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Influence of Physico-Chemical and Nutrient Parameters on Fish Occurrence and Community Structure in Nguru Lake, Yobe State, Nigeria

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Abstract The present study evaluates the influence of physico-chemical and nutrient parameters on fish community structure and occurrence in Nguru Lake, Yobe State, Nigeria, over a one-year period (January-December, 2022). Fish and water samples were collected monthly, from three randomly selected locations (Badum, Azur, and Farin Ruwa) in the lake. Physico-chemical parameters such as pH, temperature, dissolved oxygen, turbidity, electrical conductivity, and key nutrients (nitrate, nitrite, phosphorus, potassium, and ammonia) were measured in triplicate using standard procedures. Fish species composition was presented using descriptive statistics, while diversity was analyzed using biological indices, including the Shannon-Weiner, Species Evenness, and Margalef's Indices. The data obtained from the fish and water samples were further explored through Principal Components Analysis (PCA) and Canonical Correspondence Analysis (CCA) to evaluate the impact of environmental variables on fish distribution. The results of the physico-chemical parameters showed fluctuating values, though they are within the range for optimal fish growth, likewise the values of the analyzed nutrients. A total of 2654 individuals belonging to 51 fish species and 18 families, dominated by Cichlidae, which recorded 1,459 individual fish, representing 54.97%, were observed. Diversity indices indicated a moderately diverse and stable ecosystem, although elevated nutrient concentrations, particularly nitrogen and phosphorus, suggested potential stressors. CCA revealed significant correlations between nutrient levels and fish species distribution, indicating that nutrient levels, particularly nitrogen and phosphorus, play a critical role in shaping fish community dynamics. The findings highlight the need for sustainable lake management practices to conserve biodiversity and support fisheries productivity.

Keywords Aquatic Ecosystem, Fish Diversity, Nutrient Dynamics, Species Composition, Water Quality

1. Introduction

Fisheries play a vital role in global food security, serving as a key protein source and providing economic opportunities for numerous populations worldwide [1,2,3]. Additionally, fish and fishery products contribute the vast majority of the protein intake for over 400 million people in the poorest countries of Africa and Asia [4], and more so, wild capture of freshwater fish remains a vital source of income for rural livelihoods [5], and thus is regarded as a major way of combating food insecurity and poverty for many tropical forest-dwelling rural communities [5]. However, fish populations have experienced significant declines due to various challenges, such as overfishing, pollution, and habitat alteration from activities like dam construction [6]. Human activities, including pollution, eutrophication, and fishing, negatively affect the biodiversity of aquatic ecosystems [6,7], further exacerbating these declines.

Freshwater ecosystems, such as lakes, wetlands, and rivers, are home to various aquatic macrophytes that create habitats and support biodiversity for many fish species [8]. However, the degradation of these environments due to damming, pollution, and nutrient enrichment has had adverse effects on both aquatic plants and animals, threatening the ecological balance. For instance, in Nguru Lake, Nigeria, eutrophication, driven by nutrient overloads, often leads to the proliferation of non-native aquatic plants, altering fish species composition and reducing overall biodiversity in the riparian systems [9]. The growth of aquatic organisms, especially fish in any aquatic ecosystem including Nguru Lake, depends mainly on the physico-chemical parameters of that water body [10], because fish are poikilothermic animals and thus their metabolic activities rely solely on the conditions of their environment [11]. Therefore, water quality parameters, such as temperature, dissolved oxygen, pH, and nutrient levels, significantly impact fish productivity, both in temporal and spatial distribution; hence, several studies report seasonal variation and differences among stations in fish community structure [9,12,13]. Efficient management practices that preserve water quality are crucial to sustaining fish populations since fish help assess the health of aquatic ecosystems, particularly by correlating fish occurrence with water quality [14].

Varying aspects of the ecology of Nguru Lake have been recorded by previous researchers, including Abubakar et al. [15] who assessed the effects of physico-chemical factors on seasonal dynamics of phytoplankton. Abubakar et al. [16] assessed the association between benthic invertebrates and aquatic macrophytes. Moreover, Abubakar [9] also assessed the impact of emergent macrophytes on fish catch. However, there is a paucity of information on the relationship between the physico-chemical, nutrient parameters, and fish distribution of the lake. Understanding fish species composition, diversity, abundance, and relationship with physico-chemical parameters is therefore very essential for effective management, particularly in freshwater bodies where industrialization, urbanization, and agricultural activities heavily influence fish diversity and ecosystem health [17]. Therefore, this study evaluated the physico-chemical, nutrient parameters, and fish community structure of Nguru Lake, with a focus on understanding how these parameters influence fish distribution.

2. Materials and Methods

2.1. Study Area

The study was carried out in Nguru Lake, Yobe State, located in the North-eastern part of Nigeria at the border between Nigeria and the Niger Republic, about 300 km from Lake Chad. Nguru Lake is part of the Hadejia-Nguru wetland that falls within latitudes 12°48'N to 12°52'N and longitudes 10°26'N to 10°30'N, upstream of the confluence of the wetlands with an elevation of 343m to 342m above sea level. It has an area of 58,100 hectares and is bordered by a floodplain that contains a network of canals and pools. The Lake has a water capacity of 58 million cubic meters, which is essential for more than 500,000 people, mostly for water supply [9]. The Marma channel of the Lake has an average depth of 2.5 meters, although its deepest point reaches 7 meters at the height of floods in very rainy years. There is minimal variation in the depth, topography, and temperature across the different parts of the dam, with the highest depth towards the middle of the water body.

Three locations were selected randomly for the assessment of fish and water quality and nutrient parameters. The selected locations are: Badum, Azur, and Farin Ruwa with geo-coordinates of latitudes 12°48'N to 12°52'N and longitudes 10°26'E to 10°30'E with elevations of 342m to 343m above sea level (Figure 1). The stations were mapped out with a global positioning system (GPS) “Garmin eTrex 10” receiver.

Figure 1. Map of Nguru Lake Showing Sampling Locations

2.2. Physico-Chemicals Analysis

The physico-chemical and nutrient parameters were measured in the field in triplicate. The parameters that were measured *in situ*, including water temperature (WTM), atmospheric temperature (ATM), pH, Alkalinity, hardness, and electrical conductivity (EC), were measured with a multi-parameter digital probe (EZ9900SP), while dissolved oxygen was measured with the use of a dissolved oxygen meter (DO9100**)**, and transparency was measured with the Secchi disk.

2.3. Minerals and Nutrients Analysis

Nutrient analyses were carried out with water samples in triplicate from the three (3) locations, for ammonia, nitrate, nitrite, total nitrogen, phosphate-phosphorus, and potassium, and they were analysed with the spectro-photometric method using an Atomic Absorption Spectrophotometer (Bulk Scientific USA Model: 210 VGP) [18]. Magnesium and calcium were analysed using flame-photometric (Jenway UK MODEL: PFP7 Flame Photometer) fortnightly for twelve (12) months, and the samples were analysed at Yobe State University Chemistry Research Laboratory.

2.4. Fish Sampling and Identification

Fish sampling was carried out once a month, with the help of two fishermen per site using gillnet, Malian and Ndurutu traps with a minimum of 2 inches (5.1 cm) mesh sizes, hooks and lines, and clap nets. The fish were assessed immediately on the spot, after landing in the early morning (6:00 a.m – 7:00 a.m) and late evening (5:00 pm – 6.00 pm). They were arranged, sorted, enumerated, and moved to the laboratory of the Department of Biology, Yobe State University, where they were identified according to their family, species, and the number of individuals for each species was recorded. The identities of the specimens were determined through keys and descriptions in the existing fish identification guide of Olaosebikan and Raji [19] and a software application, fish identifier, with the aid of an Android phone.

2.5. Fish Species Community Structure

The different biological indices were used, the ecosystem diversities were evaluated, and the number of species present was also determined. Distribution and relative abundance indicate the presence/absence of stressors for each biological index with the following formulae or equations as described by [20,21].

Shannon-Weiner Index

$$H' = -\ \Sigma Pi Log Pi$$

Whereas, $Pi = \frac{ni}{N}$

H = Shannon-Wiener information index

Σ = Summation

Pi = Observed proportion of individuals that belong to the species

Log = Logarithm

Species Evenness Index

$$J = \frac{H}{\log\ S}$$

J = equitability measure

H = Shannon Wiener Information Index

S = the Number of species in the sample

Margalef's Index

$$d = \frac{S\ -\ 1}{\text{Log}_e\ \text{N}}$$

Where d = Diversity index

S = the Number of species

N = Number of individuals

Log_e = Natural logarithm

2.6. Data Analysis

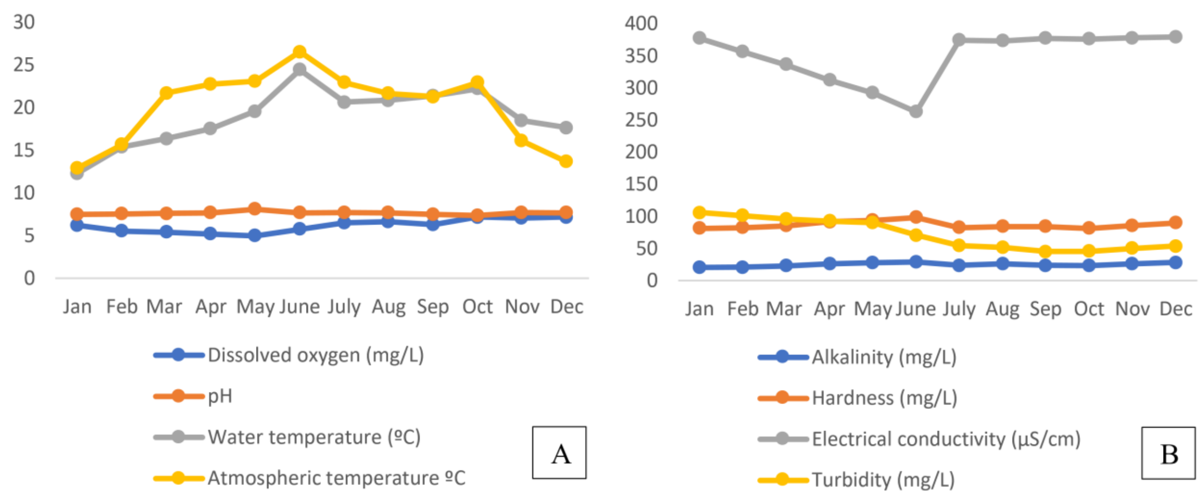
Descriptive statistics of physico-chemical parameters and fish species composition were done using Microsoft Excel (Office 365, Microsoft Corp., Berkshire, UK). Principal components analysis (PCA) was used to achieve data reduction, and this was performed using IBM SPSS, Version 29.0 (IBM Corp., Chicago, IL, USA) to reduce variable numbers in the dataset by clustering highly correlated variables into factors while retaining variability. Canonical Correspondence Analysis (CCA) was used to assess the influence of physico-chemical and nutrient parameters on fish species composition, using PAST software Version 4.03 [22].

3. Results

3.1. Trend in Physico-Chemical and Nutrient Parameters

The results of the physico-chemical parameters showed that dissolved oxygen (DO) levels were high (7.2 mg/L) in the months of October and December, while the lowest (4.9 mg/L) was observed in May (Figure 2A). The pH was found to have peaked in May (8.1), with the lowest value (7.5) recorded in January. The morning water temperature was highest (26.55 ℃) in June and lowest (12.94 ℃) in January, with atmospheric temperatures following a similar pattern, peaking at 26.60 ℃ in June and reaching a low of 12.94 ℃ in January. Alkalinity was at its highest (28.89 mg/L) in September, and the lowest value (20.55 mg/L) was recorded in January (Figure 2B). Water hardness reached a maximum of 97.56 mg/L in June, and the lowest value (81.44 mg/L) was recorded in October. Electrical conductivity showed the highest value (379.44 µS/cm) in December and the lowest (262.67 µS/cm) in June (Figure 2B). Water transparency was greatest in January (67.89 cm) and lowest in September (27.78 cm).

Potassium concentrations were highest (2.40 mg/L) in February and lowest (1.15 mg/L) in March. The highest magnesium concentration (19.16 mg/L) was recorded in February, while the lowest (9.16 mg/L) was recorded in March. Calcium levels were consistently high (1.17 mg/L) in both July and August, with the lowest concentration (0.19 mg/L) reported in March (Figure 2C). For ammonia (NH_3), the highest concentration (1.47 mg/L) was recorded in June, while the lowest (1.27 mg/L) was in October (Figure 2D). Nitrite (NO_2) levels peaked in February (0.54 mg/L) and dropped to their lowest (0.12 mg/L) in November. Nitrate (NO_3) levels were highest (41.86 mg/L) in February and reached their lowest (20.13 mg/L) in March. Nitrogen levels also followed a similar pattern, with the highest concentration (16.04 mg/L) recorded in February and the lowest (7.72 mg/L) in March. Phosphorus level was highest in February at 53.45 mg/L and dropped to its lowest (25.72 mg/L) in March (Figure 2D).



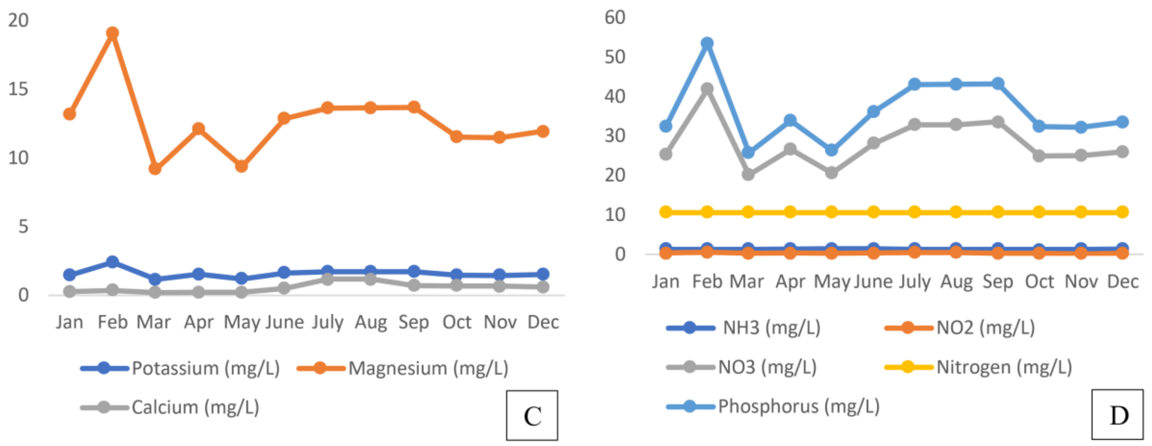


Figure 2. Monthly variation of physico-chemical and Nutrient parameters in Nguru Lake from January to December 2022. NO_3 – Nitrate, DO – dissolved oxygen, NO_2 – nitrite, WTM – water temperature in the morning, ATM – Air temperature in the morning, NH_3 – ammonia

Table 1. Fish Abundance in Nguru Lake by species and family

Family	Species	Count	Abundance (%)
Distichodontidae	*Distichodus rostratus*	45	1.70
		45	**1.70**
Shilbeidae	*Schilbei mystus*	50	1.89
		50	**1.89**
Latidae	*Lates niloticus*	26	0.98
		26	**0.98**
Arampamidae	*Heterotis niloticus*	209	7.88
		209	**7.88**
Polypteridae	*Polypterus endlecheri*	29	1.09
	Polypterus senegalensis	26	0.98
		55	**2.07**
Cichlidae	*Oreochromis niloticus*	736	27.76
	Chromidotilapia guntheri	142	5.36
	Hemichromis fasciatus	32	1.21
	Hemichromis bimaculatus	34	1.28
	Sarotheradon galilaeus	216	8.15
	Coptodon dageti	81	3.06
	Coptodon zilli	218	8.22
		1,459	**54.97**
Tetraodontidae	*Tetraodon fahaka*	8	0.30
		8	**0.30**
Claridae	*Clarias gariepinus*	85	3.21
	Clarias anguillaris	62	2.34
	Clarias macromystax	106	4.00
		253	**9.54**
Bagridae	*Bagrus bajad*	61	2.30
	Bagrus docmak	81	3.06
	Bagrus filamentosus	32	1.21
		174	**6.56**

Table 1 continued

Malepteruridae	*Malepterurus electricus*	20	0.75
		20	**0.75**
Mochokidae	*Synodontis clarias*	27	1.02
	Synodontis sorex	11	0.41
	Synodontis euptera	7	0.26
	Synodontis budgetti	21	0.79
	Synodontis occilifer	7	0.26
	Synodontis filamentosus	2	0.08
	Synodontis batensoda	6	0.23
	Synodontis schall	16	0.60
	Hemisynodontis membranaceus	10	0.38
	Chiloglanis micropogon	7	0.26
	Mochokus niloticus	11	0.41
		125	**4.72**
Mormyridae	*Mormyrops anguillloides*	42	1.58
	Mormyrops senegalensis	18	0.68
	Mormyrops hasselquisti	2	0.04
	Mormyrops macropthalmus	3	0.11
	Campylomormyrops tamandua	11	0.41
	Mormyrops rume	6	0.23
	Pollimyrus isidori	1	0.04
	Petrocephalus soudanensis	6	0.23
	Petrocephalus bane	2	0.08
		91	**3.43**
Dorosomatidae	*Pellonula leonensis*	5	0.19
		5	**0.19**
Cyprinidae	*Enteromius macrops*	3	0.11
	Barbus anema	7	0.26
	Barbus Lepidus	2	0.08
Characidae	*Hydrocynus forskalis*	51	1.92
		63	**2.38**
Alestidae	*Alestes dentex*	1	0.04
	Alestes baremus	6	0.23
	Micraalestes humilis	3	0.11
	Marcusenius cyprinoides	10	0.38
		20	**0.75**
Protopteridae	*Protopterus annectens*	41	1.55
		41	**1.55**
Citharinidae	*Citharinus citharus*	12	0.45
		12	**0.45**
	51	**2,654**	

3.2. Fish Community Structure

The results of fish species composition are shown in Table 1. A total of 2651 individuals belonging to 54 fish species and 18 families, dominated by Cichlidae, were observed. The Cichlids had 1,459 individual fish, representing 54.97%, while the least was Tetraodontidae, with 8 (0.30%) (Table 1). *Oreochromis niloticus* was the dominant fish with 736 individual fish representing 27.76%, while the lowest was *Tetraodon fahaka*, with 8 individuals representing 0.37%. The Shannon-Weiner diversity index (H), which measures species diversity by accounting for both abundance and evenness, was calculated to be 2.91, suggesting moderate to high diversity in the Lake's fish community. The evenness index (J) was 1.71, indicating a relatively balanced distribution of species in terms of abundance. The Margalef index (D), used to quantify species richness relative to the number of individuals sampled, was 6.34, reflecting a healthy and diverse ecosystem.

3.3. Dimension Reduction

The first principal component (C1) has an eigenvalue of 5.83 and explains 53.02% of the total variance in the data. This indicates that more than half of the variation in the parameters is captured by C1, making it the most influential component. The second component (C2) has an eigenvalue of 3.02 and explains 27.45% of the variance. Combined, C1 and C2 explain 80.48% of the total variance, indicating that these two components are sufficient to describe most of the variation in the dataset (Table 2).

Table 2. PCA Factor loadings of the physico-chemical and nutrient parameters in two principal components

Item	C1	C2
Eigenvalues	5.83	3.02
Variance Explained (%)	53.02	27.45
Cumulative (%)	53.02	80.48
pH	-0.255	**0.681**
Alkalinity	-0.042	**0.891**
Hardness	-0.018	**0.945**
Ammonia	-0.021	**0.935**
Nitrite	**0.818**	-0.029
Nitrate	**0.978**	-0.114
Temperature	-0.072	**0.479**
Nitrogen	**0.987**	-0.101
Phosphorus	**0.978**	-0.120
Potassium	**0.987**	-0.102
Magnesium	**0.963**	-0.141

The PCA (Principal Component Analysis) biplot illustrates the contribution of 11 important physico-chemical parameters towards the overall variation observed in the study area. Parameters such as NO_3, NO_2, P, N, and K are positioned far along Component 1, indicating that they are the primary factors influencing changes along this axis. These nutrients, often linked to eutrophication and productivity changes in aquatic systems, appear to have strong associations with variations in fish species abundance or distribution. On the other hand, parameters like Hardness, Alkalinity, NH_3, and pH are aligned with Component 2, suggesting their influence on water chemistry and buffering capacity, particularly in areas with higher mineral content. The positioning of ATM (likely atmospheric temperature) near the centre of the plot suggests a moderate influence on both axes, implying that temperature plays a balanced role in shaping the ecosystem's dynamics. Overall, the first two components captured most of the variation, with Component 1 being more strongly influenced by nutrient-related parameters and Component 2 reflecting changes in water chemistry (Figure 3).

3.4. Influence of Physico-Chemical and Nutrient Parameters on Fish Abundance

The Canonical Correspondence Analysis (CCA) results summarize the relationship between various water quality parameters and fish abundance across five canonical axes (F1-F5). The eigenvalues for the first five axes range from 0.2 to 0.06, explaining a total cumulative variance of 76.02%. The first two axes (F1 and F2) together account for 43.05% of the variance, with F1 explaining 25.71% and F2 explaining 17.34%. The value of each of the parameters reflects the strength of the parameter on fish abundance, for instance, the highest pH of -0.396 was in F2 and it was an inverse relationship, while Magnesium had the highest value (0.634) in F5 and a positive relationship (Table 3).

From the ordination plot, it is evident that certain physico-chemical parameters exhibit stronger correlations with the presence and abundance of specific fish species. The horizontal axis explains most of the variance, while the vertical axis accounts for the remaining variation. Fish species and physico-chemical parameters are displayed as points and vectors, respectively. The length and direction of the vectors represent the strength and direction of the correlation between the environmental parameters and species distribution. The CCA results show that the first canonical axis (F1), which accounts for the majority of variance, is strongly influenced by negative relationships with nutrient-related parameters like Nitrate, Phosphorus, and Nitrogen. Axis F2, which accounts for 17.34% of the variance, shows a more complex interaction with water quality parameters, with negative loadings for pH and Alkalinity (ALK), and positive loadings for Hardness (HARD) and Ammonia (NH_3). According to the CCA, species like *Bagrus bayad* (BAG), *Synodontis spp.* (SYNB, SYNF), and *Hemichromis spp.* (HEMI) shows strong positive associations with parameters such as pH, hardness, and ammonia levels, suggesting they may prefer more alkaline waters with higher hardness and ammonia concentrations. Conversely, species like *Petrocephalus bane* (PETB) and *Petrocephalus sudanensis* (PETR) are located far from the environmental vectors, indicating little or no significant correlation with the measured water quality parameters. The sampling months are well distributed across the ordination plot, with months such as March and December being positively associated with certain environmental factors like pH and hardness. In contrast, August and September appear near vectors for nitrates and nitrites, indicating that the abundance of fish species during these months could be influenced by nutrient load, likely from agricultural runoff during the rainy season (Figure 4).

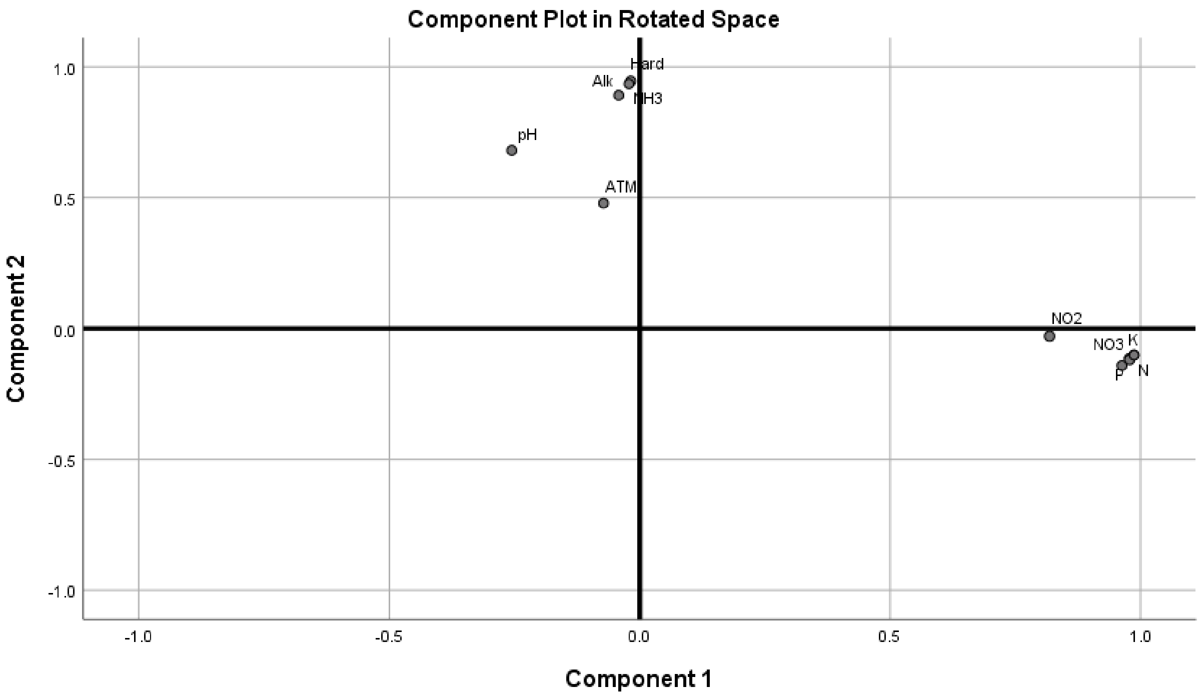


Figure 3. PCA biplot of Physico-Chemical and nutrient Parameters of Nguru Lake

Table 3. Canonical Correspondence Analysis summary for water quality parameters in Nguru Lake, Yobe

Parameter	F1	F2	F3	F4	F5
Eigenvalues	0.2	0.14	0.12	0.08	0.06
Variance Explained (%)	25.71	17.34	15.06	10.41	7.5
Cumulative (%)	25.71	43.05	58.11	68.52	76.02
Ph	0.206	-0.396	0.309	0.064	-0.145
ALK.	0.095	-0.323	0.394	-0.078	-0.162
HARD.	0.081	-0.201	0.422	-0.119	-0.155
NH_3	0.092	-0.187	0.447	-0.024	-0.117
NO_2	-0.237	-0.062	-0.094	0.349	0.311
NO_3	-0.408	-0.291	0.058	0.183	0.179
N	-0.262	-0.163	0.425	0.422	0.246
P	-0.411	-0.303	0.049	0.167	0.181
K	-0.233	-0.154	0.405	0.477	0.292
Mg	-0.199	-0.026	0.246	0.634	0.166
ATM	-0.298	-0.038	-0.041	-0.784	0.011

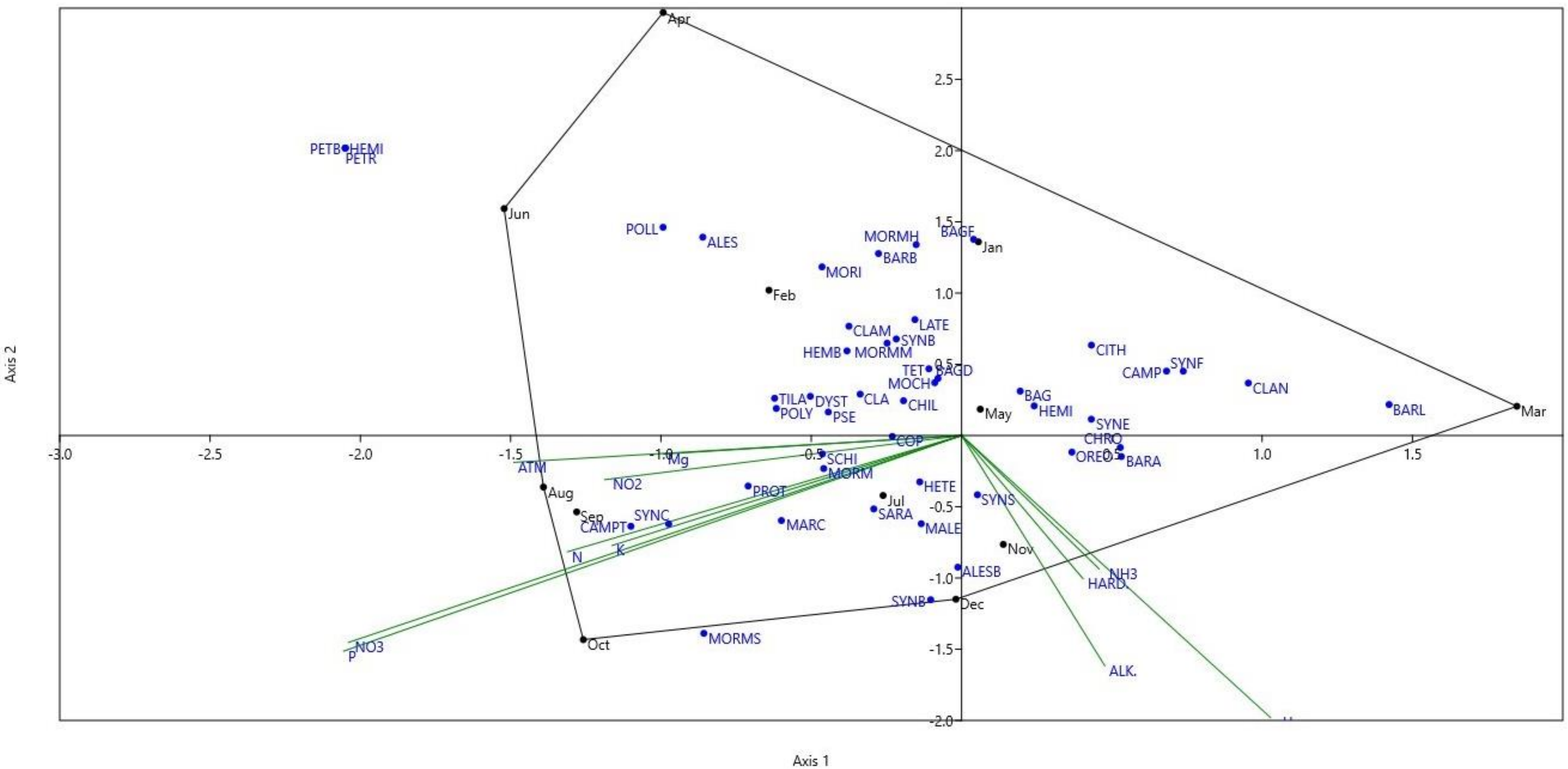


Figure 4. Canonical correspondence analysis ordination diagram showing the influence of significant fish composition and Physico-chemical in Nguru Lake

4. Discussion

The results of the present study showed that the variations in water quality parameters such as temperature, pH, alkalinity, hardness, as well as the concentrations of nutrients such as nitrogen (N), phosphorus (P), potassium (K), and ammonia (NH_3), in the Lake, have a significant role in shaping the fish community structure, as aquatic ecosystems productivity depends on such parameters since they play vital roles in the metabolic processes of the living biota of the aquatic ecosystems. The levels of all the parameters studied in the present study are within the acceptable limits of [23] for aquatic life, with the exception of ammonia, nitrite, and nitrogen. The higher levels of ammonia, nitrite, and nitrogen might be attributed to the discharge of manure and fertilizer from nearby farmlands as well as other anthropogenic activities. This agreed with the findings of [24,25,26]. Likewise, another possible reason that might lead to the higher values of nitrate could be due to the increase in dissolved oxygen which might lead to an increase in microbial activity to degrade ammonia as reported by Dauda et al. [27]. pH level was found to be neutral, though within the ranges considered adequate for aquatic life; this is similar to the reports of Abubakar and Geidam [28] in the same lake and also in line with that of [25,29,30]. The higher levels of potassium, phosphorus, and magnesium in the present study might be attributed to the anthropogenic activities such as farming, washing, and so on taking place in the lake area. The fluctuations recorded in the physico-chemical and nutrient parameters in the present study might also be attributed to seasonal and environmental conditions of the lake, as reported by Cereja et al. [31] that physico-chemical and nutrient parameters in any aquatic ecosystem are influenced by seasonal and environmental factors.

Fish diversity, composition and abundance are key indicators of good water quality parameters and healthy aquatic environments [32]. In the present study, the fishery of Nguru Lake revealed a high number of fish families with good species composition, abundance, and diversity, which can be attributed to the adequate physico-chemical and nutrient parameters, which may make more food available for optimum fish survival, growth, and reproduction. Food condition is still considered an important factor affecting the growth and reproduction of fish fauna in nature, especially in closed environments such as reservoirs and lakes [33]. Furthermore, all the fish species recorded have been reported to be present in Nigerian freshwater lakes and rivers by several studies, including Abubakar et al. [34] in Nguru Lake; Birnin-Yauri [35] in Nguru Wetland; Adaka et al. [17] in Oguta Lake; Joshua et al. [36] in Kiri Reservoir; Abbati et al. [37] in Nafada River; Oladipo et al. [38] in Jebba Lake; Wakil et al. [39] in Hadejia-Jama'are Kumodugu Yobe. However, the present study reported more species than the findings of Abubakar and Auta [40] who reported twenty-four species belonging to 13 families, and Abubakar et al. [34] who reported 38 species belonging to 17 families from Hadejia Nguru wetlands. The high number of fish species found in the present study might be attributed to the improved suitability of the environment from the physico-chemical and nutrient parameters leading to better growth, survival and reproduction, which is similar to the findings of Lawal et al. [41] in Mairuwa reservoir, that the author opined that the high number of fish found in the reservoir might be attributed to the nutrients richness of the reservoir.

The diversity of fish species observed in Nguru Lake reflects a relatively rich and balanced ecosystem. The Shannon-Weiner index (H = 2.91) and the Margalef index (D = 6.34) suggest that the Lake supports a diverse community of fish, which is indicative of a moderately stable environment. This finding aligns with other studies conducted in African freshwater bodies, where diversity tends to be high in areas with limited anthropogenic disturbance [42]. The evenness index (J = 1.71) indicates a relatively even distribution of species across the community, suggesting that no single species dominates excessively, further reinforcing the lake's ecological stability.

The observed species richness of 54 species from 18 families is in line with findings from other tropical African Lakes, where freshwater ecosystems are known for their rich biodiversity [43]. However, compared to other well-studied freshwater bodies, such as Lake Chad, which supports over 135 species [44], the slightly lower richness in Nguru Lake may be attributed to its geographic isolation and possibly localized fishing pressures.

The CCA analysis reveals that certain fish species are closely associated with specific water quality parameters in Nguru Lake. The clustering of species around the vectors for nutrients such as phosphorus and nitrogen highlights the potential for nutrient enrichment to affect species composition and distribution. Species like *Clarias gariepinus* (CLA) and *Oreochromis niloticus* (OREO) are seen in closer proximity to these nutrient parameters, suggesting their reliance on more nutrient-rich environments. The analysis provides insight into the ecological preferences of different fish species in Nguru Lake and how they may respond to varying water quality conditions throughout the year. Increases in nutrient concentrations, particularly during months of higher agricultural runoff, may favour species that are more tolerant of eutrophic conditions, such as Clarias and Oreochromis, while less tolerant species may be negatively affected. Overall, the results highlight the intricate relationships between fish species and water quality parameters in Nguru Lake, offering valuable information for managing fish populations and preserving biodiversity in the face of changing environmental conditions.

Water quality parameters exhibited clear patterns of influence on fish distribution and abundance. pH and alkalinity played crucial roles in determining species occurrence, particularly for sensitive species. The CCA (Canonical Correspondence Analysis) results revealed that certain fish families, such as Cichlidae and Cyprinidae, were positively associated with higher pH and alkalinity values. This is consistent with findings from other aquatic systems, where fish diversity and abundance often peak in environments with neutral to slightly alkaline pH levels, as these conditions support optimal metabolic and reproductive activities [45,46].

Additionally, water hardness and nutrient load (i.e., nitrogen and phosphorus) were important factors influencing the spatial distribution of species. The positive correlation between NH_3, NO_3, and the occurrence of tilapia and catfish species suggests that these species are more tolerant to elevated nutrient levels, which could be linked to agricultural runoff and organic matter decomposition in the Lake's watershed. Nutrient enrichment, particularly nitrogen and phosphorus, is known to promote fish biomass, especially in eutrophic systems, although it can lead to adverse effects like hypoxia if left unchecked [47]. However, Neijnens et al. [48], after conducting a meta-analysis of the effects of nutrient enrichment on freshwater organisms, admitted the insufficiency of data to perform a meaningful analysis on nutrient enrichment and the effects on fish community structure.

Nutrient parameters, particularly nitrogen and phosphorus, significantly impact fish abundance, especially for species in the Clariidae and Mormyridae families. High concentrations of these parameters in some months correlate with increased fish abundance. These fluctuations are likely due to natural inputs and human activities like agriculture and fishing [49]. High nutrient concentrations, particularly nitrate and ammonia, may indicate anthropogenic sources like fertilizer runoff and untreated sewage. These influxes can increase primary productivity and support higher fish biomass. However, excessive nutrient loading can lead to eutrophication and oxygen depletion, and negatively affect fish survival [50].

5. Conclusions

This study highlights the intricate relationships between water quality, nutrient dynamics, and fish community structure in Nguru Lake. The influence of physico-chemical parameters such as pH, alkalinity, hardness, and nutrient concentrations on fish occurrence underscores the importance of integrated lake management strategies that balance fishery productivity with ecosystem health.

The findings of this study have significant implications for the sustainable management of Nguru Lake’s fishery resources. The diversity indices indicate that Nguru Lake supports a rich and diverse fish community, yet the observed nutrient enrichment patterns suggest that the ecosystem could be vulnerable to anthropogenic pressures, particularly nutrient loading from agricultural runoff. As other studies have suggested, maintaining optimal water quality is critical for sustaining fish populations in tropical lakes. Therefore, monitoring physico-chemical and nutrient parameters is essential to ensure the Lake remains a productive and balanced ecosystem.

Ethics and Integrity Statements

Data Availability

Original data used for the study is available with the corresponding author and it can be made available anytime based on request.

Ethics and Permit Approval Statement

The research was carried out in compliance with local ethical standard as approved by the ethical committee of Federal University Dutsin-Ma, Katsina State, Nigeria.

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Conflict of Interest

The authors declare no conflicting interests.

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Authors Contribution

Conception and design of the study – Geidam and Dauda
Acquisition of data – Geidam and Salim
Analysis and interpretation of data – Dauda, Salele, and Saba
Drafting of the manuscript – Saba and Salim
Revision of the manuscript – All the authors
Final approval of the manuscript – All the authors

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