

Influence of Seasonality on Water Quality Parameters and Fisheries Economic Returns in the Hadejia-Nguru Wetlands, Nigeria

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Abstract

The seasonal influx of agricultural, municipal and industrial pollutants into the Hadejia-Jama'are Wetlands become alarming due to chemicals from irrigation, animal manure and human excretory wastes in this study. However, these factors influence the water quality and indirectly affect the biodiversity, leading to a decline in fish yield, which in turn affects fisheries' economic returns negatively. This study presents a comprehensive analysis of physicochemical parameters measured across three experimental sites (Nguru, Hadejia and Guri) within the Hadejia-Nguru Wetlands, bi-annual period of eighteen (18) months between August, 2024 and January, 2026. Therefore, this extended monitoring period captures two complete hydrological cycles, encompassing four distinct seasons, these include the two (2) wet seasons (April to October) and two dry seasons (November to March). Analytically, parameters such as temperature, pH, turbidity, DO, BOD, alkalinity, EC and NH₃ were assessed using NIFFR Calorimetric Test Kits; thus, provided robust analysed data for seasonal variations in this work. Also the well-structured questionnaires were administered for the assessment of fisheries economic returns at the nine (9) sampling points across these three (3) stations in HNWS. Software such as MS-Excel (2016) and SPSS Version-23 were used for the analysis. Therefore, radar charts were generated from monthly data that revealed distinct seasonal patterns which are crucial for understanding the spatio-temporal dynamics of water quality and their implications for fisheries management. These findings revealed the insight that extensively coincided with some domestic literature on Nigerian river systems and wetland fisheries. In this research, the bi-annual comparison revealed consistently the alkalinity patterns between years, with variations of less than 5% between corresponding months. Also, there is strong positive correlation ($r=0.747$) between alkalinity and BOD, ($r=-0.806$) between DO and temperature. Whereas, this trend revealed contrarily and strong negative correlation the strong positive correlation ($r=0.834$) between temperature and ammonia. Though, to some extent exposes seasonal variations between months and across the three experimental sites. In this work it was discovered that the physicochemical parameters showed distinct patterns, with wet season turbidity peaks (8.0-8.5 NTU) and dry season temperature maxima (30.0-30.5°C). Notwithstanding, Nguru maintained the most stable conditions, while Guri presented the most challenging environment. Also, the outcome of this study exposed the fisheries annual yield and economic returns for the three (3) study sites. However, the estimated annual economic yields of N54.86 million, N49.64 million and N40.80 million in Nguru, Guri and Hadejia respectively, with a total aggregate yield of N145.3 million per annum. Based on these findings it was discovered that the effort peaked at 30 to 32 man-days daily in the wet season. Hence, the monitoring of physicochemical variables and fisheries economic returns in the HNWS help to establish the baseline information that guides the management and conservation of its resources, also to enhance the livelihood and economic development.

Keywords: Economic returns, Fisheries, Physicochemical parameters, pollutants & Wetlands

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INTRODUCTION

Fisheries are the sectors or disciplines in the natural science that concerns with aquatic renewable natural resources, aquatic ecosystems, water, biotics and to some extent deals with coastal, estuaries, inland ecosystem activities and aquaculture (Geidam et al., 2025).

Therefore, fisheries resources are renewable and or distinctive based on at least one of the following factors; quality of the physicochemical parameters, as many species have wider spatial distribution. Fisheries can contribute greatly to the food security, socio-economic growth and its development in the developing and developed countries, particularly, job creations, local fisheries business and foreign trades earnings to enhance the standard of livings (Ahmed et al., 2025). The freshwater bodies in Sub-Saharan Africa, especially the Northern Nigerian regions, are blessed with several rivers, seasonal streams, and artificial and natural lakes (Juma'ah et al., 2025). Thus, fisheries intensively concerns with its sustainable management and conservations (Geidam et al., 2025).

However, several species show wider temporal variations in abundance due to environmental quality among other factors such as food abundance and predation pressure (Vivekanandan, 2017; FAO, 2022, Nababa et al., 2022 & Thompson, et al., 2023).

The Hadejia-Nguru Wetlands (HNWs), a vital floodplain ecosystem lies between Northeastern and Northwestern Nigeria supporting over 1.5 million livelihoods; face a critical knowledge deficit that threatens sustainable fisheries management and food security. The Komodugu-Yobe River, which empties into Lake Chad, is formed by the Hadejia and Jama'are rivers, creating these vast floodplains known as the HNWs. These wetlands are managed by the authority of Hadejia-Jama'are river basins, the river lies on the extreme edge of the southern Sahel savanna that situated Northeast/West with central coordinates 10° 33' 00" East 12° 39' 00" North (Geidam et al., 2026). The wetlands were between 152 and 305 meters above sea level and covered an area of roughly 350,000 hectares. According to Abaje et al., (2017); Sharma (2023) & UNESCO (2023) the tropical climate is characterized by two distinct seasons: wet (May-September) and dry (October-April). The rainfall is between 500 and 600 mm, and the temperature ranges from 12°C during the harmattan season (cold) from December to January (Geidam et al., 2026); to about 40°C during the hot season around in April (Abubakar et al., 2012). These ecosystems are made up of seasonally flooded pools and permanent lakes linked by a system of channels. Hence, over 60

million people in developing nations rely on freshwater fishing for their survival. Though, approximately seven million tonnes of fishes are produced annually in seventy-one (71) low-income countries, accounting for 80% of the world's inland fisheries capture (FAO, 2022).

Multifaceted approaches that combine genomics, socio-economics; study enhances the functions of diversity modelling and help to project SSP with regards to climate impacts (Free et al., 2025). An innovative blockchain-based catch traceability, trans-boundary MSE frameworks, and CRISPR-assisted resilience breeding assures sustainable fisheries management. These coupled with inclusive integration that includes ethical and local knowledge it is crucial to meet global conservation targets (Free et al., 2025).

Advances in Bayesian modelling and artificial intelligence-assisted analytics have further enhanced the efficiency, transparency, and robustness of assessments, allowing managers to balance biological sustainability with economic and social objectives (Froese et al., 2024). Fish biodiversity has wide range of socio-economic and ecological significance (Meinam & Singh, 2023). Fish communities also serve as indicators of environmental quality, as reductions in species richness often reflect habitat disturbance or pollution (Castorani et al., 2025).

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Socially, fish biodiversity underpins cultural traditions, recreational fisheries, and food security, sustaining the livelihoods of millions of people worldwide (Kura et al., 2023; Lynch et al., 2025).

However, the productivity and sustainability of inland fisheries depend on relatively stable environmental conditions, especially water temperature, flow dynamics, and water quality. Thus, the diverse fish stocks supported fisheries generate substantial global revenue and

supply essential dietary protein based on an economic standpoint. Globally, several hundred millions enjoys from cheapest protein, tourism, commerce and employment in the freshwater capture fisheries (Arthur, 2024). Economically, almost more than 10% of the world population are relying on fisheries as a source of employment; thus their majority were females (Odioko and Becer, 2022). Therefore, fisheries in the United States generated approximately \$321 billion in sales and supported about 2.3 million jobs in 2022, while in many developing countries fish provide up to half of total animal protein intake (NOAA, 2025). In Nigeria, that are fisheries dependents exceeded 1.74 million; hence this subsector contributes about 1.09% to the National GDP IN 2020 and 0.97% at third quarter of 2021 (NBS 2022), also Nigerian freshwater fisheries 33% out of 1.123 million metric tonnes. In 1997 Hadejia-Nguru Wetlands has an annual fish catch of over 6000 MT with economic returns of N480 million (Eaton and Sarch, 1997). Recently reported that the 40% of the national catch obtained from inland fisheries system that operating formal co-management system but the 50% involved intensive fisher participation which is more commonest in local levels (FAO, Duke University and World Fish, 2023).

Therefore, this region spanning across Jigawa and Yobe States, thus it constitute a critical component of the Hadejia-Jama'are River Basin and serve as a lifeline for over 1.5 million people who depend on the ecosystem services for their livelihoods (Ayeni et al., 2019; Nguru et al., 2025). However, these wetlands support diverse climate dependent economic activities including fishing, crop production, livestock grazing, and fuelwood collection, making them indispensable to the regional economy and food security (Dagona et al., 2024). According to Neiland et al. (2000), the seasonal flood pulse is the primary driver of fish production in Nigerian floodplain wetlands, with recruitment success closely tied to the timing and magnitude of flooding.

Nevertheless, both the seasonal and spatial dynamics of water quality parameters and their relationship to fish biodiversity are unmonitored, leaving managers blind to emerging environmental stressors that may amplify climate and fishing impacts. Annual fish productivity and economic valuation of wetland fisheries lack empirical estimation, preventing cost-benefit analysis of conservation investments and obscuring the true contribution to rural livelihoods.

Moreover, an ideal economic policy, yield and revenue estimation quantifies the opportunity costs of conservation, enabling incentive-compatible management that balances short-term livelihood needs with long-term sustainability. To attain these goals, this study aimed to investigate the status of the physicochemical parameters and fisheries economic returns of some water bodies in Hadejia-Nguru wetlands.

MATERIALS AND METHODS

Study Area

The Hadejia-Nguru Wetlands (HNWs) is extensive floodplains created by the Hadejia and Jama'are rivers to form the Komodugu-Yobe River which drains to Lake Chad. The HNWs (Figure 1.) is managed by the authority of Hadejia-Jama'are river basins, the river lie on the extreme edge of the southern Sahel savanna in north-eastern part of Nigeria with central coordinates 10° 33.00' East 12° 39.00' North; the wetlands covered an area of about 350,000 ha and altitude 152- 305m. The climate of the wetland is characterized by two distinct seasons; wet (May-September) and dry season (October-April), rainfall is between 500-600 mm, whereas temperature ranges from 12°C during harmattan season (cold) to about 40°C during hot season, (Abbati et al., 2020). The ecosystem comprises permanent lakes and seasonally flooded pools connected by a network of channels.

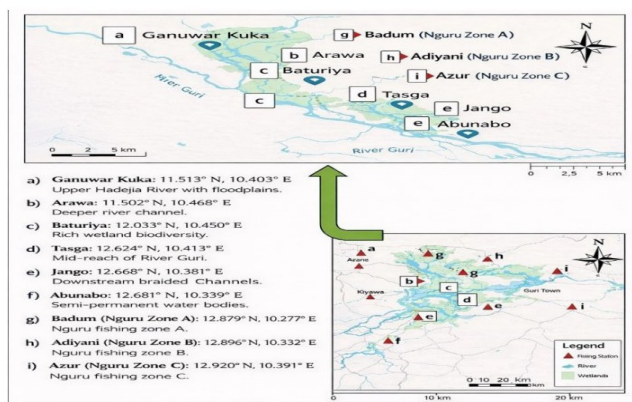


Fig1: Map of the study area

Sampling Design

The study was conducted in HNWs at three (3) major fishing areas namely, Hadejia, Guri and Nguru lakes positioned as lower stream, mid-stream and upper stream respectively. Therefore, the three (3) skilled data enumerators were employed, assisted, and covered the locations chosen for this study. Thus, the random sampling methodology was employed and the data were collected forth nightly for the period of 18 months starting from August, 2024 to January, 2026.

Estimation of Annual Biological Yield:

The following model was used and the annual biological yield also had been determined;

$$W = W_t = W_f^* W = W_t = W_f^* [1 - \exp(-K^*(t - t_0))]^3 [1 - \exp(-K^*(t - t_0))]^3$$

Where W_t is the corresponding weight of mid-length at age(t), W_f is maximum weight at infinity, W_t is weight of a given fish at a time, k is growth coefficient, and t is period.

Annual Effort(fA)

This is based on Bi-annual Strata Constant Efforts (BASCE), however the structured questionnaires were used and the fishing frequencies across all seasons were evaluated. This can be given as wet season constant effort=30 man days per day and dry season constant effort=1 per day except for March and April deemed to be having average of 20 man days (Yusuf & Abdulkarim, 2015)

Estimation of Annual Economic Yield: The annual economic yield was estimated by Thompson and Bell (1934) and Abdulkarim et al. (2009).

Water Sampling and its chemistry analysis

Water samples were collected bi-monthly throughout the study period (18 months) from nine (9) sampling points designated for this experiment. All the samples were collected at the morning hours, between 7:00am and 9:00am at spot using NIFFR Calorimetric Kits (Bukar, et al., 2021 & Nwonumara, et al., 2022).

Determination of Temperature

Temperature of the water was determined after recording the surface temperature (T_2) using mercury in glass thermometer graduated in degree Celsius (°C). The thermometer was inserted directly into the water at about a depth of 5cm and left for 1 to 1.5 minutes until the mercury came to a standstill. After which the water temperature was recorded as (T_1) (Nababa et al., 2022).

Determination of Turbidity

The determination of turbidity was done using Secchi disc; thus the water transparency for the period of this study was recorded. It was dipped at 30cm depth until the alternate colours disappeared and reappeared, in which the two depths were recorded (Sadauki et al., 2022 & Geidam et al., 2026).

Chemical Analysis of the water properties

All chemical properties of water such as Dissolve oxygen (DO), Alkalinity, Ammonia, Nitrate and pH were analyzed and evaluated Calorimetrically using NIFFR water testing kits (Nababa et al., 2024 & Geidam et al., 2026).

BIOLOGICAL PROPERTIES OF WATER

Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) was determined according to a standardized technique, presently called the bolted/closed bottle test, described in the Worldwide Standards ISO 5815-1:2003. Physicochemical Determination of Biological Oxygen Demand after n-days (BOD-n). The collected samples were kept for five days (Day 5 DO) in a dark condition and then run the second DO analysis, the difference between the D_1 and D_2 is termed BOD (Bukar, et al., 2021).

Statistical Analysis

The physicochemical water quality parameters and fisheries economic returns data were processed in Microsoft Excel (2016) especially radar charts' presentation and SPSS (version 23) using chi-square and descriptive statistics at a significance level of $p < .005$ were computed accordingly. Therefore, the descriptive statistics such as mean and standard deviation were analysed in SPSS with a 0.005 confidence interval.

RESULTS AND DISCUSSION

Results

Physicochemical Parameters of Hadejia-Nguru Wetlands

Mean physicochemical Parameters of HNWs

In this study, the mean bi-annual data were collected for the period of 18 months; thus these spanned from March, 2024 to August, 2025, it revealed the full hydrological variability of eight parameters in the HNWs had showed in Table 1. The seasonal cycles profoundly influence all physicochemical parameters through different mechanisms including dilution effects during floods, concentration during dry periods, temperature fluctuations and variations in biological activity. However, the comprehensive analysis of physicochemical parameters measured bi-annual across three experimental sites (Nguru, Hadejia,

and Guri) within the Hadejia-Nguru Wetlands up to the period of 18 month (August, 2024 to January 2026) had presented in Table 1. This extended monitoring period covered two complete hydrological cycles, encompassing four distinct seasons: two wet seasons (April-October) and two dry seasons (November-March). Therefore, the sufficient data on the Temperature, pH, Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand

(BOD₅, alkalinity, Conductivity, and Ammonia (NH₃) were provided. Thus, in this work pronounced seasonal variations and analysed for Maximum, Minimum, Average and SD. The radar charts illustrate these monthly variations, revealing characteristic patterns that align with the region's hydrological regime in Figures 2-10, and in Table 1.

Table 1: Mean Range of Physicochemical Parameters (September, 2024-August, 2025) of HNWs

PARAMETERS	EXPERIMENTAL SITES			
	Nguru	Guri	Hadejia	F A O / W H O (2017);(2020)
Temperature °C	22.00 – 30.00 + 2.12	22.00 – 30.50 + 2.30	22.00 – 30.50 + 2.40	<35.00
pH	6.00 – 8.00 + 0.51	5.50 – 9.00 + 0.48	6.00 – 7.50 ± 0.42	6.50-8.50
Turbidity	4.00 – 8.00 + 1.21	4.00 – 8.50 + 0.85	4.50 – 8.00 + 0.90	20 – 80
DO	6.00 – 8.00 + 0.50	6.50 – 8.50 + 0.50	6.00 – 8.00 + 0.38	< 5mg
BOD	0.83 – 2.80 ± 0.44	0.50 – 2.80 ± 0.54	0.50 – 2.60 ± 0.45	< 5
Alkalinity	21.50 – 32.50 ± 2.30	20.50 – 32.00 ± 2.32	20.50 – 32.50 ± 2.11	25-100
Conductivity	62.00 – 190.00 + 18.83	60.00 – 122.00 + 13.23	59.00	300-900
NH ₃	0.10 – 0.40 + 0.08	0.20 – 0.40 + 0.08	0.10 – 0.40 + 0.08	0.30

FootNote: Maximum, $M\bar{}$ = Minimum, SD = Standard Deviation, NH^3 = Ammonia, NH^3 = Ammonia, DO = Dissolved Oxygen, BOD₅ = Biochemical Oxygen Demand, pH = Potential Hydrogen Concentration, °C = Degree Celsius

Bi-Annual water quality parameter of Hadejia-Nguru Wetlands

Figure 2: explored that, the 18-month bi-annual data collection spanning March 2024 to August 2025 captured the full hydrological variability of the Sudano-Sahelian climate regime in this work. The Hadejia-Nguru Wetlands experience a distinct unimodal rainfall pattern with the

wet season extending from April to October and the dry season from November to March. This seasonal cycle profoundly influences all physicochemical parameters through mechanisms including dilution effects during floods, concentration during dry periods, temperature fluctuations and biological activity variations.

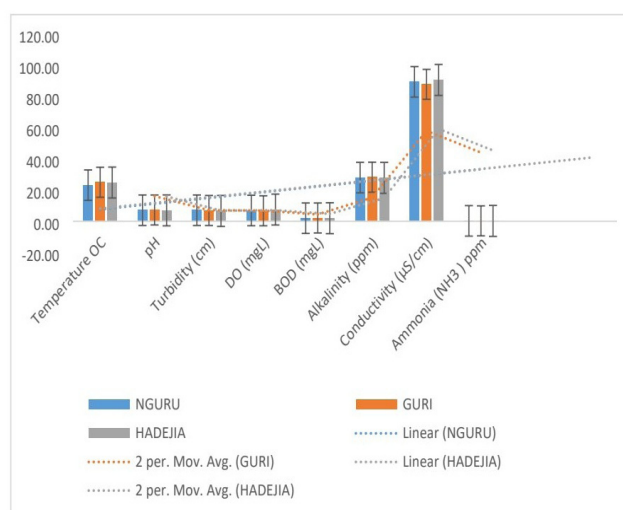


Fig2: Bi-Annual water quality parameter of Hadejia-Nguru Wetlands

Seasonal Temperature Variations

In this work the monthly temperature radar charts revealed distinct seasonal patterns across the 18 month period. However, the peak temperatures that ranged between 30.0 and 30.5°C were recorded during the hot dry season months from March to May, while minimum temperatures (22.0 to 22.5°C) occurred during the cool harmattan period between December and February. The coefficients of variation across the sites were given as 2.12 and 2.40°C indicates relatively stable thermal conditions within each season.

Therefore, by comparing the three sites, Guri consistently recorded the highest mean temperature (26.9°C), followed by Hadejia (26.0°C) and Nguru (25.5°C). This gradient likely reflects differences in water depth, flow rates, and riparian vegetation cover. In these findings, the 18-month bi-annual data revealed that the second year (2025) exhibited slightly elevated temperatures levels as compared with the first year (2024), with mean increases of 0.3-0.5°C across all sites.

Seasonal pH Variations

In this study, the bi-annual comparison revealed that pH

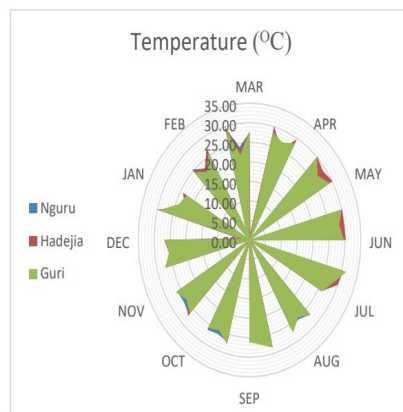


Fig3: Monthly Temperature radar chart of Hadejia-Nguru Wetlands

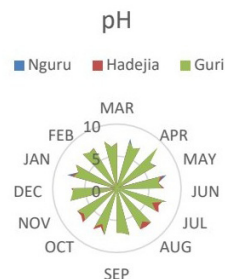


Fig4: Monthly pH radar chart of Hadejia-Nguru Wetlands

values in the second wet season (2025) were consistently 0.2 to 0.4 units lower than the corresponding months in 2024 had shown in Figure 4. Thus, the monthly pH radar charts exhibits flawless seasonal patterns of variations in hydrological conditions. However, the maximum pH values (8.0-9.0) were recorded during the peak dry season months (February-April) but the minimum pH values (5.5-6.0) occurred during the early wet season (May-June) when runoff from surrounding agricultural lands introduces organic acids and buffered soils.

Site-specific analysis reveals that Hadejia maintained the most stable pH conditions (mean: 7.15, range: 6.0-7.5), while Guri showed the widest fluctuations (mean: 7.04, range: 5.5-9.0). Nguru exhibited intermediate variability (mean: 7.03, range: 6.0-8.0). These differences

likely reflect varying degrees of buffering capacity with direct effects of alkalinity level (Table 4.26), agricultural influence, and biological activity at each site.

Seasonal Turbidity Variations

In this study, the turbidity exhibited the most unique seasonal fluctuations among all parameters measured had presented in Figure 5. These findings, the radar charts were employed and revealed the peak turbidity values that ranged between 8.0 and 8.5 NTU during the peak wet season months from July to September. However, the minimum turbidity between 4.0 and 4.5 NTU occurred during the late dry season from February to April.

Site comparison reveals interesting patterns: Guri consistently recorded the highest turbidity values (mean:

6.90NTU), followed by Hadejia (6.82 NTU) and Nguru (6.00 NTU).

The 18-month data revealed that turbidity in the second wet season (2025) was 15-20% higher than the

corresponding period in 2024. This trend is concerning given the strong negative correlation($r=-0.978$)between turbidity and fish catches.

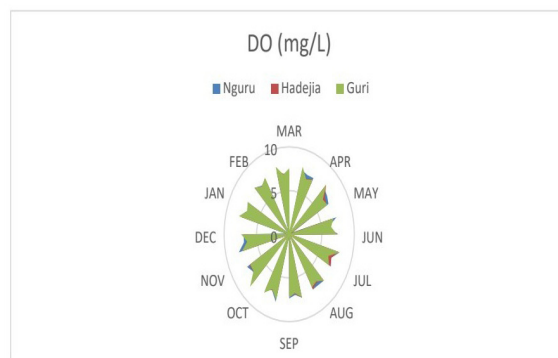


Fig5: Monthly Turbidity radar chart of Hadejia-Nguru Wetlands

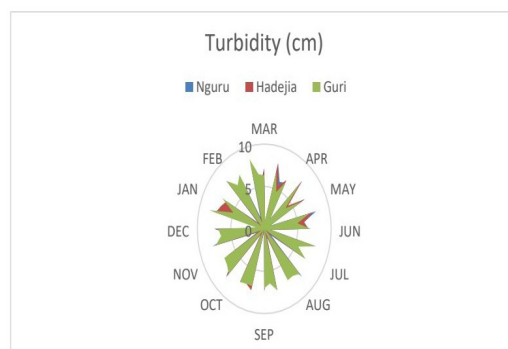


Fig6: Monthly DO radar chart of Hadejia-Nguru Wetlands

Seasonal Dissolved Oxygen Variations

Figure 6: also revealed that, Dissolved oxygen showed characteristic seasonal patterns driven by the relationship between temperature, biological activity, and hydrological conditions. Maximum DO concentrations (8.0-8.5mg/L) were recorded during the cool dry season months (December-February).

Site-specific patterns reveal that Nguru maintained the highest mean DO concentrations (7.30 mg/L), followed by Guri (7.22 mg/L) and Hadejia (7.17 mg/L).

The bi-annual comparison showed that minimum DO concentrations in 2025 were 0.3 to 0.5 mg/L lower than the corresponding months in 2024, The strong negative correlation($r=-0.806$) between DO and temperature in this study.

Seasonal BOD Variations

Figure7: explored that, biochemical oxygen demand exhibited clear seasonal patterns linked to organic matter inputs and decomposition rates. Peak BOD values (2.6-2.8 mg/L) occurred during the late wet season (August-

October). Minimum BOD levels (0.5-0.83 mg/L) were recorded during the mid-dry season from January to March.

Site comparison reveals that Nguru recorded the highest mean BOD (1.85 mg/L), followed by Guri (1.75 mg/L) and Hadejia (1.65 mg/L). The 18-month data showed that peak BOD values in the second wet season (2025) were 10-15% higher than in 2024.

Seasonal Alkalinity Variations

Figure8: below revealed, total alkalinity showed moderate seasonal fluctuations driven by dilution effects and carbonate dynamics. Maximum alkalinity (32.0-32.5 mg/L) occurred during the late dry season between March and April. Minimum values (20.5-21.5 mg/L) were recorded during the peak wet season from July to August. Site comparison reveals that Hadejia maintained the highest mean alkalinity (29.66 mg/L), followed by Guri (29.60mg/L) and Nguru (28.90 mg/L). The narrow ranges across sites were less than 1 mg/L difference.

The bi-annual comparison showed consistent alkalinity

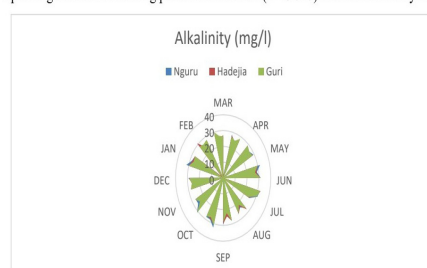


Fig7: Monthly BOD radar chart of Hadejia-Nguru Wetlands

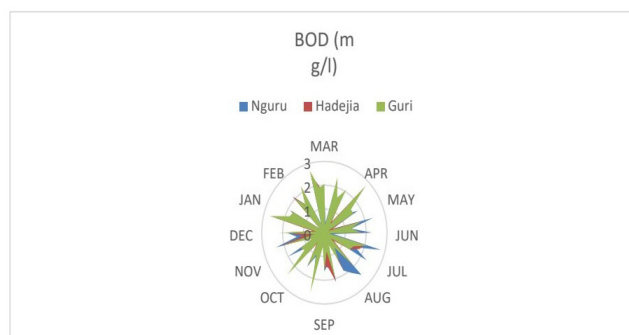


Fig8: Monthly Alkalinity radar chart of Hadejia-Nguru Wetlands

patterns between years, with variations of less than 5% between corresponding months. The strong positive correlation ($r=0.747$) between alkalinity and BOD

Seasonal Conductivity Variations

Figure 9: below revealed, Electrical Conductivity exhibited the widest seasonal range among all parameters, reflecting the strong influence of hydrological conditions on ionic concentrations. Maximum EC ($121-190 \mu\text{S/cm}$) occurred during the late dry season (March-May), while minimum values ($59-62 \mu\text{S/cm}$) were recorded during the peak wet season (July-September). Site comparison reveals that Nguru recorded the highest mean EC ($88.90 \mu\text{S/cm}$) and the widest range ($62-190 \mu\text{S/cm}$), followed by Hadejia ($84.69 \mu\text{S/cm}$, range: $59-121 \mu\text{S/cm}$) and Guri ($83.70 \mu\text{S/cm}$, range: $60-122 \mu\text{S/cm}$). The 18-month data revealed that peak EC values in the second dry season (March-May 2025) were 15-20% higher than the corresponding period in 2024.

Seasonal Ammonia Variations

Figure 10: Ammonia concentrations showed distinct seasonal patterns linked to temperature, pH, and organic matter inputs. Maximum ammonia levels (0.40 ppm) occurred during the hot dry season from March to April. Minimum values ($0.10-0.20 \text{ ppm}$) were recorded during the cool wet season (July-September).

Site comparison reveals that Hadejia recorded the highest mean ammonia (0.29 ppm), while Nguru and Guri showed identical means (0.26 ppm). The maximum values at all sites (0.40 ppm) were recorded and elevated. The bi-annual comparison showed that ammonia concentrations in the second year (2025) were consistently 10-15% higher than corresponding months in 2024. This trend is concerning given the strong positive correlation ($r = 0.834$) between temperature and ammonia.

Annual Fishing Effort and Economic Yield

The (Table 2) showed the fishing effort intensiveness and sustainability of exploitation across the Hadejia-Nguru wetlands. Annual fish off-take (E: efforts) from the

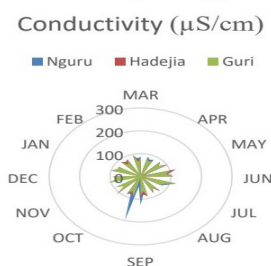


Fig9: Monthly Conductivity radar chart of Hadejia-Nguru Wetlands

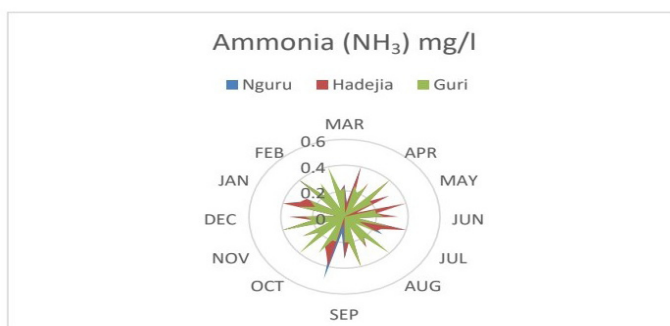


Fig10: Monthly Ammonia radar chart of Hadejia-Nguru Wetlands

wetlands has been estimated at approximately (9,821), (9,064) and (9,373) for Nguru, Guri, and Hadejia fishing stations respectively with peak daily catches during the wet season. The average number of active fishermen from all stations ranged from 28-33 (wet season) and 14-26 (dry season) respectively. The estimated annual economic value of the studied water bodies in HNW was presented in (Table 5, 6 & 7). Grand total Economic Yield of fisheries production is approximately N54,864,700 highlighting the substantial contribution of fisheries to rural and coastal

inhabitants' livelihoods. At the household level, fishing contributes significantly to income, with average annual returns exceeding those from other wetland-based activities such as fishing gear fabrication, boat construction and floodplain agriculture.

Estimation of Annual Economic Yield

Fishes are traded in number and in weight at Nguru fishing zones and observed pattern of trade shows that, fish of approximately high quality (HQ) are characterized by the

Table2: Estimated Annual Efforts (f_A) of Nguru Reservoir

S/N	Month	Total fishing Days (TFD)	Average effort per day	Total effort (Mandays/Month)
1	January	31	30	930
2	February	28	25	700
3	March	31	20	620
4	""April	30	20	600
5	*	31	32	992
6	*June	30	32	960
7	*July	31	32	930
8	*August	31	32	992
9	""September	30	32	960
10	October	31	22	682
11	November	30	15	450
12	December	31	15	465
	Total			9,281/year

""denotes season intersection period ** Wet season period

Table3: Estimated annual efforts (f_A) of River Guri

S/N	Month	Total Fishing Days (TFD)	Average Effort Per Day	Total effort (Mandays/Month)
1	January	31	27	837
2	February	28	24	672
3	March	31	27	837
4	""April	30	25	750
5	*May	31	30	930
6	*June	30	30	900

7	*July	31	29	899
8	*August	31	23	713
9	***September	30	31	930
10	October	31	22	682
11	November	30	16	480
12	December	31	14	434
	Total			9,064/year

***denotes season intersection period ** Wet season period

Table 4: Estimated annual efforts $(f_A)(f_A)$ of River Hadejia

S/N	Month	Total fishing Days (TFD)	Average effort per day	Total effort (Mandays/Month)
1	January	31	33	899
2	February	28	27	756
3	March	31	22	682
4	***April	30	21	630
5	*May	31	30	930
6	*June	30	27	810
7	*July	31	30	930
8	*August	31	31	961
9	***September	30	28	840
10	October	31	26	806
11	November	30	18	540
12	December	31	19	589
	Total			9,373/year

***denotes season intersection period **Wet season period

good looking and firmness/freshness of scales, skin, fins, and eyes while the low quality (LQC) are characterized by the short of the aforementioned qualities in addition to the deprived odor in some cases.

DISCUSSION

Physicochemical Parameters in Hadejia-Nguru Wetlands

Table 5: Estimated Annual Economic Yield of Nguru Reservoir (N)

Parameters	Small & medium sizes ($\leq 8-28$ cm)	Large size ($\leq 28-44$ cm)
Total Catch	18,160	12,200
Ratio of high to low quality Catches	6:4	6:4
High quality catches (HQC)kg	10,896	7,320
Low quality catches (LQC)kg	7,246	4,880
Price of high HQC Fish(N/kg)	1850	2500
Price of LQC Fish(N/kg)	850	2100
Economic Yield of HQC(N)	20,157,600	18,300,000
Economic Yield of LQC (N)	6,159,100	10,248,000
Total Economic Yield (HQC + LQC)(N)	26,316,700	28,548,000

Grand total Economic Yield = N 54,864,700 Economic Yield = Price x Catches(kg)

Table 6: Estimated Annual economic yield of River Guri (N)

Parameters	Small and medium sizes ($< 8-28$ cm)	Large size ($\leq 28-44$ cm)
Total Catch	16,160	11,200

Ratio of high to low quality Catches	6:4	6:4
High quality catches (HQC) kg	9,696	6,720
Low quality catches (LQC)kg	6,464	4,480
Price of high HQC Fish(N/kg)	1850	2500
Price of LQC Fish(N/kg)	850	2100
Economic Yield of HQC (N)	17,937,600	16,800,000
Economic Yield of LQC (N)	5,494,400	9,408,000
Total Economic Yield (HQC + LQC)	23,432,000	26,208,000

Grand total EconomicYield=N49,640,000 EconomicYield=Price x Catches(kg)

Table7:Estimated Annual economic yield of River Hadejia (N)

Parameters	Small and medium sizes-	Large size (≤28-44cm)
Total Catch	14,260	8,600
Ratio of high to low quality Catches	6:4	6:4
High quality catches (HQC)kg	8,556	5,160
Low quality catches (LQC) kg	5,704	3,440
Price of high HQC Fish(N/kg)	1850	2500
Price of LQC Fish(N/kg)	850	2100
Economic Yield of HQC(N)	15,828,600	12,900,000
Economic Yield of LQC(N)	4,848,400	7,224,000
Total Economic Yield (HQC+LQC)(N)	20,677,000	20,124,000

Grand total Economic Yield=N 40,801,000· EconomicYield=PricexCatches(kg)

In this study, it was explored that, the 18-month bi-annual data were collected which spanned from March 2024 to August 2025 captured the full hydrological variability of the Sudano-Sahelian climate regime had presented in Table 1 and Figure 2-10. The Hadejia-Nguru Wetlands experience a distinct unimodal rainfall pattern with the wet season extending from April to October and the dry season from November to March. This seasonal cycle profoundly influences all physicochemical parameters through mechanisms including dilution effects during floods, concentration during dry periods, temperature fluctuations, reported by Geidam et al. (2026) and also, biological activity variations exists (Birnin-Yauri, 2015) in HNWs and Juma'ah et al. (2025). Thus, the water quality variables are important in the assessment of water resources; these include physical, chemical and biological indices that support the aquatic lives in this study. This is commensurate with the study of Geidam et al. 2026 in Nguru Lake.

However, the Nguru Lake, Guri and Hadejia wetlands are parts of HNWs that are among the most significant inland wetland ecosystems that located between the Sudano-Sahelian Zone at the extremities of North-West and Northeastern parts, Nigeria. This is in consensus and contradiction with several studies conducted by Dirisu et al.(2015) in Agbede Wetlands; Birnin-Yauri (2015), in HNWs; Geidam et al. (2026), in the same wetland; Rabiou et al. (2018) in Watari Reservoir; Hassan and Ibrahim (2021), in Katsina.

Therefore, this research presents a comprehensive analysis of physicochemical parameters measured such as Temperature, D.O, BOD, Turbidity, EC, ALK, NH₃ and Nitrate. These variables were forth nightly studied for the period of 18 months (March 2024- August 2025); because they are of paramount important within the Hadejia-Nguru Wetlands. This was in line with the studies of Birnin-Yauri, (2015) in the same wetlands; Usman and Maitera (2025) in Watari Reservoir. This extended monitoring period captures two complete hydrological cycles, encompassing four distinct seasons: two wet seasons (April-October) and two dry seasons (November-March), provided robust data for seasonal variation analysis. This is also agreed with the work of Waziri and Ogugbuaja (2010) and Sani et al.(2019).

In this study, the findings revealed that water temperatures of Nguru Lake were optimal for aquatic lives, though there were fluctuations due to seasonality and climate changes. This work is similarly reported by Gwana et al.(2017) that reported temperature range of 22.03 to 22.90°C from Alao Reservoir, Maiduguri.

Contrarily, the temperature was higher in Guri (midstream) that was varied to the report of Sani et al (2019) that revealed the mean level of 33.43±0.22°C in Bodna River; and very close value of 33.70±0.55 reported during dry season. In this work, the concentration of the D.O was significantly higher in Nguru Lake as compared with Guri (Midstream) and the Hadejia (Upstream). This low

D.O pattern in Hadejia's could be due to water stagnation conditions might experience during its depletion. The low D.O were discovered at the late wet season, that is, between August and October when temperatures elevated, accompanied by increased organic loading and reduced light penetration limit during photosynthetic oxygen production.

Furthermore, these D.O levels are within the guideline limit prescribed by WHO (2017). Hence, there is strong inverse relationship between the D.O and BOD also with Temperature increase leading to the declined in D.O. This is lined the various works conducted in the wetland systems such as Waziri and Ogugbuaja (2010); Badejo et al. (2017) around Gashua area. In accordance with Onuoha et al. (2018), increase in temperature triggers the biodegradation to elevate BOD. This consequently decreases D.O. Thus, BOD is required in the decomposition of organic matter by nitrosomonas and nitrobacter (Birnin-Yauri, 2015). Therefore, BOD is useful in the conversion of toxic ammonia (N-NH_3) into normal nitrate (N-NO_3) (N-NO_3 in the water bodies). In this study, the BOD observed slightly higher than that of Badejo et al. (2017), unlike the works of Birnin-Yauri (2015) who reported extremely higher BOD levels of 4.11 and 14.91 mg/l . Moreover, the Temperature, BOD, D.O and pH as water quality index helps in ensuring ecological equilibrium in fisheries management and conservation. This was commensurate with the works of Godwin and Oborakpororo, (2019); Ibrahim and Hassan, (2021) and Geidam et al. (2026).

In this work, peak Electrical Conductivity level was reported in the second dry season from March to May 2025 with 15-20% higher than the corresponding period in 2024; suggesting either reduced wet season recharge or increased evaporative concentration. This trend has implications for fish osmoregulation and overall ecosystem health.

Outstandingly, E.C exhibited the widest seasonal range among all parameters and reflecting the strong influence of hydrological conditions on ionic concentrations. The higher E.C occurred during the late dry season between March and May once evaporative concentration is at peaks; while low levels were recorded during the extreme wet season from July to September; this was influence by excessive rainwater dilution.

Comparatively, Nguru Lake reveals the highest mean E.C with the widest margin; its greater variability likely reflects its position in the wetland complex, experiencing both concentrated dry season conditions and significant wet season dilution.

Therefore, the influxes of ionic substances raise the levels of EC in the wetlands in these findings. This is reported higher by Birnin-Yauri, (2015), who recorded 260-375 $\mu\text{S/cm}$ due the huge organic sediment accumulated during dry season will be responsible for siltation. This this was similarly reported by Geidam et al. (2026), who affirmed that the sedimentation is resulted by run-off. Thus the E.C level (59.00-190.00 $\mu\text{S/cm}$) reported in this study in HNW systems is far above to that of Badejo et al. (2017) who with the highest value of 0.72 $\mu\text{S/cm}$.

Although, the radar charts generated from monthly data revealed the distinct seasonal patterns that are crucial for understanding the temporal dynamics of water quality and their implications for fisheries management in this work.

Conversely, the dry season period from November to March brings concentrated conditions, higher temperatures and increased ammonia toxicity risk, creating physiological stress for fish but also triggering spawning migrations in floodplain-dependent species. This could be due to maximum values at all sites (0.40 mg/l) approached levels that can cause sub-lethal effects on fish, particularly when combined with elevated pH that increase the proportion of toxic un-ionized ammonia (NH_3). This could be aggravated to the anthropogenic activities that threatening the reservoirs (Juma'ah et al., 2025).

However, the floodplain wetlands in the Sahelian region exhibit dramatic seasonal changes in water quality parameters, with flood pulses triggering fish migration, spawning, and recruitment according to several studies conducted by Welcomme (1979); Hollis et al. (1993); Waziri et al. (2010) and Badejo et al. (2017) in around Gashua-River Yobe, also reported by Geidam et al. (2026) in the same Wetlands. The radar charts (Figures 12-20) illustrate these monthly variations, revealing characteristic patterns that align with the region's hydrological regime.

Seasonal Temperature Variations

In this study, the Guri (midstream) consistently exposed the higher temperature with 26.9°C, among the three sites but Hadejia and Nguru wetlands were slightly differed. These higher temperatures of Guri might be attributed to shallower water depths and reduced shading due to shortage of aquatic macrophytes unlike in Nguru Wetlands. This could be attributed to the Nguru's lower temperatures that aggravated to its greater water exchange with the main river channel and denser riparian cover. These lower temperatures enhance oxygen solubility and reduced biological demand of conserves oxygen in Nguru. Therefore, the monthly temperature radar charts reveal distinct seasonal patterns in the overall experimental

period had showed in Figure 3 of this work. This implies that, there is vulnerability in the wetland system to warming trends.

In these findings, the peak temperatures of 30.0 to 30.5°C were recorded during the hot dry season months of March to May, but the minimum obtained between 22.0 and 22.5°C that observed during the cool harmattan period from December to February. This is in lined with the study of Gwana et al. (2017). However, the coefficient of variation across sites were revealed the values SD between 2.12 and 2.40°C that indicating relatively stable thermal conditions within each season. This gradient likely reflects differences in water depth, flow rates, and riparian vegetation cover. Guri's higher temperatures may be attributed to shallower water depths and reduced shading. Also, Nguru's lower temperatures could result from greater water exchange with the main river channel similarly reported by Abubakar et al. (2012) & Geidam et al. (2026) and denser riparian cover reported by Birni-Yauri (2015), and Kutama et al. (2016).

More so, the bi-annual data revealed that the second year (2025) exhibited slightly elevated temperatures compared to the first year (2024), with mean increases of 0.3-0.5°C across all sites. This warming trend was consistent with climate change projections for the Sahel region (Abubakar et al., 2016). This could have the implications for fish metabolism, oxygen solubility, and ammonia toxicity. Thus the seasonality in the level of turbidity exhibited the most unique temporal fluctuations among all parameters measured had shown in Figure 5 of this work. Though, the opaque or transparency level of any water bodies determines the turbidity; hence seasonality influences its intensity.

However, the radar charts reveals the higher turbidity levels at the onset of wet season that is, from July to September, and this was agreed with the findings of Oladeji et al. (2021) who reported similar value of alkaline range. In Contrast, Aliyu et al. (2025), who reported 64.33 NTU at Gubi Dam within HJKY in the dry season. This occurs when the intense rainfall generates surface runoff carrying suspended sediments from agricultural fields and eroded riverbanks. Thus, the low turbidity levels were discovered during the late dry season between February and April in this study. This could be associated with the reduced runoff and sediment settling resulted in clearer waters.

Therefore, the site comparison reveals interesting patterns: Guri consistently recorded the highest turbidity, where by Nguru obtained lower. Thus, the low levels of turbidity indicate less alluvial soil and potash mining

in the area. Although, the higher value of 54.65 (FTU) was discovered by Dirisu and Olomukoro (2015). In this study, the gradient likely reflects the sites' positions within the wetland complex, with Guri receiving more sediment-laden inflows from upstream agricultural areas. Suggesting increased erosion or agricultural intensification in the catchment area. Though, Nguru Lake benefits from greater water residence time allowing sediment settling. In this work the electrical conductivity reported is lower than the study of Geidam et al. (2026), who reported much higher levels of EC in Nguru Lake; Godwin and Ansari (2016) who reported 1,329.00 $\mu\text{S}/\text{cm}$ at the peak of dry season in Aleiro Dam.

In the course of this study, during this lengthy period, it was uncovered that turbidity in the second wet season at 2025 was higher with 15-20% than the corresponding period in 2024, thus suggesting increased erosion or agricultural intensification in the catchment area. This was conformed to the study of Birnin-Yauri, (2015); Usman and Maitera (2025). This ecological devastation might be due to climate change and anthropogenic influences. Thus pollution deteriorates water quality and upsets ecological balance and causes greatest fatality to all living organisms. This is in lined with the findings of Usman and Maitera (2025). Also, implies that the trend concerns given the strong inverse association ($r = -0.978$) between turbidity and fish catches, indicating that sediment loading may be progressively impacting fishery productivity.

Seasonal Variations in Dissolved Oxygen Concentration

In this study, it was discovered that the variability in dissolved oxygen levels had showed characteristic seasonal patterns driven by the relationship between temperature, biological activity and hydrological conditions as depicted in Figure 6. More so, the higher DO levels were discovered during the cool dry season from December to February due to lower temperatures enhance oxygen solubility and reduced biological demand of consumes oxygen. Thus, increase in the concentration of D.O, leading to decline in physiological activity of aquatic animals. This was corroborated with the study of Waziri and Ogugbuaja (2010) in Gashua area: Adedeji et al. (2023) in Geriyo Lake and Upper Benue River in Adamawa, those reported that rise in temperature, decreases the D.O and as well raises BOD. Though, the lower D.O's levels ranged from 6.0 to 6.5 mg/L that occurred during the late wet season (August to October); these were resulted due to elevated temperatures, increased organic loading and reduced light penetration limit photosynthetic oxygen production.

However, the site-specificity patterns revealed that Nguru

Lake maintained the highest D.O levels whereas, Guri and Hadejia bears similar levels. This pattern likely reflects differences in water exchange rates, with Nguru's connection to the main river channel providing better oxygenation, while Hadejia's more stagnant conditions may experience periodic oxygen depletion. In addition the higher level of D.O could be due to the abundance of macrophytes in Nguru Lake and surrounding wetlands.

Nevertheless, this bi-annual study exposes that the low DO levels in 2025 as compared to the corresponding months in 2024; thus this revealing the declining trend that influences the fish survival during stressful periods. In accordance with Adamu and Wudil (2017), who reported that both the D.O and BOD could be influenced by seasonality. Hence the stream water quality is poorer than wetland systems (Godwin et al., 2023). Notwithstanding, all levels of BOD remained well below the EU threshold range between 3.0 and 6.0 mg/L for fisheries, indicating that the wetlands maintain good organic water quality despite the upward trend. This pattern may reflect differences in organic matter sources that increase pollution, with Nguru receiving more inputs from upstream settlements and agricultural areas, while Hadejia's more open waters allow greater dilution and oxygenation. In the wet season, the runoff carries organic matter from agricultural lands into the floodplains vegetation in the wetlands. Also, the lowest BOD levels were reported at the mid-dry season between January and March due to reduced inputs and slower decomposition rates prevail.

In this study, the monthly pH radar charts were demonstrated clear seasonal patterns that linked to photosynthetic activity and hydrological conditions had depicted in Figure 4. Therefore, the bi-annual comparison revealed that pH concentration in the second wet season at 2025 were consistent with 0.2 to 0.4 units lower than the corresponding months in 2024; thus suggesting increased organic loading or reduced buffering capacity in this work.

However, this stability is important for pH buffering and fish health, as rapid alkalinity fluctuations can stress aquatic organisms. Seasonal pH variations occurs due to increase in the rate of exploitation of alluvial clayey soil by the pottery influences the rise in the levels of pH and alkalinity (Aliyu et al. 2025). It suggests that organic decomposition contributes significantly to the carbonate budget. This worsens to reduced water volumes and intense photosynthetic activity by phytoplankton and macrophytes drive pH upward through carbon dioxide depletion.

Therefore, this trend warrants monitoring as pH levels

approaching 5.5 can stress fish populations, particularly during critical reproductive periods. This was attributed to the temperature and change in rainfall patterns of HNWs. This stability is important for pH buffering and fish health, as rapid alkalinity fluctuations can stress aquatic organisms. It suggests that organic decomposition contributes significantly to the carbonate budget. This was similarly reported by Aliyu et al. (2025). However, the highest monthly pH levels that ranged between 8.0 and 9.0 were reported at the peak dry season (February-April) in this work. Though, the pH discovered in this study is within alkaline nature. Unlike the findings reported by the Badejo et al. (2017) which is slightly close and below the neutral within the seasons. This was resulted due to decrease in water volumes and intense photosynthetic activities by phytoplankton and macrophytes drive pH upward through carbon dioxide depletion. Conversely, low pH levels were occurred in the early wet season between May and June due to runoff from surrounding agricultural lands introduces organic acids and buffered soils. Thus, the site-specific analysis reveals that Hadejia maintained the most stable pH a condition while Guri showed the widest fluctuations and this was aligned with the work of Gwana et al. (2017) in Alao Reservoir Maiduguri. Nevertheless, Nguru exhibited intermediate variability that is optimum for aquatic lives. This was commensurate with the work of Adamu and Wudil, (2017) who reported similar range in Watari Reservoir. This implies that these differences likely reflect varying degrees of buffering capacity with direct effects of alkalinity level could be due to influence of agricultural effluent, and biological activity at each site.

In this work, the total alkalinity values varies seasonally; thus the insight of the findings, that exposed seasonal fluctuations driven by moderate dilution effects and carbonate dynamics had shown in Figure 8. However, the higher alkalinity levels occurred during the late dry season that is from March to April. This was associated with the evaporative concentration and carbonate precipitation elevate buffering capacity. Although the degree of buffering varying with direct effects of alkalinity levels had depicted in **Table 4.26**; this can be influence by agricultural and biological activity at each site. This was also lower than the level of 405.06 mg/l reported by Olawale, (2016) and Badejo et al. (2017) during rainy season with 444.0 ± 23.09 mg/l in Gashua-River Yobe which were far above the tolerable level (25-100 mg/l) prescribed by FAO/WHO (2017). In this study, the lower level of alkalinity were reported at the peak of wet seasons between July and August due to the dilution effect of rainwater and reduces ionic concentrations.

In the studies of Aliyu et al. (2025) who have reported the desirable level of alkalinity ($6667 \pm 833 \text{ mg/l}$ in Gubi Reservoir; while lower value found in Lake Alao with 45.38 mg/l as reported by Gwana et al. (2017).

Impacts of Climate Change on Bi-Annual Trends of Water Quality Parameters

The bi-annual comparison between the first (2024) and second (2025) years of the study reveals vis-à-vis trends that may reflect climate change impacts on the wetland system in this study. The observed increases in temperature ($0.3\text{-}0.5^\circ\text{C}$), ammonia ($10\text{-}15\%$), and turbidity ($15\text{-}20\%$) between years suggest progressive environmental degradation that could accelerate under future climate scenarios. These entails that it is higher than subsequent corresponding months in 2024. It suggests the increasing nutrient loading from agricultural runoff or other sources and this is in lined with the studies of Juma'ah et al. 2025 in Watari Reservoir, Bagwai & Geidam et al. (2026) in Nguru Wetlands.

In this work, the ammonia concentrations in Figure 10 had presented distinct seasonal patterns linked to temperature, pH and organic matter inputs. Comparatively, the highest ammonia was observed in Hadejia, whereas Nguru and Guri with identical means of 0.26 ppm respectively.

Though, the higher ammonia levels of 0.40 mg/l were discovered in the hot dry season between March and April; and this could be resulted due to the elevated temperatures enhance decomposition rates and reduced water volumes limit dilution. Thus, the lower levels of 0.10 to 0.20 mg/l were recorded at the cool wet season from July to September: this was attributed to the dilution rate of substances and lower temperatures reduce ammonia production and toxicity. Although this study had revealed the ammonia recorded were within the recommended level. These values were below the findings of Badejo et al. (2017) who recorded 1.09 ± 0.13 in Gubi Reservoir; Gwana et al. (2017) also reported lower value of 0.14 as peak level in Lake Alao. This trend is concerning given the strong positive correlation ($r=0.834$) between temperature and ammonia, which amplifies toxicity risks during the hot season. Unlike the non/less toxic ammonia that is regarded as nitrate (NO_3) has reported within the safety margin of NIS/SON, (2015) & WHO (2017). This is in concord with the findings of Olawole, (2016); Aliyu et al. (2025) in Gubi Reservoir that exposed the value of 8.37 mg/l $8.28 \pm 0.06 \text{ mg/l}$; thus similar value reported by Hassan and Ibrahim (2021) in the wet season at Kwanar-Are Dam; also, less value reported by Dirisu and Olomukoro (2015) with 3.80 mg/l ; but Godwin et al. (2023) had reported lesser value of 0.13 . However, the higher nitrate

reported by Olubanjo and Adeleke, (2020) who recorded 36.47 mg/l at Osse River in Kogi State. Therefore, these findings were within the acceptable level for aquatic lives (WHO, 2017).

According to Ibrahim et al. (2025), climate change is projected to increase temperatures and alter rainfall patterns in the Hadejia-Nguru region, with potential consequences for water availability, quality and ecosystem services. The bi-annual data from this study provide an early indication of these changes, emphasizing the need for adaptive management strategies that build resilience into the wetland-fisheries system.

Management Implications

The seasonal and site-specific patterns identified in this study have several management implications. First, the wet season turbidity peaks suggest that sediment control measures, including riparian buffer establishment and watershed management, should be prioritized to protect fish habitat and feeding efficiency.

Second, the dry season ammonia and temperature maxima highlight the need for enhanced monitoring during this critical period, with management interventions such as maintaining minimum environmental flows to ensure adequate dilution and oxygenation. The site-specific differences suggest that management strategies should be tailored to local conditions, with particular attention to Guri's challenging environment.

Third, the bi-annual trends indicate that proactive measures are needed to address emerging threats before they reach critical levels. This could include nutrient management in agricultural areas, control of invasive species such as *Typha* (Abdullahi et al., 2019), and restoration of hydrological connectivity to maintain ecosystem functions.

Annual Fishing Effort and Sustainability Implications

In these findings, it was estimated annual fishing efforts across the three sites ranged from approximately 9,064 to 9,373 man-days per year, reflecting year-round fishing activity with pronounced seasonal peaks during the wet season had depicted in Table 2-4. This is in conformity with the studies of NOAA (2025); Thorson et al. (2025). Thus, the wet season increase in effort coincides with fish migration, spawning, and floodplain expansion, thereby intensifying pressure on vulnerable life stages. This was corroborated with the work of Wakil et al. (2021)

Consistently, the higher level of effort that coupled with the absence of closed seasons or effective effort controls; thus this was aligned with the finding of Abubakar et al. (2016),

Bwala 2020). Also current study explains the elevated fishing mortality rates observed across all stocks, it further suggest that current effort levels exceed the carrying capacity of the system. In accordance with FAO (2024), the global exploitation status for rapid biodiversity triage was accounted for 37% of stocks exceed maximum sustainable yield threshold. This is in turn rendering the fisheries biologically and economically unsustainable in the long term without management intervention. This is in lined with the report of Bwala (2020); Wakil et al. (2021); Geidam et al. (2025).

Economic Yield versus Biological Sustainability

In this study, the estimated annual economic yields demonstrate the substantial contribution of fisheries to livelihoods within the HNWs had presented in Table 5-7 However, the combined annual revenues exceeding N54million across the three water bodies, fisheries clearly represent a major source of income, food security, and employment. Hence, the high quality fish accounted for the largest share of total revenue, underscoring the economic importance of maintaining stock quality and size structure.

Therefore, the high economic returns must be interpreted cautiously, thus the current profitability appears to be achieved at the expense of stock health, as evidenced by excessive exploitation rates and truncated age structures. This is coincide with the study of Kawsar et al. (2023), who affirmed that the wellbeing status of a species depends on overall health and prosperity of the fish species that consist of both physical and behavioural state. As documented by SOFIS report of FAO (2022), the situation reflects a classic trade-off between short-term economic gains and long-term sustainability. Although, the continuous overexploitation is likely to reduce average fish size, degrade catch quality, and ultimately lower economic returns over time. This was commensurate with the study of Felix et al. (2018) and contracted with the report of federal department of fisheries and aquaculture (FDFA, 2015).

CONCLUSION

The 18-month bi-annual analysis of physicochemical parameters in the Hadejia-Nguru Wetlands reveals distinct seasonal patterns and site-specific characteristics that provide valuable insights for fisheries management. The wet season is characterized by dilution effects, increased turbidity, and moderate temperatures, while the dry season brings concentrated conditions, elevated temperatures, and increased ammonia toxicity risk.

Site comparison reveals that Nguru offers the most stable

conditions for fish production; Hadejia provides good buffering capacity but requires monitoring of ammonia levels, while Guri presents the most challenging conditions due to high temperatures, turbidity, and pH fluctuations.

The bi-annual trends observed between 2024 and 2025, including increases in temperature, ammonia, and turbidity; thus suggest progressive environmental changes that may reflect climate change impacts. The strong correlations between water quality parameters and fish catches demonstrate the sensitivity of wetland fisheries to environmental conditions and highlight the importance of integrated water resource management that considers fisheries requirements alongside other water uses.

The wetlands currently provide substantial economic benefits and food security, it is crucial to balance these short-term gains with long-term sustainability efforts. Encouraging fishers to adopt adaptive best conventional recommended fishing practices that align with sustainable practices can reduce fishing pressure, especially in response to climatic variability.

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Authors Contributions

I Abdulsalam Sani Nababa conducted this study in collaboration with the field assistants and participated in all the aspects in this research. Nababa, AS, Yusuf Z.A and Umaru, Joel have analyzed the data, while Geidam, Mustapha Baba & Nababa AS interpreted the results. Finally, all the authors proofread this article and reviewed the relevant literatures.

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