International Journal of Innovative Biosciences Research 14(1):91-100, Jan.-Mar., 2026

 www.seahipublications.org ISSN: 2467-8457

doi:10.5281/zenodo.19126505

Water Quality Characteristics and Fish Community Structure of Ashaka River, North-Eastern Nigeria

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ABSTRACT

Freshwater ecosystems in sub-Saharan Africa are increasingly subjected to anthropogenic disturbances, yet ecological baseline data for many inland rivers remain inadequate. This study evaluated the physicochemical characteristics and fish community structure of Ashaka River, Funakaye Local Government Area, Gombe State, Nigeria. Monthly sampling was conducted across four stations during the rainy season to capture spatial and temporal variability. Standard analytical procedures were used to determine water quality parameters, while fish specimens were collected from artisanal catches and identified to species level. Diversity indices and Fulton's condition factor were calculated to assess ecological integrity and fish health status. Dissolved oxygen ranged from 4.77 to 5.94 mg/L, while pH values were slightly acidic to near neutral (5.56–6.34). Electrical conductivity (70–120 µS/cm) showed significant temporal variation ($p < 0.05$), suggesting seasonal ionic enrichment associated with catchment runoff. Nitrate and ammonia concentrations remained below eutrophic thresholds. A total of seven fish species belonging to five families were recorded. The assemblage was dominated by Bagrus bayad and Clarias gariepinus, whereas Hydrocynus forskahlii and Mormyrus rume occurred in low abundance. The Shannon–Wiener diversity index ($H' = 1.53$) indicated moderate diversity but low species richness. Fulton's condition factor ranged from 0.79 to 0.96, suggesting moderate physiological well-being. The findings indicate that Ashaka River remains moderately productive but exhibits early signs of ecological simplification and anthropogenic influence. Continuous biomonitoring and sustainable fisheries management are recommended to prevent biodiversity decline.

Keywords: Freshwater ecology; fish diversity; water quality assessment; ecological indicators; Nigerian inland waters

INTRODUCTION

Freshwater ecosystems are among the most biodiverse yet most threatened ecosystems globally. Although they cover less than 1% of the Earth's surface, they support approximately 10% of known species and nearly one-third of vertebrate diversity (Reid et al., 2019; Tickner *et al.*, 2020). Despite their ecological and socio-economic importance, freshwater systems are experiencing faster biodiversity declines than terrestrial and marine ecosystems, largely due to anthropogenic pressures including pollution, habitat fragmentation, overexploitation, and climate change (IPBES, 2019; WWF, 2022).

Rivers are dynamic lotic systems whose ecological integrity depends on hydrological regime, physicochemical stability, and catchment land use (Allan & Castillo, 2007; Grill *et al.*, 2019). In tropical regions, strong seasonal rainfall patterns significantly influence nutrient transport, sediment load, and ionic composition of river systems (Datry *et al.*, 2018). Agricultural runoff, sand mining, and domestic effluent discharge can alter dissolved oxygen levels, electrical conductivity, and nutrient concentrations, thereby affecting aquatic biodiversity (Palmer *et al*., 2019; Vörösmarty *et al.*, 2021).

Water quality parameters such as temperature, dissolved oxygen (DO), pH, electrical conductivity (EC), nitrate, and ammonia directly influence fish metabolism, growth, reproduction, and survival (Boyd, 2020; Whitfield, 2017). Dissolved oxygen remains a primary determinant of fish distribution and abundance, particularly in tropical systems where elevated temperatures reduce oxygen solubility. Electrical conductivity often serves as an indicator of catchment disturbance and dissolved ion enrichment from runoff (Chapman, 2016). Excess nutrient inputs may stimulate primary productivity but can also trigger eutrophication and habitat degradation when concentrations exceed ecological thresholds (Dodds & Smith, 2016).

Fish assemblages are widely used as ecological indicators because they integrate environmental conditions over time and respond predictably to habitat alteration and water quality changes Pont *et al.*, 2018). Alterations in fish community composition, species dominance, and diversity indices often reflect cumulative ecological stress. In disturbed tropical rivers, tolerant and air-breathing species frequently dominate, while sensitive taxa decline, resulting in reduced species richness and biotic homogenization (Toussaint et al., 2016; Su et al., 2021).

In Nigeria, inland fisheries play a crucial role in food security, rural employment, and protein supply (FAO, 2022). However, many river systems in the northern region remain poorly studied despite increasing anthropogenic activities and climatic variability. Rivers within the Sudan–Sahel ecological zone are particularly vulnerable to hydrological instability, sedimentation, and nutrient fluctuations associated with seasonal rainfall (Oguntunde et al., 2018). Yet, comprehensive ecological assessments combining physicochemical parameters with fish community structure remain limited.

Ashaka River, located in Funakaye Local Government Area of Gombe State, supports artisanal fisheries, irrigation farming, and sand mining activities. These activities may alter water chemistry, substrate composition, and habitat complexity, potentially influencing fish assemblage dynamics. Establishing baseline ecological data is therefore essential for sustainable fisheries management, conservation planning, and long-term monitoring in northeastern Nigeria.

This study was designed to evaluate the physicochemical characteristics and determine fish species composition and diversity of Ashaka River, The results provide updated baseline information necessary for evidence-based management of inland water resources in Nigeria.

MATERIALS AND METHODS

Study Area

Ashaka River is located in Funakaye Local Government Area, Gombe State, northeastern Nigeria (approximately 10°56′–10°59′N and 11°24′–11°27′E). The river lies within the Sudan–Sahel ecological zone, characterized by marked wet and dry seasons. The rainy season typically extends from May to October, while the dry season spans November to April. Mean annual temperature ranges between 28°C and 40°C, with peak temperatures occurring between March and May.

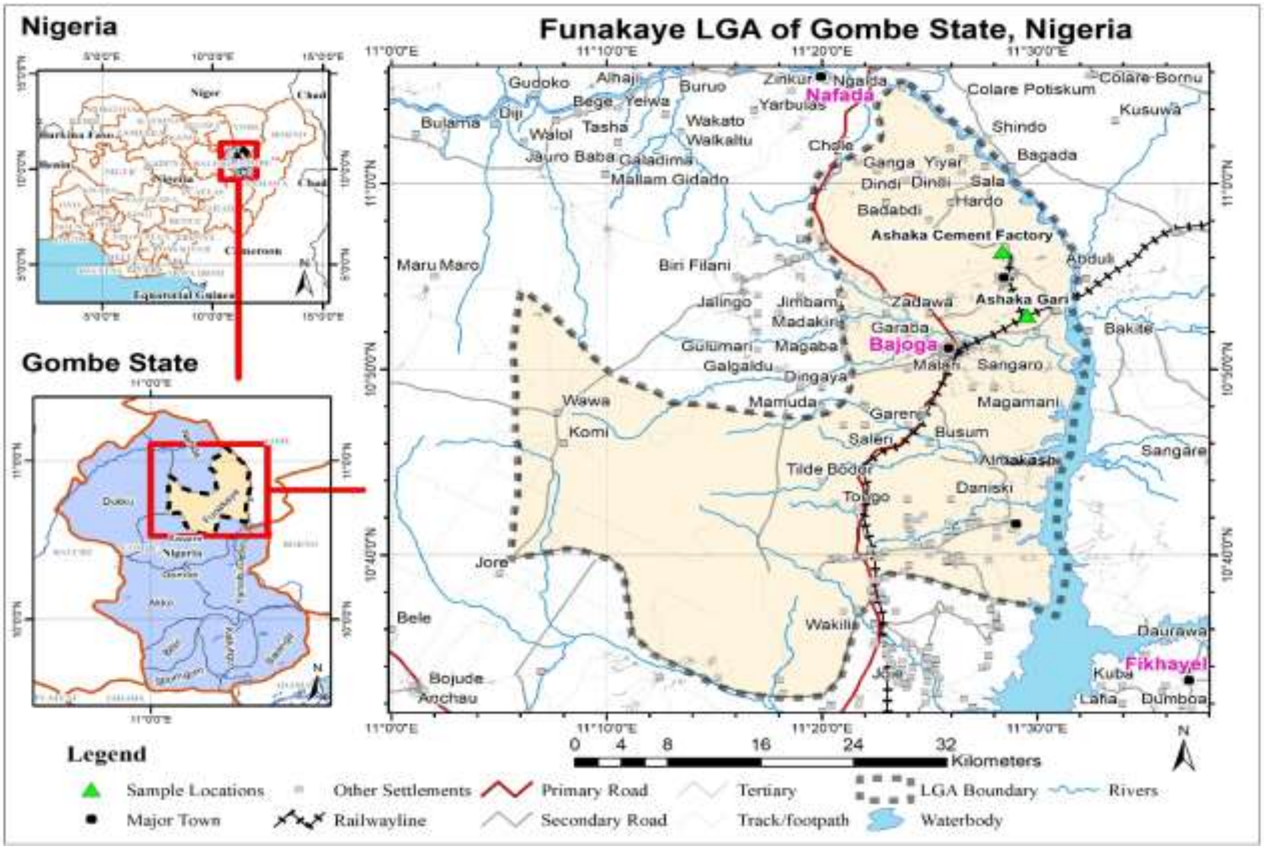

Figure 1: Map of Study Area showing Study/Sample Location

The river serves multiple socio-economic functions, including artisanal fisheries, irrigation farming, washing, livestock watering, and localized sand mining. Surrounding land use includes small-scale agriculture and settlement clusters, which may influence nutrient loading and sediment dynamics through surface runoff, particularly during the rainy season.

Sampling Design and Field Procedures

Four sampling stations were selected along the river based on observable gradients of anthropogenic disturbance:

I. Station A (Upstream reference zone) – Minimal direct anthropogenic influence.
II. Station B (Agricultural zone) – Adjacent to irrigated farmlands.
III. Station C (Sand mining zone) – Active sediment extraction area.
IV. Station D (Downstream settlement zone) – Close to human habitation and domestic activities.

Sampling was conducted monthly during the rainy season (six consecutive months) to capture temporal variability associated with hydrological fluctuations. At each station, three replicate measurements were taken for physicochemical parameters to ensure accuracy and reduce measurement error. All sampling was conducted between 08:00 and 11:00 h to minimize diel variability in dissolved oxygen and temperature.

Physicochemical Analysis

The following water quality parameters were measured in situ and in the laboratory following standard procedures (APHA, 2017; Boyd, 2020): Water temperature (°C): Measured using a calibrated digital thermometer. pH: Determined using a portable pH meter (pre-calibrated with buffer solutions). Dissolved Oxygen (DO, mg/L): Measured using a digital DO meter. Electrical Conductivity (EC, µS/cm): Measured using a conductivity meter. Total Dissolved Solids (TDS, mg/L): Determined using a TDS meter. Salinity (ppt): Derived from conductivity measurements. Nitrate (NO_3^-, mg/L): Determined using spectrophotometric methods. Ammonia (NH_3, mg/L): Determined using the phenate method. Water samples for nutrient analysis were collected in pre-cleaned polyethylene bottles, stored in ice chests at 4°C, and analyzed within 24 hours to prevent chemical alteration.

Fish Sampling and Identification

Fish samples were obtained from artisanal fishers operating at each sampling station using gill nets (mesh sizes 2–5 cm), cast nets, and lift nets. Sampling effort was standardized by recording fishing duration and gear type to reduce bias in species representation.

Specimens were sorted, counted, and identified to species level using standard taxonomic keys and reference guides (Froese & Pauly, 2023). Scientific nomenclature was verified using Fish Base. The following species were recorded: *Clarias gariepinus, Bagrus bayad, Oreochromis niloticus, Labeo coubie, Chrysichthys nigrodigitatus, Hydrocynus forskahlii, Mormyrus rume*. For each specimen, total length (cm) was measured using a measuring board, and body weight (g) was recorded using a digital balance (±0.01 g accuracy).

Diversity Indices

Fish community structure was assessed using the following indices:

I. Shannon–Wiener Diversity Index (H′)
II. Simpson's Diversity Index (1–D)
III. Margalef Richness Index (d)

Condition Factor

Fish physiological condition was assessed using Fulton's Condition Factor (K):

Where:

W = weight (g)

L = total length (cm)

Values of K close to or greater than 1 indicate good physiological condition, whereas lower values may suggest environmental stress or limited food availability (Froese, 2006).**Statistical Analysis**

Data were analyzed using SPSS (Version 25) and Microsoft Excel. (mean ± standard deviation) were computed. Analysis of Variance (ANOVA) was used to test spatial and temporal differences in water quality parameters. Statistical significance was accepted at $p \leq 0.05$.

RESULTS

Physicochemical Characteristics of Ashaka River

Table 1: Physicochemical Characteristics of Ashaka River

parameter	Site A	Site B	Site C	Site D	P-value
Electrical conductivity (μS/cm)	**79.08±21.89^{b}**	**79.00±22.92^{b}**	**84.67±22.49^{ab}**	**102.50±28.79^{a}**	**0.003***
Total Dissolved Solids (mg/L)	**48.29±16.59^{a}**	**46.67±11.40^{a}**	**45.04±11.12^{a}**	**45.04±12.70^{a}**	**0.799**
Dissolved Oxygen (mg/L)	**5.38±1.83^{a}**	**5.39±1.81^{a}**	**5.21±1.74^{a}**	**5.33±1.78^{a}**	**0.985**
Temperature (°C)	**29.22±1.88^{a}**	**28.36±2.38^{a}**	**28.63±1.75^{a}**	**28.63±1.58^{a}**	**0.477**
Salinity (mg/L)	**49.71±18.17^{a}**	**49.71±16.13^{a}**	**52.42±13.33^{a}**	**53.17±15.08^{a}**	**0.815**
Ph	**5.86±1.37^{a}**	**5.85±1.34^{a}**	**5.71±1.43^{a}**	**5.83±1.33^{a}**	**0.981**
Ammonia (NH_3) (mg/L)	**0.45±0.25^{a}**	**0.43±0.25^{a}**	**0.46±0.28^{a}**	**0.42±0.22^{a}**	**0.939**
Nitrate (mg/L)	**0.45±0.25^{a}**	**0.43±0.25^{a}**	**0.46±0.28^{a}**	**0.42±0.22^{a}**	**0.939**

Temperature

Water temperature ranged from 28.0 to 40.0 °C, with higher values recorded during peak rainfall months. Although minor spatial variations were observed among stations, differences were not statistically significant ($p > 0.05$). Elevated temperatures corresponded with reduced dissolved oxygen concentrations, reflecting the inverse relationship between temperature and oxygen solubility in tropical freshwater systems (Boyd, 2020).

pH

The river exhibited slightly acidic to near-neutral conditions, with pH values ranging from 5.56 to 6.34. No significant spatial or temporal differences were observed ($p > 0.05$). The slightly acidic condition may be influenced by organic matter decomposition and surface runoff during the rainy season.

Dissolved Oxygen (DO)

Dissolved oxygen concentrations ranged from 4.77 to 5.94 mg/L. Although values fluctuated across months, variations were not statistically significant ($p > 0.05$). The recorded DO levels fall within the lower acceptable range for tropical freshwater fish survival. Stations with higher anthropogenic activity (Stations C and D) exhibited relatively lower DO values compared to the upstream reference station.

Electrical Conductivity (EC)

Electrical conductivity ranged from 70 to 120 µS/cm. Significant temporal variation was observed ($p < 0.05$), with higher values recorded during peak rainfall months. The increase in EC likely reflects enhanced ionic input from agricultural runoff and sediment disturbance associated with sand mining activities.

Total Dissolved Solids (TDS) and Salinity

TDS values ranged between 42 and 49 mg/L, while salinity remained low throughout the sampling period. Neither parameter showed significant spatial or temporal variation ($p > 0.05$). The low TDS values indicate minimal dissolved pollution input and confirm the freshwater nature of the river.

Nutrient Concentrations

Nitrate and ammonia concentrations remained below 0.5 mg/L across all stations. No significant differences were observed ($p > 0.05$). These values are below eutrophic thresholds and suggest limited nutrient enrichment during the study period.

Fish Species Composition and Abundance

A total of 3,152 fish individuals representing seven species and five families were recorded during the study period. The species composition is presented in Table 2

Table 2: Fish Species Identified in Ashaka River

S/N	English Name	Local Name (Hausa)	Scientific Identification	Family
1	African Catfish	Qawara	*Clarias gariepinus*	Clariidae
2	African Carp	Qaraya	*Labeo coubie*	Cyprinidae
3	Bagrid Catfish	Tarwada	*Bagrus bayad*	Bagridae
4	Moonfish / Silver Catfish	Kurungu	*Chrysichthys nigrodigitatus*	Claroteidae
5	Mormyrid (Elephant-snout Fish)	Bordo	*Mormyrus rume*	Mormyridae
6	Nile Tilapia	Karfasà	*Oreochromis nilotitus*	Cichlidae
7	Tiger Fish	Ragon Ruwa	*Hydrocynus forskahlii*	Alestidae

The fish assemblage was numerically dominated by, *Bagrus bayad, Clarias gariepinus* These two species collectively accounted for more than 50% of total individuals captured. Moderate representation was observed for *Oreochromis niloticus* and *Chrysichthys nigrodigitatus* while the low abundance species included *Hydrocynus forskahlii* and *Mormyrus rume* Spatially, Station A (upstream reference) exhibited relatively higher species richness compared to downstream stations. Stations C and D, characterized by sand mining and settlement activities, showed reduced abundance of sensitive taxa.

Fish Community Diversity

Table 3: Diversity indices computed for the entire study period are summarized below:

Diversity indices	Values
Shannon–Wiener Index (H′):	1.53
Simpson's Index (1–D)	0.755
Margalef Richness Index (d):	0.7448
Pielou's Evenness (J′):	0.7864

The Shannon index indicates moderate diversity, while the relatively low Margalef richness value suggests limited species richness. The evenness index indicates a moderately balanced distribution of individuals among species, although numerical dominance by a few taxa was evident.

Condition Factor (K)

Fulton's condition factor ranged from 0.79 to 0.96 across species. The highest mean K value was recorded in *Clarias gariepinus*, while the lowest was observed in *Mormyrus rume*. Most species exhibited K values below 1, suggesting moderate physiological condition. No extreme deviations indicating severe environmental stress were observed. Variations in condition factor corresponded with species-specific ecological adaptations and feeding strategies.

DISCUSSION

Physicochemical Characteristics

The physicochemical parameters recorded in Ashaka River indicate a moderately stable freshwater system, although seasonal fluctuations reflect hydrological and anthropogenic influences. The temperature range is typical of tropical rivers within the Sudan–Sahel ecological zone and aligns with values reported for northern Nigerian inland waters (Oguntunde *et al.,* 2018; Boyd, 2020). Elevated temperatures during peak rainfall months likely reduced dissolved oxygen solubility, as reflected in the inverse relationship observed between temperature and DO concentrations. In tropical systems, prolonged exposure to elevated temperature can increase metabolic demand in fish while simultaneously reducing oxygen availability, potentially creating suboptimal physiological conditions (Whitfield, 2017; Boyd, 2020).

Dissolved oxygen values were within the lower acceptable limits for tropical freshwater fish survival. Although not critically low, values approaching 5 mg/L may impose mild physiological stress, particularly for sensitive species (Chapman, 2016). The relatively lower DO levels observed at stations influenced by sand mining and settlement activities suggest localized organic loading or increased sediment disturbance. Similar patterns have been documented in rivers experiencing moderate anthropogenic pressure, where organic inputs and reduced water mixing lower oxygen availability (Vörösmarty *et al.,* 2021).

Electrical conductivity showed significant temporal variation, with higher values during peak rainfall. Increased conductivity during rainy months is commonly attributed to surface runoff transporting dissolved ions from agricultural lands into river systems (Dodds & Smith, 2016). Although the recorded EC values remain within freshwater limits, the significant seasonal increase suggests catchment-derived ionic enrichment. Conductivity has been widely used as an indicator of watershed disturbance and anthropogenic influence in tropical rivers (Palmer et al., 2019).

Nitrate and ammonia concentrations remained below eutrophic thresholds (<0.5 mg/L), indicating limited nutrient pollution during the study period. This suggests that while agricultural activities occur along the river, nutrient loading has not yet reached levels associated with eutrophication. However, continued monitoring is necessary, as nutrient accumulation can occur progressively in river systems under increasing land-use pressure (Tickner *et al.,* 2020).

The physicochemical characteristics indicate that Ashaka River is not severely degraded but is experiencing early signals of anthropogenic influence, particularly through seasonal ionic enrichment and localized oxygen reduction.

Fish Community Structure and Dominance Patterns

The fish assemblage comprised seven species from five families, reflecting relatively low species richness compared to larger Nigerian river systems. The moderate Shannon–Wiener diversity index (H′ = 1.53) suggests a community structure that is neither highly diverse nor severely impoverished. However, the low Margalef richness index indicates limited taxonomic representation.

The dominance of *Clarias gariepinus* and *Bagrus bayad* is ecologically significant. These species are known for their tolerance to fluctuating environmental conditions, including low dissolved oxygen and habitat disturbance. In particular, *Clarias gariepinus* possesses accessory air-breathing organs that enable survival under hypoxic conditions, giving it a competitive advantage in disturbed habitats (Froese & Pauly, 2023). Dominance by tolerant taxa is commonly reported in moderately impacted tropical rivers (Pont *et al.,* 2018; Su *et al.,* 2021).

Conversely, the low abundance *of Hydrocynus forskahlii* and *Mormyrus rume* may reflect sensitivity to habitat disturbance, sedimentation, or reduced prey availability. Tigerfish species typically require well-oxygenated, flowing waters and are often reduced in abundance in systems experiencing environmental stress (Toussaint *et al.,* 2016). Similarly, mormyrids are known to depend on structurally complex habitats and stable water quality conditions.

The observed assemblage pattern suggests moderate ecological simplification, where species capable of tolerating environmental fluctuations become numerically dominant while more specialized taxa decline. Such biotic homogenization has been identified as a major consequence of freshwater ecosystem disturbance globally (Reid *et al.,* 2019; Tickner *et al.,* 2020).

Diversity Indices

The Shannon index value (1.53) indicates moderate diversity but does not reflect high ecological complexity. In comparison, relatively undisturbed tropical rivers often report Shannon values exceeding 2.0 (Pont *et al.,* 2018). The Simpson index (0.755) further confirms moderate dominance by a few species.

The relatively high evenness index (0.7864) suggests that although richness is limited, individuals are moderately distributed among species. However, evenness alone does not compensate for low species richness. Reduced richness may be associated with seasonal hydrological constraints, fishing pressure, habitat alteration from sand mining, or limited floodplain connectivity.

Hydrological variability in Sudan–Sahel rivers can strongly influence fish recruitment and species persistence, particularly during irregular flood regimes (Oguntunde *et al.,* 2018). Therefore, both climatic variability and anthropogenic disturbance likely contribute to the observed diversity pattern.

Condition Factor

Fulton’s condition factor values (0.79–0.96) indicate moderate physiological condition across species. Values below 1 suggest that while fish are surviving and reproducing, environmental conditions may not be optimal. The relatively higher condition factor observed in Clarias gariepinus further supports its ecological resilience and adaptability to fluctuating environmental conditions.

Lower condition factor values recorded for *Mormyrus rume* may indicate greater sensitivity to habitat quality or food resource limitations. Condition factor has been widely used as an indirect measure of habitat suitability and energy reserve status in freshwater fish (Froese, 2006). The condition factor results align with the diversity findings, suggesting a moderately productive ecosystem that is not severely degraded but may be under gradual ecological pressure.

Management Implications

The combined physicochemical and biological evidence suggests that Ashaka River remains functionally productive but is showing early indicators of ecological simplification. Dominance by tolerant taxa, moderate diversity values, and slight reductions in dissolved oxygen at disturbed stations point toward increasing anthropogenic influence.

Proactive management strategies including regulation of sand mining, establishment of riparian buffer zones, and seasonal fisheries management are recommended to prevent further biodiversity decline. Long-term ecological monitoring integrating hydrological, chemical, and biological indicators will be essential for sustainable river management in northeastern Nigeria.

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