Original Article

Influence of Selected Water Quality Parameters on Fish Species Abundance in Eko-Ende Reservoir, Nigeria

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Received: December 28, 2025 | Review began: January 23, 2026 | Review ended: April 09, 2026 | Published: April 10, 2026

Abstract

Introduction

This study was conducted to assess selected water quality parameters and evaluate their effects on fish species abundance and morphometric characteristics in the reservoir.

Methods

Monthly sampling of water and fish was done from the Sampling Points (SP_A, SP_B, and SP_C) for 12 months.

Results

Temperature (23.19 ± 1.18°C) and pH (6.79 ± 0.92) were highest in SP_B, dissolved oxygen was highest in SP_A (4.21 ± 1.12 mg/L) and SP_C (4.21 ± 1.14 mg/L), while ammonia was similar across the sampling points, with 0.02 ± 0.01 mg/L. The mean values of water quality parameters were highest in the dry season, and Student's t-test indicated significant differences in temperature and ammonia between the wet and dry seasons ($p < 0.05$). The first principal component (PC1) (68.5%) and the second principal component (PC2) (24.3%) jointly explained 92.8% of the total variance, with ammonia and pH having negative values in PC1 (−0.551) and PC2 (−0.990), which indicated an inverse relationship to the PC. A total of 1,279 individuals (five families and nine species) were recorded. *Coptodon zillii* and Cichlidae were the most abundant species (17.59%) and family (60.3%), respectively. A very high correlation was observed between fish abundance and most water quality parameters. The length-weight relationship values were significant ($p < 0.05$) for *Alestes baremose* ($b = 2.87$, $R^2 = 0.13$) and *Sarotherodon galileaus* ($b = 2.85$, $R^2 = 0.23$), with a negative allometric growth pattern ($b < 3$), indicating that fish increase in length at a faster rate than in weight. Most K-values were greater than 1, which indicates a good condition for fish species.

Conclusion

The results suggest that the reservoir may provide suitable conditions for fish species, substantiated by the water quality and condition factor values. Hence, regular awareness of environmental management and fishing activities around the reservoir must be of the utmost importance for the maintenance of the water quality and the sustainability of fish species.

Categories: Biodiversity conservation, Fishery ecology

Keywords: fish composition, growth pattern, morphometric characteristics, sustainability, aquatic ecosystem

Introduction

Fish is a major animal protein source in Africa and is categorized as a renewable resource. Its amino acid profile is balanced, and consumption is across all cultures and religions, hence its high demand worldwide [1,2]. Capture fisheries in Nigeria contribute approximately 70-80% of total fish production, with the artisanal fisheries subsector accounting for about 85-90% of capture fisheries output, representing roughly 60-70% of the total domestic fish supply [3]. Despite the numerous importance of fish, the natural lakes and their resources have received little attention [4]. With the rate of industrialization and urbanization over the last decade, waste generation and pressure on aquatic resources have increased [5]. Other environmental factors, such as water depth, fishing activities, climatic fluctuations, pollution from point or non-point sources, and availability of food, can influence fish abundance and distribution [6]. Fish live in water and are very sensitive to changes in the aquatic chemistry, and maintenance of water in terms of quality and quantity for fish survival is essential [7,8]. Key water quality parameters, including temperature, dissolved oxygen (DO), pH, and ammonia, play vital roles in regulating fish metabolism, survival, and distribution, thereby influencing fish production and justifying their assessment in this study [8].

In aquatic ecosystem management, tools such as the biometric studies on fish species are important as they provide information about the environment in relation to the physiological and morphometric characteristics of the fish [9]. The length-weight relationship (LWR) provides information on the growth pattern, fish health, life history, the condition of habitats, the well-being of fish, and the general morphological characteristics of the fish [10]. The LWR varies with species and is affected by the biological and environmental factors in the aquatic environment [11]. The “b” (regression coefficient) value changes with time and can indicate different periods in the fish such as the stages of gonads, the appetite of fish, or the fullness of the stomach. The growth pattern may either be isometric ($b = 3$) or allometric, which is further divided into positive ($b > 3$, i.e., the fish appears heavy as it grows) and negative allometry ($b < 3$, i.e., fish appear slimmer as it grows). The condition factor (K) is also an important tool as it is derived from the LWR, and it assesses the suitability of the aquatic environment for the fish growth. When K values are 1 or close to 1, the fish is in good condition, and when less than 1, the fish is in poor growth condition [12].

Eko-Ende is one of the oldest reservoirs in Osun State and is encompassed by diverse human activities such as dredging, agriculture, cattle herding, and fishing activities. Due to a lack of preliminary information on the fish species impoundment study, the report by Taiwo [13] was used as baseline information for the reservoir and reported it to be rich and diversified in fish species. Similarly, other reservoirs within the region, such as Owalla [4,13], Erinle [14,15], Opa [16], Osinmo [17], and Asejire [18], have been investigated. This study, therefore, seeks to examine water quality and evaluate its influence on fish abundance and growth patterns in the reservoir.

Materials And Methods

Study area

The Eko-Ende reservoir is located between latitudes 7°53′24.000″N and 7°57′0.000″N, and longitudes 4°31′48.000″E and 4°35′24.000″E, in Ifelodun Local Government Area of Osun State (Figure *1*). It was impounded on the Otin River in 1973 for the purpose of storing and supplying potable water to communities in the area. The reservoir has a capacity of 5.5 million cubic metres. The climate of the area is tropical, with an average temperature of 26°C and an average annual rainfall of 1,254 mm, which peaks in July and September. Three sampling points (SP_A, SP_B, and SP_C) were randomly selected based on accessibility and the characteristics of the reservoir. Water and fish species were collected monthly for 12 months (December 2021 to November 2022) to cover both dry and wet seasons.

How to cite this article:
Iyiola A O, Taiwo Y F, Ipinmoroti M O (April 10, 2026) Influence of Selected Water Quality Parameters on Fish Species Abundance in Eko-Ende Reservoir, Nigeria. Curues J. Agri. Food Sci 2 : es44497-025-00047-8. DOI https://doi.org/10.7759/s44497-025-00047-8

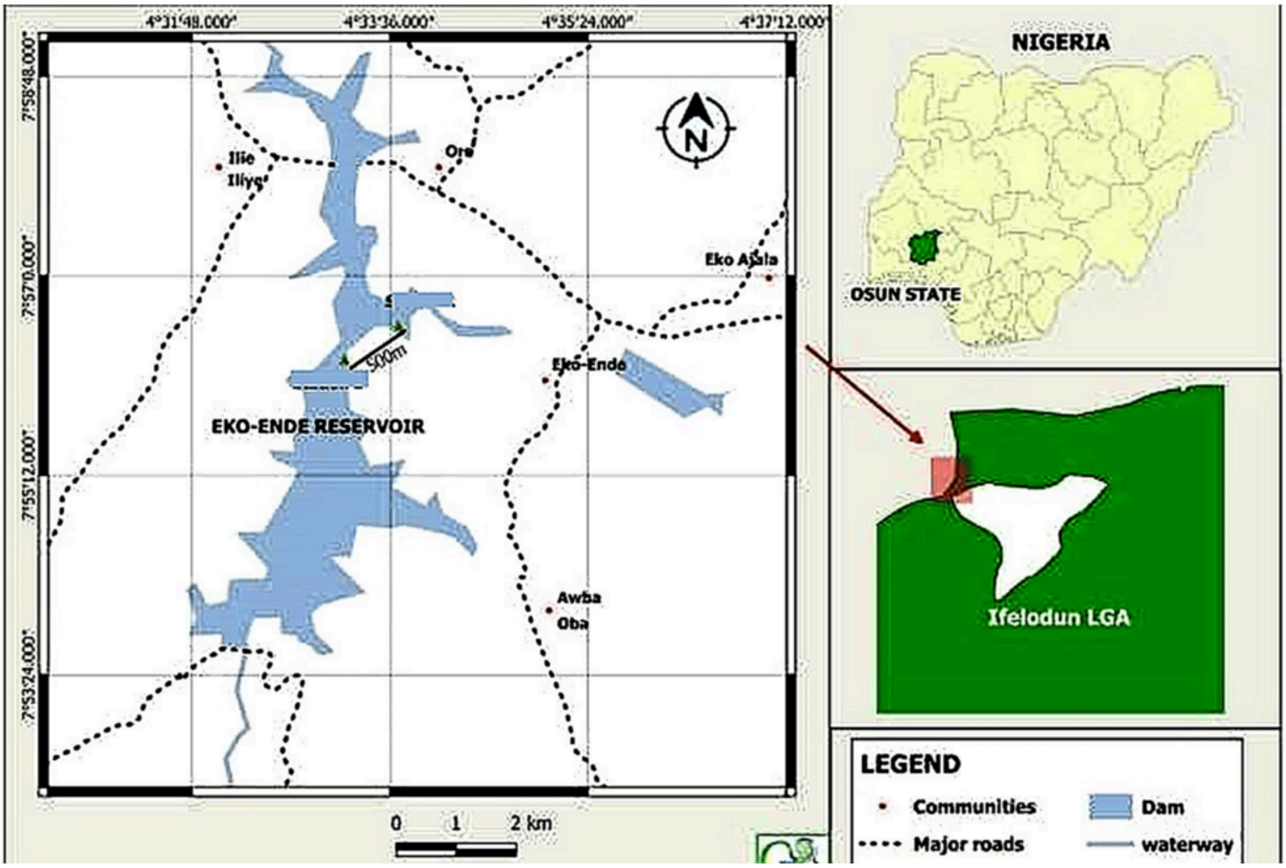

FIGURE 1: Map of Eko-Ende reservoir

Water quality parameters

Water samples were collected monthly from the three randomly selected sampling points on the reservoir between the early hours of 0700 and 0800 Greenwich Mean Time (GMT) using sterile 10 mL sampling bottles. DO was measured using Extech DO600 Waterproof ExStik II Dissolved Oxygen Meter (USA), with readings recorded in milligrams per litre (mg/L). Ammonia and pH were measured using API Freshwater Multitest Kits, as instructed by the manufacturer. Temperature was measured using a thermometer, which was dipped into the sample water, and readings were recorded in degrees Celsius (°C). Temperature, DO, ammonia, and pH were measured from the water samples because they are considered core water quality indicators in fish culture. They directly influence fish survival, growth, metabolism, and overall health in fish. The roles of each parameter in the aquatic environment are distinct and yet interconnected, collectively determining the suitability of the aquatic habitat for fish production.

Fish sampling

Field sampling of fish species was done monthly from December 2021 to November 2022 at the three sampling points using monofilament gill nets of mesh sizes 25 and 45 mm (10 m × 3 m) set from 1900 GMT and retrieved the next day at 0700 GMT. At each point, three replicate nets were deployed at each sampling period. Nets were checked every 6 hours to reduce mortality and bias in catch. The fishing effort across the sampling months and points was standardized by maintaining consistent net number, net length, and soak time. The fish species were sorted and identified to the lowest taxonomic level using the guide by Froese and Pauly [19], and abundance was recorded per sampling points, months, and seasons.

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Morphometric characteristics

Length-Weight Relationship

The length and weight of each fish species were measured using a measuring board in centimeters and a sensitive scale in grams, respectively. The LWR was determined as expressed by Pauly [20] (Equation 1), and the linear regression of the log transformation as expressed by Le Cren [21] (Equation 2).

$$W = aL^b \tag{1}$$

$$\log(W) = \log(a) + b\log(L) \tag{2}$$

where, W = body weight of fish (g), L = standard or total body length of fish (cm), and a and b = constants b is the slope and between 2 and 4 and a is the intercept.

Condition Factor (K)

It was calculated as described by Le Cren [21] (Equation 3).

$$K = \frac{100W}{L^3} \tag{3}$$

where, K = condition factor of fish species, W = weight of fish species, and L = length of fish species.

Statistical analysis

The data variables were standardized, and the sample size (n) used for analysis was 36 (3 replicates each month across 12 months of study). One-way analysis of variance was used to separate the means of water quality parameters across the sampling months, and post hoc analysis was conducted using least significant difference analysis. The Pearson correlation coefficient (r) was determined between monthly fish abundance and water quality parameters. Principal component analysis (PCA) was used to reduce dimensionality of the water quality dataset, identify the major environmental gradients, and examine the relationships between water quality parameters and fish species distribution. In the equation, the dependent variable (Y) was fish abundance, while the independent variables (X) were the PC scores accounting for the highest variability. Data were analyzed using the Statistical Package for Social Sciences (SPSS) statistical package 25.0, and results were considered significant when $p \leq 0.05$.

Results And Discussion

Water quality parameters

The investigation of water quality parameters is important as it gives information about the condition of water in terms of its physical, chemical, and biological characteristics [1,22]. The mean water quality parameters measured across the SP_A, SP_B, and SP_C are presented in Tables *1*-*3*, respectively. The highest temperatures were recorded in February (dry season) in SP_A, SP_B, and SP_C, with values of 26.20 ± 0.138°C, 26.50 ± 0.01°C, and 26.00 ± 0.01°C, respectively. The lowest temperatures occurred in August (wet season), with values of 17.00 ± 0.00°C, 17.80 ± 0.00°C, and 17.10 ± 0.02°C in SP_A, SP_B, and SP_C, respectively. Overall mean temperatures of 22.94 ± 1.91°C, 23.19 ± 1.18°C, and 23.09 ± 1.02°C were observed in SP_A, SP_B, and SP_C, respectively. The highest mean temperature observed in SP_B (23.19 ± 1.18°C), the least in SP_A (22.94 ± 1.91°C), and the overall mean value (23.07 ± 0.02°C) were within the recommended range of 21-30, as stated by FAO [3]. Most of the monthly mean values were within the recommended range, except for July and August in SP_A (17.10 ± 0.01°C, 17.00 ± 0.00°C), SP_B (17.60 ± 0.10°C, 17.80 ± 0.00°C), and SP_C (17.20 ± 0.00°C, 17.10 ± 0.02°C), respectively. The reduced temperature in July and August was expected because of the prevailing wet season, which is characterized by a reduction in atmospheric temperature [23]. Similarly, reports by Echebima and Obafemi [24] in major climatic zones in Nigeria, Abaje and Oladipo [25] in Kaduna state, and Dike et al. [26] corroborated the findings of this study.

For pH, the highest values were recorded in November (dry season) in SP_A (7.05 ± 0.10), December and April in SP_B (7.04 ± 0.00, respectively), and September in SP_C (7.10 ± 0.00). The lowest values were observed in October for SP_A and SP_B (6.20 ± 0.01 and 6.29 ± 0.03, respectively) and in February for SP_C (6.20 ± 0.00). Overall mean pH values of 6.77 ± 0.02, 6.79 ± 0.92, and 6.18 ± 0.95 were recorded in SP_A, SP_B, and SP_C, respectively. The mean pH value was highest in SP_B (6.79 ± 0.92) and least in SP_C (6.18 ± 0.95), with an overall mean pH value (6.58 ± 0.00) that was below the range of 6.9-9, as recommended by Andem et al. [27]. Most of the mean monthly values were within the recommended range, except for February (6.17 ± 0.10), July (6.41 ± 0.01), August (6.55 ± 0.01), and October (6.29 ± 0.03) in SP_A; February (6.17 ± 0.10), July (6.41 ± 0.01), August (6.55 ± 0.01), and October (6.29 ± 0.03) in SP_B; and February (6.20 ± 0.00), July (6.26 ± 0.00), and August (6.27 ± 0.00) in SP_C.

Similarly, DO was highest in February, with 5.03 ± 0.03 mg/L, 5.02 ± 0.03 mg/L, and 5.04 ± 0.03 mg/L, and least in July and August in SP_A (3.10 ± 0.20 mg/L) and SP_B (3.10 ± 0.01 mg/L) and August in SP_C (3.08 ± 0.10 mg/L), with overall mean of 4.21 ± 1.12, 4.15 ± 0.99, and 4.21 ±1.14 mg/L in SP_A, SP_B, and SP_C, respectively. Lastly, ammonia had similar values of 0.03 mg/L across the sampling months, and the highest was observed in March (0.04 ± 0.00 mg/L) and November (0.04 ± 0.02 mg/L) for SP_B and SP_C, respectively. Mean values were 0.02 ± 0.01 mg/L, 0.02 ± 0.01 mg/L, and 0.02 ± 0.01 mg/L, respectively, for SP_A, SP_B, and SP_C, respectively. The DO is an important parameter that dictates the condition of living organisms in water. It can affect the growth and behaviour of fish species in aquatic environments, and its concentration decreases with increases in salinity, temperature, humidity, and algal blooms. Most of the monthly values were above the recommended range of 4.0 mg/L, as reported by United States Environmental Protection Agency [28], with the highest values in SP_A (4.21 ± 1.12 mg/L) and SP_C (4.21 ± 1.14 mg/L), and the least in SP_B (4.15 ± 0.99 mg/L). DO is very crucial to life processes, and it must be optimal for physiological activities [29,30]. The measurements in July and August in points SP_A (3.10 ± 0.20 and 3.10 ± 0.01 mg/L, respectively), SP_B (3.08 ± 0.00 and 3.12 ± 0.21 mg/L, respectively), and SP_C (3.12 ± 0.00 and 3.08 ± 0.10 mg/L, respectively) were below the recommended levels. They may be because of reduced temperature in these months, which coincides with the wet season [23,25,31].

Ammonia has a direct relationship with temperature, and it is a product of the decomposition of organic matter [32,33]. Their increased concentration in the aquatic environment inhibits DO, and levels below 0.05 mg/L are desirable [27]. Mean values and overall mean (0.02 ± 0.16 mg/L) were below the recommended level of 0.05 mg/L, which indicated less organic pollution in the water. In July and August, ammonia was not measured because of minimal agricultural, refuse, and sewage disposal and other human-induced activities, which could cause an increase in ammonia concentration around the reservoir catchment [27].

Months/Parameters	Temperature (°C)	pH	DO (mg/L)	Ammonia (mg/L)
December[1]	24.08 ± 0.08	7.03 ± 0.00	4.20 ± 0.11	0.03 ± 0.03
January[1]	23.00 ± 0.10	6.80 ± 0.00	4.33 ± 0.13	0.02 ± 0.00
February[1]	26.20 ± 0.01	6.60 ± 0.01	5.03 ± 0.03	0.03 ± 0.12
March[1]	25.00 ± 0.11	7.00 ± 0.00	4.77 ± 0.12	0.03 ± 0.00
April[2]	25.37 ± 0.21	7.01 ± 0.21	4.40 ± 0.14	0.03 ± 0.32
May[2]	25.86 ± 0.28	7.01 ± 0.00	4.73 ± 0.00	0.03 ± 0.01
June[2]	24.00 ± 0.10	7.03 ± 0.10	4.22 ± 0.00	0.01 ± 0.00
July[2]	17.10 ± 0.01	6.30 ± 0.30	3.10 ± 0.20	0.00 ± 0.00
August[2]	17.00 ± 0.00	6.25 ± 0.00	3.10 ± 0.01	0.00 ± 0.00
September[2]	21.10 ± 0.11	7.00 ± 0.00	4.31 ± 0.01	0.02 ± 0.01
October[2]	23.15 ± 0.03	6.20 ± 0.01	4.20 ± 0.05	0.02 ± 0.09
November[1]	23.41 ± 0.19	7.05 ± 0.10	4.08 ± 0.08	0.03 ± 0.11
Mean	22.94 ± 1.91	6.77 ± 0.02	4.21 ± 1.12	0.02 ± 0.01

TABLE 1: Mean and standard error of water quality parameters measured at SPA

[1] November–March (Dry Season). [2] April–October (Wet Season).
Mean values with different superscripts within a column are significantly different ($p < 0.05$).
DO, Dissolved Oxygen; SPA, Sampling Point A

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Months/Parameters	Temperature (°C)	pH	DO (mg/L)	Ammonia (mg/L)
December[1]	24.04 ± 0.10	7.04 ± 0.00	4.15 ± 0.11	0.03 ± 0.00
January[1]	23.08 ± 0.07	6.90 ± 0.10	4.27 ± 0.11	0.01 ± 0.10
February[1]	26.50 ± 0.01	6.17 ± 0.10	5.02 ± 0.03	0.03 ± 0.01
March[1]	25.30 ± 0.00	7.00 ± 0.10	4.75 ± 0.21	0.04 ± 0.00
April[2]	25.37 ± 0.11	7.04 ± 0.00	4.37 ± 0.14	0.03 ± 0.10
May[2]	25.86 ± 0.30	7.01 ± 0.00	4.67 ± 0.10	0.03 ± 0.32
June[2]	24.20 ± 0.02	7.02 ± 0.00	4.12 ± 0.02	0.01 ± 0.00
July[2]	17.60 ± 0.10	6.41 ± 0.01	3.08 ± 0.00	0.00 ± 0.00
August[2]	17.80 ± 0.00	6.55 ± 0.01	3.12 ± 0.21	0.00 ± 0.00
September[2]	22.22 ± 0.01	7.00 ± 0.00	4.11 ± 0.00	0.02 ± 0.00
October[2]	23.05 ± 0.02	6.29 ± 0.03	4.11 ± 0.02	0.01 ± 0.01
November[1]	23.21 ± 0.02	7.02 ± 0.02	4.04 ± 0.02	0.02 ± 0.01
Mean	23.19 ± 1.18	6.79 ± 0.92	4.15 ± 0.99	0.02 ± 0.01

TABLE 2: Mean and standard error of water quality parameters measured at SPB

[1] November–March (Dry Season). [2] April–October (Wet Season).
Mean values with different superscripts within a column are significantly different ($p < 0.05$).
DO, Dissolved Oxygen; SPB, Sampling Point B

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Months/Parameters	Temperature (°C)	pH	DO (mg/L)	Ammonia (mg/L)
December[1]	24.00 ± 0.00	7.03 ± 0.01	4.25 ± 0.11	0.03 ± 0.01
January[1]	23.03 ± 0.10	7.00 ± 0.00	4.30 ± 0.01	0.03 ± 0.00
February[1]	26.00 ± 0.01	6.20 ± 0.00	5.04 ± 0.03	0.03 ± 0.00
March[1]	25.20 ± 0.13	7.00 ± 0.00	4.79 ± 0.10	0.02 ± 0.01
April[2]	25.37 ± 0.03	7.02 ± 0.10	4.42 ± 0.14	0.03 ± 0.01
May[2]	25.86 ± 0.26	7.01 ± 0.01	4.79 ± 0.01	0.03 ± 0.02
June[2]	24.07 ± 0.01	7.02 ± 0.02	4.17 ± 0.01	0.01 ± 0.00
July[2]	17.20 ± 0.00	6.26 ± 0.00	3.12 ± 0.00	0.00 ± 0.00
August[2]	17.10 ± 0.02	6.27 ± 0.00	3.08 ± 0.10	0.00 ± 0.00
September[2]	23.10 ± 0.02	7.10 ± 0.00	4.20 ± 0.00	0.02 ± 0.01
October[2]	23.00 ± 0.00	6.36 ± 0.00	4.29 ± 0.00	0.03 ± 0.01
November[1]	23.19 ± 0.11	7.01 ± 0.00	4.12 ± 0.01	0.04 ± 0.02
Mean	23.09 ± 1.02	6.18 ± 0.95	4.21 ± 1.14	0.02 ± 0.01

TABLE 3: Mean and standard error of water quality parameters measured at SPC

[1] November–March (Dry Season). [2] April–October (Wet Season).
Mean values with different superscripts within a column are significantly different (p < 0.05).
DO, Dissolved Oxygen; SPC, Sampling Point C

Correlation of water quality parameters across the sampling points

The correlation coefficient (r) of water quality parameters across the sampling points is presented in Table 4. In SP_A, significant relationships (p<0.05) were observed between temperature and pH (r = 0.622, p = 0.03). For pH in SP_A, it was significant (p<0.05) with temperature (r = 0.622, p = 0.03) and ammonia (r = 0.640, p = 0.025) in SP_A, temperature (r = 0.638, p = 0.026) and ammonia (r = 0.669, p = 0.017) in SP_B, and temperature in SP_C (r = 0.683, p = 0.014). DO and ammonia in SP_C were significantly different (p<0.05) (r = 0.698, p = 0.012). A negative relationship was observed only between pH in SP_A and pH in SP_C (r = –0.044).

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In SP_B, significant differences ($p<0.05$) were observed between temperature and pH in SP_A ($r = 0.638$, $p = 0.026$). Significant differences ($p<0.05$) were observed between DO and ammonia in SP_C ($r = 0.696$, $p = 0.012$). For ammonia, significant relationships ($p<0.05$) were observed with pH in SP_A ($r = 0.669$, $p = 0.017$) and ammonia in SP_C ($r = 0.505$, $p = 0.037$). A negative relationship was observed between pH in SP_B and pH in SP_C ($r = -0.028$).

In SP_C, significant differences ($p<0.05$) were observed between temperature and pH in SP_A ($r = 0.683$, $p = 0.014$). Ammonia was significantly different ($p<0.05$) with DO in SP_A ($r = 0.698$, $p = 0.012$), DO in SP_B ($r = 0.696$, $p = 0.012$), and ammonia in SP_B ($r = 0.605$, $p = 0.037$). A negative relationship was observed between pH in SP_C and pH in SP_B ($r = -0.044$), and pH in SP_A ($r = -0.028$).

From the correlation coefficient analysis, a high and significant correlation ($p<0.05$) was observed between temperature and pH, pH and ammonia in SP_A, pH in SP_A and temperature and ammonia in SP_B, pH in SP_A and temperature in SP_C, DO in SP_A and ammonia in SP_C, and ammonia and pH in SP_A. The correlation was high because the r-values are between 0.61 and 0.8, as reported by BMJ [34]. Seasonal relationship between water quality parameters expressed higher values in the dry season (from November to March) than in the wet season, which extended from April to October. Significant relationships ($p<0.05$) were observed between the temperature and DO values in both seasons, as expressed by the t-test analysis. The increased temperature is expected as a peculiar characteristic of the dry season [23].

Similarly, DO and pH are expected to increase due to the increased photosynthetic activity generated by the increased temperature. During the dry season, the reservoir serves as a source of water for irrigation and cattle, which were observed during the study. Run-offs from farmlands and cattle dung may be potential causes of increased ammonia during this period [22,30,32], coupled with the low level of water in the reservoir due to low rainfall. Conversely, the low levels of mean water quality values observed in the wet season may be because of the dilution created by increased rains, which is peculiar to the wet season [27].

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		Sampling Point A				Sampling Point B				Sampling Point C			
Parameters		Temp	pH	DO	Ammonia	Temp	pH	DO	Ammonia	Temp	pH	DO	Ammonia
Temp	r-value	1	0.622	0.935	0.88	0.994	0.306	0.942	0.811	0.981	0.282	0.949	0.765
	p-value		0.031	0	0	0	0.333	0	0.001	0	0.375	0	0.004
pH	r-value	0.622	1	0.569	0.64	0.638	0.878	0.546	0.669	0.683	-0.044	0.542	0.476
	p-value	0.031		0.054	0.025	0.026	0	0.066	0.017	0.014	0.892	0.069	0.118
DO	r-value	0.935	0.569	1	0.848	0.96	0.218	0.995	0.821	0.964	0.019	0.996	0.698
	p-value	0	0.054		0	0	0.496	0	0.001	0	0.952	0	0.012
Ammonia	r-value	0.88	0.64	0.848	1	0.874	0.365	0.855	0.898	0.885	0.119	0.869	0.894
	p-value	0	0.025	0		0	0.244	0	0	0	0.713	0	0
Temp	r-value	0.994	0.638	0.96	0.874	1	0.31	0.963	0.833	0.992	0.198	0.967	0.733
	p-value	0	0.026	0	0		0.327	0	0.001	0	0.536	0	0.007
pH	r-value	0.306	0.878	0.218	0.365	0.31	1	0.19	0.4	0.367	-0.028	0.193	0.252
	p-value	0.333	0	0.496	0.244	0.327		0.553	0.198	0.24	0.932	0.547	0.429
DO	r-value	0.942	0.546	0.995	0.855	0.963	0.19	1	0.835	0.957	0.093	0.996	0.696
	p-value	0	0.066	0	0	0	0.553		0.001	0	0.774	0	0.012
Ammonia	r-value	0.811	0.669	0.821	0.898	0.833	0.4	0.835	1	0.836	0.07	0.831	0.605

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	p-value	0.001	0.017	0.001	0	0.001	0.198	0.001		0.001	0.829	0.001	0.037
Temp	r-value	0.981	0.683	0.964	0.885	0.992	0.367	0.957	0.836	1	0.101	0.966	0.749
	p-value	0	0.014	0	0	0	0.24	0	0.001		0.756	0	0.005
pH	r-value	0.282	-0.044	0.019	0.119	0.198	-0.028	0.093	0.07	0.101	1	0.08	0.143
	p-value	0.375	0.892	0.952	0.713	0.536	0.932	0.774	0.829	0.756		0.805	0.657
DO	r-value	0.949	0.542	0.996	0.869	0.967	0.193	0.996	0.831	0.966	0.08	1	0.725
	p-value	0	0.069	0	0	0	0.547	0	0.001	0	0.805		0.008
Ammonia	r-value	0.765	0.476	0.698	0.894	0.733	0.252	0.696	0.605	0.749	0.143	0.725	1
	p-value	0.004	0.118	0.012	0	0.007	0.429	0.012	0.037	0.005	0.657	0.008	

TABLE 4: Correlation coefficient of water quality parameters across the sampling points

Correlation is significant when $p \leq 0.05$ (2-tailed); $n = 36$
DO, Dissolved Oxygen

Seasonal water quality parameters and paired t-test analysis

The seasonal mean values and paired t-test analysis for water quality parameters are presented in Table *5*. The dry season had the highest values for temperature (22.35°C), pH (6.86), DO (4.48 mg/L), and ammonia (0.03 mg/L). The results of the paired t-test analysis showed significant relationships ($p<0.05$) between the pairs of wet and dry season temperature ($p = 0.04$) and wet and dry season ammonia ($p = 0.00$), with mean values of -2.01 ± 0.87 and -0.01 ± 0.00. The negative t-values indicated that the mean values are less than the comparison values. The significant seasonal differences in temperature and ammonia observed indicated poorer water quality in the dry season, which may negatively affect fish abundance due to increased ammonia toxicity.

Pairs	Mean	Standard Error Mean	n	
Temperature (WS)	22.34	0.21	36	
Temperature (DS)	22.35	0.12	36	
pH (WS)	6.74	0.01	36	
pH (DS)	6.86	0.03	36	
Dissolved Oxygen (WS)	4.00	0.12	36	
Dissolved Oxygen (DS)	4.48	0.03	36	
Ammonia (WS)	0.02	0.00	36	
Ammonia (DS)	0.03	0.01	36	
t-test Pairs	**Mean**	**Standard Error Mean**	**t**	**P-value**
WS & DS Temperature	-2.01	0.87	-2.31	0.04*
WS & DS pH	-0.11	0.14	-0.81	0.43
WS & DS Dissolved Oxygen	-0.47	0.17	-2.81	0.14
WS & DS Ammonia	-0.01	0.00	-3.38	0.00*

TABLE 5: Seasonal and paired t-test results of water quality parameters

n = 36; t indicates independent t-test value.
WS, Wet Season; DS, Dry Season
*Statistical significance at $p < 0.05$

PCA of water quality variables

The Eigen analysis of the correlation matrix is presented in Table *6*, and the biplot for PC1 and PC2 is shown in Figure *2*. The first principal component (PC1) had an eigenvalue of 2.7381 and a variance of 68.5%, with positive values for temperature (0.585), pH (0.130), DO (0.581), and ammonia (0.551). The second principal component (PC2) had an eigenvalue of 0.9715 and a variance of 24.3%, with a negative value for pH (–0.990), while others were positive. PC1 and PC2 accounted for 92.8% of the total variability and were chosen.

From the PCA eigenvalues, it was observed that PC1 (68.5%) and PC2 (24.3%) accounted for 92.8% of the total data variability. The PC1 represented the most variation in water quality data, while the PC2 represented the second most variation in data. In PC1, it was observed that the temperature (0.585), pH (0.130), and DO (0.581) measures had a positive coefficient, which indicated that these water quality variables are positively associated with the first principal component. Temperature and pH had strong positive contributions to PC1 because their values were relatively high, while pH had a weak positive contribution because the loading was small. The negative coefficient observed for ammonia (–0.551) indicated a moderate negative contribution to the PC1. These conditions of temperature, DO, and pH are generally favorable for fish survival, as higher DO and lower ammonia concentrations can reduce stress and support better physiological performance in fish. Therefore, fish species abundance and distribution in the reservoir are likely positively associated with PC1. In contrast, the high ammonia levels and their negative loading on PC1 may indicate poorer water quality and could negatively affect fish abundance.

The PC2 (24.3%), which is strongly influenced by pH (–0.990), suggests that variations in pH also play a role in determining the distribution of fish in the reservoir, although to a lesser extent than the variables in PC1. Overall, the dominance of PC1 and PC2 with cumulative variance of 92.8% indicates that these key water quality parameters are major drivers influencing fish species abundance in the reservoir.

The multiple linear regression analysis (Equation 4) showed that PC1 had a significant positive effect on fish abundance (b_1 = 1.35, $p<0.05$), which indicated that fish distribution is strongly influenced by the water quality gradient. PC2 had a positive but non-significant effect (b_2 = 0.54, $p>0.05$). The model explained a high proportion of the variance in fish abundance (R^2 = 0.78), which suggests that variations in water quality parameters summarized by PCA are key determinants of fish abundance.

$$\mathrm{Fish} = 2.00 + 1.35(\mathrm{PC1}) + 0.54(\mathrm{PC2}) \tag{4}$$

Variable	PC1	PC2	PC3	PC4
Temperature	0.585	0.073	-0.371	-0.718
pH	0.130	-0.990	-0.037	0.025
Dissolved Oxygen	0.581	0.109	-0.408	0.695
Ammonia	-0.551	0.042	0.833	0.023
Eigen Value	2.7381	0.9715	0.2421	0.0483
Proportion	0.685	0.243	0.061	0.012
Cumulative	0.685	0.927	0.988	1.000

TABLE 6: Eigen analysis values for correlation matrix of water quality parameters

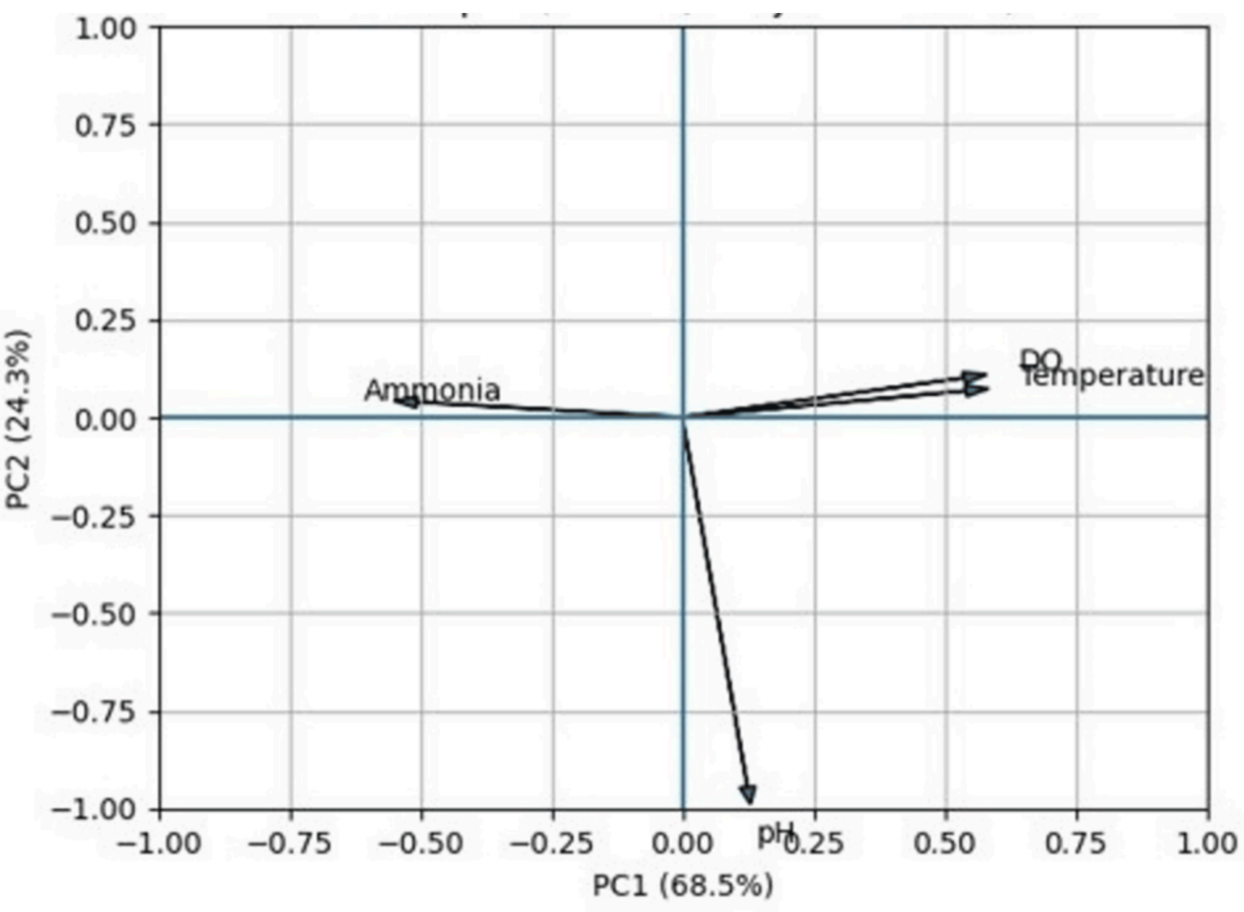

FIGURE 2: Biplot of the first and second components for water quality parameters

Fish abundance

Fish Abundance by Months

The fish abundance across the sampling months during the study is presented in Table *7*. A total of 1,279 individuals belonging to 5 families and 9 species were identified during the study, while 664 individuals belonging to 10 families and 16 species were reported by Taiwo [13]. During the study, family Cichlidae was the most abundant (60.28%) and comprised four species (*Coptodon zillii* was the highest with 17.57% and *Sarotherondon galileaus* was the least with 12.12%), while Taiwo [13] reported 69.27% of Cichlids comprising seven species (*C. mariae* was the highest with 17.02% and *Chromidotilapia guentheri* the least with 1.51%). *C. guentheri*, *C. dageti*, and *Hemichromis fasciatus* were not encountered during the study. The least family observed during the study was Centropomidae (1.88%) with 1 species (*Lates niloticus*), while families Anabantidae (0.15%) and Cyprinidae (0.15%) with one species each (*Ctenopoma nebulosum* and *Barbus leonensis*, respectively) were reported in the previous study.

Both *C. nebulosum* and *B. leonensis* were not encountered during the present study, while *L. niloticus* was not observed in the previous study. *Coptodon zilli and L. niloticus* were the most (17.59%) and least (1.88%) abundant fish species during the study, while *C. mariae* was the most abundant (17.02%), and *C. nebulosum and B. leonensis* were the least abundant (0.15%) in the study by Taiwo [13]. Generally, 12 species were not encountered in the present study but in the previous [13], namely: *Brycinus longipinnis, C. nebulosum, Parachanna obscura, C. dageti, H. fasciatus, C. guentheri, Clarias gariepinus, B. leonensis, Hepsetus odoe, Marcusenius senegalensis, Pollimyrus isidori*, and *Schilbe intermedius*, while three species, namely *Alestes baremose, Hydrocynus forskalhi,* and *L. niloticus*, were encountered in the present

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study and not in the previous study. Six species, namely *Chrysichthys nigrodigitatus, C. zillii, C. mariae, Oreochromis niloticus, S. galileaus,* and *Mormyrus rume*, were encountered in both studies. During the study, the highest monthly relative abundance was observed in February (11.81%), while the lowest was recorded in August (2.35%).

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Species	Dec (2021)	Jan (2022)	Feb (2022)	Mar (2022)	Apr (2022)	May (2022)	June (2022)	Jul (2022)	Aug (2022)	Sept (2022)	Oct (2022)	Nov (2022)	Total	Taiwo [13]	Total (%)	Taiwo [13]
Alestidae																
Alestes baremose	19	16	21	17	14	8	7	9	9	8	5	11	144	NE	11.26	NE
Brycinus longipinnis	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	23	NE	3.46
Hydrocynus forskalhi	9	8	15	11	9	8	5	2	2	7	6	11	93	NE	7.27	NE
Total*	28	24	36	28	23	16	12	11	11	15	11	22	237	23	18.53	3.46
Anabantidae																
Ctenopoma nebulosum	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	1	NE	0.15

Bagridae																
Chrysichthys nigrodigitatus	21	21	41	18	20	16	17	6	6	13	11	15	205	61	16.03	9.19
Centropomidae																
Lates niloticus	3	5	2	7	5	NE	NE	NE	NE	NE	NE	2	24	NE	1.88	NE
Channidae																
Parachanna obscura	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	4	NE	0.60
Cichlidae																
Chromidotilapia guentheri	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	10	NE	1.51

Coptodon mariae	16	21	5	28	18	19	14	9	6	11	14	9	170	113	13.29	17.02
Coptodon zillii	22	20	35	19	21	29	19	9	4	11	20	16	225	59	17.59	8.88
Coptodon dageti	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	90	NE	13.55
Hemichromis fasciatus	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	54	NE	8.13
Oreochromis niloticus	23	22	30	25	20	19	16	8	1	19	20	18	221	22	17.28	3.31
Sarotherodon galileaus	18	16	1	21	19	17	17	8	1	13	15	9	155	112	12.12	16.87
Total*	79	79	71	93	78	84	66	34	12	54	69	52	771	460	60.28	69.27
Clariidae																

Clarias gariepinus	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	3	NE	0.45
Cyprinidae																
Barbus leonensis	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	1	NE	0.15
Hepsetidae																
Hepsetus odoe	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	16	NE	2.41
Mormyridae																
Marcusenius senegalensis	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	17	NE	2.56
Mormyrus rume	6	4	1	2	4	2	3	2	1	5	7	5	42	2	3.28	0.30
Pollimyrus	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	9	NE	1.35

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isidori																
Total*	6	4	1	2	4	2	3	2	1	5	7	5	42	28	3.28	4.21
Schilbeidae																
Schilbe intermedius	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	67	NE	10.19
Total**	137	133	151	148	130	118	98	53	30	87	98	96	1279	664	100	100
Relative total (%)	10.71	10.40	11.81	11.57	10.16	9.23	7.66	4.14	2.35	6.80	7.66	7.51	100			

TABLE 7: Fish abundance during the study period in comparison with a previous study

Total * refers to total fish species within each family.
Total ** refers to the overall total within each family.
NE, Not Encountered

Fish Abundance Per Sampling Point

Overall, SP_A recorded the most abundant species of *C. nigrodigitatus* (50.7%), *L. niloticus* (45.8%), *C. mariae* (49.4%), *C. zillii* (47.6%), *O. niloticus* (50.7%), *S. galileaus* (51.0%), and *M. rume* (42.9%), SP_B was highest for *H. forskalii* (44.1%), while SP_C recorded the highest relative abundance for only *A. baremoze* (37.5%). For each species, *A. baremoze* was highest in SP_C (37.5%) and least in SP_A (26.4%), *H. forskalh*i was highest in SP_B (44.1%) and least in SP_C (24.7%), *C. nidrogidigatus* was highest in SP_A (50.7%) and least in SP_C (22.9%), *L. niloticus* was highest in SP_A (45.8%) and least in SP_C (20.8%), *C. mariae* was highest in SP_A (49.4%) and least in SP_B (24.1%), *C. zillii* was highest in SP_A (47.6%) and least in SP_C (14.2%), *O. niloticus* was highest in SP_A (50.7%) and least in SP_C (14.9%), *S. galileaus* was highest in SP_A (51.0%) and least in SP_C (18.1%), and *M. rume* was highest in SP_A (42.9%) and least in SP_C (26.2%).

Fish Abundance and Water Quality Parameters

The Pearson correlation coefficients (r) between fish abundance and water quality parameters are presented in Table *8*, and the corresponding p-values were not statistically significant (p>0.05). Fish abundance showed correlations of 0.891 with temperature, −0.191 with pH, 0.896 with DO, and 0.855 with ammonia. Similarly, temperature exhibited correlation coefficients of −0.095 with pH, 0.957 with DO, and 0.887 with ammonia. The correlation coefficients for pH were −0.226 with DO and 0.016 with ammonia. DO and ammonia had an r-value of 0.856. Pearson correlation presents the strength of the relationship between the variables measured. As observed from the analysis, a very high relationship was observed between most of the variables measured during the study. Fish abundance showed very high correlations with temperature (r = 0.891), DO (r = 0.896), and ammonia (r = 0.855). Similarly, temperature was highly correlated with DO (r = 0.957) and ammonia (r = 0.887), while DO also showed a strong correlation with ammonia (r = 0.856). These relationships were considered very strong because the r-values ranged between 0.8 and 1.0. However, these correlations were not statistically significant [35]. On the other hand, the relationships between fish abundance and pH (r = −0.191), temperature and pH (r = −0.095), and pH and ammonia (r = 0.016) were very weak, as the r-values ranged between 0.01 and 0.2. The negative correlations between fish abundance and pH, as well as between temperature and pH, indicate that a decrease in pH corresponds to increasing acidity of the water. Such conditions may make the environment less suitable for aquatic life [36].

Parameters	**Fish Abundance**	**Temperature (°C)**	**pH**	**Dissolved Oxygen (mg/L)**
Temperature (°C)	0.891			
pH	-0.191	-0.095		
Dissolved Oxygen (mg/L)	0.896	0.957	-0.226	
Ammonia (mg/L)	0.855	0.887	0.016	0.856

TABLE 8: Pearson correlation between fish abundance and water quality parameters

n = 36
Not statistically significant at p > 0.05.

LWR of fish species

The LWR of some fish species encountered during the study is presented in Table *9*. The LWR expresses the relationship between two variables, i.e., length and weight, which can provide information about the wellness, fatness, well-being, and environmental suitability for the fish [21]. A significant relationship (p<0.05) was observed between *S. galileaus* (p = 0.00) and *A. baremose* (p = 0.01). The regression coefficients (b) for the LWR were *O. niloticus* (b = 2.73), *C. zilli* (b = 2.65), *S. galileaus* (b = 2.85), *C. mariae* (b = 2.62), *A. baremose* (b = 2.87), and *C. nigrodigitatus* (b = 2.70). The coefficient of variation (R^2), which describes the magnitude of the relationship between length and weight for the species, was 0.22 for *O. niloticus*, 0.19 for *C. zilli*, 0.23 for *S. galileaus*, 0.21 for *C. mariae*, 0.13 for *A. baremose*, and 0.12 for *C. nigrodigitatus*. A negative allometric growth pattern was observed for all the fish species because the b-values were less than 3, as reported by Le Cren [21]. These b-values of the growth exponent (b) less than 3 indicate negative allometric growth, suggesting that the fish increases in length at a faster rate than in body weight. Positive allometric and isometric growth patterns are exhibited by fish species with b-values greater than 3 and equal to 3, respectively [21].

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Fish Species	a	b	p-value	R^2 value	Growth Pattern
Oreochromis niloticus	1.22	2.73	0.81	0.22	Negative allometry
Coptodon zillii	1.44	2.65	0.16	0.19	Negative allometry
Sarotherodon galileaus	1.62	2.85	0.00*	0.23	Negative allometry
Coptodon mariae	1.48	2.62	0.65	0.21	Negative allometry
Alestes baremose	1.26	2.87	0.01*	0.13	Negative allometry
Chrysichthys nigrodigitatus	1.37	2.70	0.07	0.12	Negative allometry

TABLE 9: The length-weight relationship of some abundant fish species during the study period

In the table, a is the constant, b is the regression coefficient, p is the probability value for the length-weight relationship, and R^2 is the coefficient of determination.
*Statistical significance at $p < 0.05$.

Condition factor of fish species

The condition factor (K) for the fish species calculated during the study is presented in Table *10*. *Oreochromis niloticus* had the highest value (2.12 ± 0.14), followed by *C. mariae* (2.08 ± 0.11), *A. baremoze* (1.92 ± 0.02), *C. zillii* (1.32 ± 0.01), *C. nigrodigitatus* (1.21 ± 0.20), *S. galilaeus* (1.12 ± 0.20), *H. forskalii* (0.97 ± 0.21), and *M. rume* (0.81 ± 0.12), while the lowest value was recorded for *L. niloticus* (0.76 ± 0.14). The K values calculated for all the fish species ranged between 0.76 and 2.12. The values calculated for most species (*A. baremose*, *C. mariae*, *C. nigrodigitatus*, *C. zillii*, *O. niloticus*, and *S. galileaus*) were greater than 1, indicating that these fish are in good physiological condition. This suggests favorable environmental conditions and adequate food availability despite the negative allometric growth pattern ($b < 3$). *H. forskalii*, *L. niloticus*, and M. rume showed values less than 1, which indicates they are experiencing suboptimal environmental conditions [21].

Fish Species	Condition Factor ± Standard Error
Alestes baremose	1.92 ± 0.02
Coptodon mariae	2.08 ± 0.11
Chrysichthys nigrodigitatus	1.21 ± 0.20
Coptodon zillii	1.32 ± 0.01
Hydrocynus forskalhi	0.97 ± 0.21
Lates niloticus	0.76 ± 0.14
Mormyrus rume	0.81 ± 0.12
Oreochromis niloticus	2.12 ± 0.14
Sarotherondon galileaus	1.12 ± 0.20

TABLE 10: The condition factor of fish species encountered during the study

n = 36

Conclusions

It was observed from the study that the reservoir has great potential to sustain fish species, and it was evident by the increased fish abundance when compared with the previous study on the reservoir. The findings highlight that key water quality parameters, including temperature, DO, pH, and ammonia, are fundamental in regulating fish metabolism, survival, and distribution, and thus exert a strong influence on fish production. PCA showed that the main environmental gradient, driven by temperature, DO, pH, and ammonia, explained most of the variation. Regression analysis indicated that this gradient had a significant effect on fish abundance, with higher DO and moderate temperature enhancing fish production, while ammonia had negative effects. These findings confirm that key water quality parameters regulate fish survival and productivity, justifying their assessment in this study. The number of families and species of fish was reduced. Cichlids were observed to be the most abundant with high diversity. *C. zilli* was the most abundant species, and the peak abundance was observed in the dry season. Generally, all the sampled fish species exhibited a negative allometric growth pattern. Similarly, the water quality parameters were within the recommended ranges, which posed good conditions for fish species to thrive. Hence, the environment is suitable for fish species, and conscious efforts must be geared towards maintaining this condition.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Adams O. Iyiola, Yetunde F. Taiwo, Mabel O. Ipinmoroti

How to cite this article:
Iyiola A O, Taiwo Y F, Ipinmoroti M O (April 10, 2026) Influence of Selected Water Quality Parameters on Fish Species Abundance in Eko-Ende Reservoir, Nigeria. Curues J. Agri. Food Sci 2 : es44497-025-00047-8. DOI https://doi.org/10.7759/s44497-025-00047-8

Acquisition, analysis, or interpretation of data: Adams O. Iyiola

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Critical review of the manuscript for important intellectual content: Adams O. Iyiola, Yetunde F. Taiwo, Mabel O. Ipinmoroti

Supervision: Adams O. Iyiola

Disclosures

Plant subjects: All authors have confirmed that this study did not involve any herbarium specimen. **Human subjects:** All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** The study involves the use of animal subjects, The permission for handling fish species from reservoir was waived ethics committee, protocol no The permission for handling fish species from reservoir was waived . **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statements

The datasets (and/or code) supporting this study are available from the corresponding author upon reasonable request.

Acknowledgements

I would like to appreciate the painstaking efforts of the fishermen who assisted in fish identification and gear operations. This study is not an extension of a previous paper.

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How to cite this article:
Iyiola A O, Taiwo Y F, Ipinmoroti M O (April 10, 2026) Influence of Selected Water Quality Parameters on Fish Species Abundance in Eko-Ende Reservoir, Nigeria. Curues J. Agri. Food Sci 2 : es44497-025-00047-8. DOI https://doi.org/10.7759/s44497-025-00047-8

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