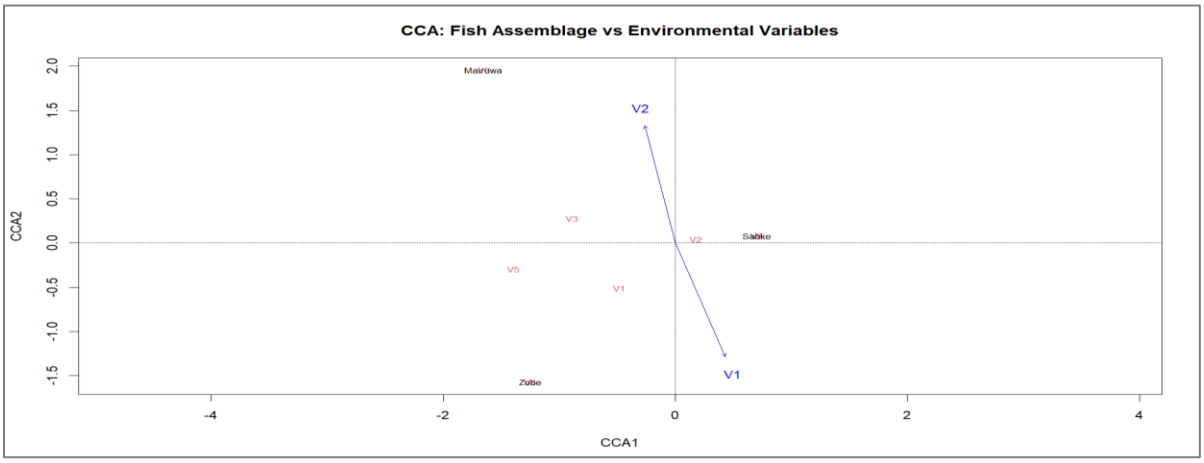

Figure 3: CCA biplot of fish assemblage and environmental variables

Table 9: The Numerical abundance of food items in the stomach of the fish in Zobe Reservoir, Sabke Reservoir and Mairuwa Reservoir in Katsina State

Diet composition revealed clear trophic roles. In Zobe, S. mystus consumed primarily insects (56.6%), water fleas (16.6%), and crustaceans (10%), confirming its insectivorous niche. This corroborates the findings of Devi *et al.* (2024), who reported similar feeding behavior in Nigerian freshwater systems. In Sabke, L. niloticus consumed mostly fish parts (90%), indicating strict piscivory, while O. niloticus fed primarily on plant matter (37 parts), confirming herbivory. In Mairuwa, C. gariepinus demonstrated a mixed diet of animal and plant matter, including plastics (6.6%), which shows exposure to anthropogenic pollution. This aligns with Wakil *et al.* (2014), who reported omnivory in C. gariepinus from Lake Alau, and also highlights growing environmental threats.

The numerical abundance of food items further reinforced dietary specialization. In Zobe, *O. niloticus* consumed 115 plant parts, reaffirming its herbivory, while *C. gariepinus* ingested 26 maggots, 5 fish parts, 16 plastics, and various algae, reflecting omnivory and environmental opportunism. In Sabke, *L. niloticus* fed on 36 fish parts, emphasizing piscivory. In Mairuwa, B. bayad consumed 51 fish parts, 15 eggs, and 29 insects, supporting its role as a carnivore.

Table 9: The Numerical abundance of food items in the stomach of the fish in Zobe Reservoir, Sabke Reservoir and Mairuwa Reservoir in Katsina State

		Food items (numerical abundance)															
Sites	Species	Crustacean			Molluscs		Fish		Insect		Worm	Plant	Algae			Plastic	Digested food
		Amphipod	water flea	Crayfish	bladder snail	red-rimmed melanian	fish parts	fish eggs	insect parts	chronomid larvae	Maggot	plant parts	chlorella vulgaris	Diatom	filamentous green algae	plastic	
Zobe reservoir	*Schilblemystus*	5	6	0	0	0	0	3	32	0	0	0	0	0	0	0	8
	Oreochromisniloticus	0	0	0	0	0	0	0	0	0	0	115	0	0	0	0	6
	Clariasgariepinus	0	0	1	0	0	5	3	3	0	26	5	4	0	2	16	2
	Alestes nurse	0	0	0	0	0	0		27	5	2	0	0	0	0	0	9
	Synodontisclarias	0	0	0	0	0	0	3	27	0	6	10	0	1	0	0	8
Sabke reservoir	*Latesniloticus*	0	0	0	0	0	36	0	9	0	0	0	0	0	0	0	2
	Oreochromisniloticus	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	5
	Phetrocephalus bane	0	16	0	0	0	0	69	0	0	0	19	0	0	0	0	4
	Schilblemystus	0	0	0	0	0	0	10	72	0	0	7	0	0	0	0	8
	Clariasgaripinus	0	0	6	0	0	85	3	0	0	8	4	0	0	0	3	2
Mai ruwa reservoir	*Clariasgaripinus*	0	0	0	13	0	47	10	17	0	16	9	0	0	0	3	2
	Oreochromisniloticus	0	0	0	0	0	2	9	9	0	0	33	0	0	0	0	4
	Bagrusbayad	0	0	0	0	0	51	15	29	0	0	0	0	0	0	5	2
	Schilblemystus	0	4	0	0	0	0		22	0	0	3	0	0	0	0	11
	Synodontisclarias	0	2	0	0	0	8	2	38	0	0	0	0	0	0	0	8

These findings corroborate Demeke *et al.* (2015) and Tesfahun (2018), who emphasized dietary diversity and plasticity in African freshwater fishes as essential for resource partitioning and ecological balance.

Correlation analyses between water quality parameters and fish assemblages provided additional ecological insights. In Zobe, temperature showed a moderate positive correlation with pH, suggesting that warmer conditions may enhance microbial and algal activity, thereby increasing pH through photosynthetic CO_2 uptake. A weak negative correlation between temperature and S. mystus abundance shows thermal sensitivity in this species, while a strong positive correlation with O. niloticus supports its thermal adaptability, which is consistent with the findings of Nababa *et al.* (2022).

In Sabke, the moderate negative correlation between pH and EC indicates that ionic concentration may lower pH, possibly through increased carbonic acid formation or organic matter decomposition. A moderate positive correlation between temperature and *C. gariepinus* shows that higher temperatures may improve its metabolic rate and foraging activity. Turbidity and total hardness were strongly correlated, supporting Suleiman and Audu (2014), who reported that suspended minerals increase both hardness and turbidity.

In Mairuwa, a strong positive correlation between temperature and pH indicates a stable thermal regime favorable for aquatic productivity. A strong positive correlation between TSS and *S. mystus* shows this species benefits from turbid conditions, possibly due to increased benthic food availability or shelter. Conversely, a strong negative correlation between chemical oxygen demand (COD) and O. niloticus abundance indicates that higher organic pollution adversely affects its population, supporting findings by Nababa *et al.* (2022). This is further corroborated by Nyanti *et al.* (2018), who found that while O. niloticus can tolerate elevated suspended solids, it is sensitive to organic pollutants and oxygen stress.

CONCLUSION

This study revealed significant variations in environmental conditions, fish diversity, and feeding behavior across the Zobe, Sabke, and Mairuwa reservoirs. While all three reservoirs maintain stable temperatures and pH levels suitable for aquatic life, differences in dissolved oxygen, biological oxygen demand, and conductivity indicate distinct ecological conditions. Sabke reservoir, with higher dissolved solids and oxygen levels, supports large populations of Latesniloticus and Oreochromisniloticus, while Mairuwa shows greater species diversity. Analysis of fish diets highlights species-specific feeding strategies, with *Clarias gariepinus consuming larger prey (and occasionally plastics), Schilbe mystus feeding on insects, and Lates niloticus* exhibiting carnivorous tendencies. Correlation analysis emphasizes how water quality parameters like temperature, COD, and suspended solids influence fish abundance, emphasizing the critical role of habitat conditions in shaping fish communities. These findings highlight the need for continued monitoring and ecosystem-based management to sustain biodiversity and ecological health in these inland waters.

RECOMMENDATIONS

Based on the observed environmental variability and its influence on fish diversity and trophic dynamics, it is recommended that reservoir-specific management strategies be developed to address localized ecological conditions. Regular monitoring of key water quality parameters should be prioritized to mitigate pollution impacts and sustain fish populations. Efforts should also focus on reducing anthropogenic inputs to preserve water quality and ecosystem integrity. Furthermore, habitat restoration and adaptive fisheries management should be implemented to enhance species resilience and maintain ecological balance across the reservoirs.

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