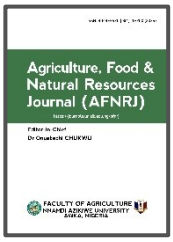
Agr. Foo. Nat. Res. J. Volume 5, Issue 2, Page: 108-116

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj



Original Article

Fish diversity and community structure of Ona lake, Asaba, Nigeria

OPEN ACCESS

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DOI: https://doi.org/10.5281/zenodo.23124254

Editor: *Onyekachi CHUKWU, Nnamdi Azikiwe University, NIGERIA*

Received: *July 29, 2026*
Accepted: *September 4, 2026*
Available online: *September 30, 2026*

Peer-review: *Externally peer-reviewed*

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Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support.*

ABSTRACT

Freshwater ecosystems in West Africa are threatened by anthropogenic disturbances, necessitating baseline biodiversity assessments for conservation planning. This study evaluated fish diversity and species composition in Ona Lake, Asaba, Delta State, Nigeria. Five stations representing habitat gradients were sampled: S1 Inlet, S2 Vegetated, S3 Open Water, S4 Shallow, and S5 Outlet. Monofilament gill nets (30-70 mm), cast nets (6 mm mesh), and baited traps were deployed for 12 hours overnight during sampling. A total of 2,811 individuals representing 18 species across 14 families were recorded. Cichlidae (815) and Clariidae (507) were dominant, with Oreochromis niloticus and Clarias gariepinus the most abundant species. Shannon–Wiener diversity (H') ranged from 1.34 to 2.04, indicating moderate diversity, with the highest value at S2. Simpson's index ranged from 0.73 to 0.87, while evenness (0.96-0.98) indicated balanced species distribution. Dissolved oxygen was positively associated with species richness ($r = 0.89$, $p < 0.0001$), whereas nitrate was negatively associated with evenness ($r = -0.93$, $p < 0.0001$) and diversity ($r = -0.91$, $p < 0.0001$). Reduced oxygen and elevated nutrients were associated with dominance by tolerant taxa, particularly Oreochromis niloticus and Clarias gariepinus. Analysis of variance showed significant station differences in mean length ($F = 13.505$, $p < 0.0001$), mean weight ($F = 3.035$, $p = 0.0188$), and abundance ($F = 5.513$, $p = 0.0003$), while month was not significant during February–April 2025. Despite healthy biodiversity indices, spatial variation suggests emerging anthropogenic pressures. These findings provide baseline data for conservation planning and sustainable fisheries management in Ona Lake.

KEYWORDS: *Freshwater ecosystem, Ichthyofaunal composition, Species richness, Shannon-Wiener index*

INTRODUCTION

In Nigeria, inland artisanal fisheries employ an estimated 1.5 million people and contribute approximately 20% of domestic fish production (FAO, 2022). Small-scale fisheries remain critical for food security in rural communities. Globally, small-scale fisheries employ millions of people and are significant sources of nutrition, food security, and livelihood, catering for many people (FAO, 2018). Freshwater ecosystems are essential for supporting biodiversity, fisheries, and community livelihoods, especially in developing regions such as Nigeria (Offem *et al*., 2009). Inland water bodies, including lakes, are reservoirs of diverse fish species that contribute significantly to food security and rural economies. Species richness and abundance in freshwater ecosystems are influenced by interacting abiotic, biotic and spatial-habitat processes. Spatial connectivity influences colonization and dispersal, while biotic processes such as foraging, predation and reproduction shape local assemblages (Sheaves *et al*., 2015). Temperature, Dissolved Oxygen, Nutrient concentrations, etc. make up the abiotic factors that influence ecological processes in Freshwater ecosystems (Rau *et al*., 2019). However, fluctuations of these abiotic factors and undeniable anthropogenic stressors created by pollution, habitat destruction, and overfishing increasingly threaten these ecosystems (Ji, 2008). Anthropogenic stressors including

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nutrient enrichment and habitat modification are major threats to freshwater fish assemblages in West African lakes (Adeyemi and Ogunfowokan, 2013 and Adewale *et al*., 2024). Length-weight relationships provide information on fish condition and growth patterns, which are useful indicators of environmental stress in freshwater systems Froese 2006. In this study, LWR was used to assess fish condition across pollution gradients in Ona Lake.

The freshwater fish contribute significantly to the livelihood of the people, especially in the developing world (Sayer *et al*., 2018). Globally, 25% of freshwater fish species are assessed as threatened with extinction, with habitat loss, pollution, overexploitation, invasive species and climate-related pressures as primary drivers (Dudgeon 2012; IUCN, 2023). In West Africa, declining water quality is a key concern for inland fisheries. With the loss of freshwater biodiversity, their essential support to human well-being will be lost too (Albert *et al*., 2020). Nigeria has approximately 270 described freshwater fish species, with new records and taxonomic revisions on-going (FishBase, 2025). These species inhabit freshwater bodies such as streams, reservoirs, lakes and rivers which make up about 12% of Nigeria's total surface area as reported by Nazeef & Abubakar (2013). State, Nigeria. Field observations during Feb–Apr 2025 noted surrounding farmland, riparian vegetation and encroaching urban development. Despite its socio-economic relevance to surrounding communities, the fish biodiversity of the lake remains poorly documented. Specifically, diversity indices and biometric condition were used to identify pollution-impacted zones requiring targeted management, and to establish baseline metrics for future monitoring of Ona Lake.

This study assessed spatial variation in fish diversity and biometric condition in relation to selected water quality parameters in Ona Lake during Feb–Apr 2025, to provide baseline data for local management.

MATERIALS AND METHOD

Study Area

Ona Lake 6°13′N, 6°41′E is a shallow 2.2 km² lake with max depth 3.2 m. It receives input from seasonal streams at S1 and drains at S5. Surrounding land use includes farmland and low-density housing. It supports artisanal fishing and serves as a water source for surrounding communities. Ona Lake is located within Asaba, the capital city of Delta

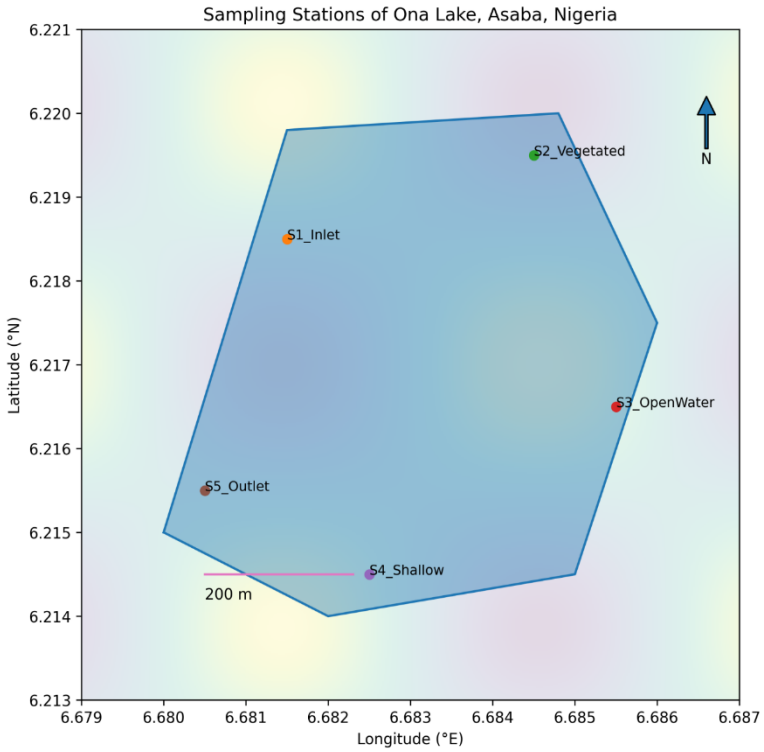


Figure 1. Sampling stations and digitized boundary of Ona Lake, Asaba, Delta State, Nigeria.

Five sampling stations (S1–S5) were spatially distributed to represent inlet, vegetated margin, open water, shallow bank, and outlet zones. The map is projected in geographic coordinates (WGS 84; EPSG:4326). Scale bar represents 200 m.

Sampling Design

Five sampling stations (S1 – S5) representing contrasting habitat and hydrological conditions within Ona Lake. The geographic coordinates of each station were recorded using a handheld GPS as presented in Figure 1. Fish samples were collected monthly between February and April 2025. Sampling was undertaken on (1st and 15th of each sampling month) at each station. At every sampling occasion, the same standardized fishing effort was applied across stations, comprising 3 gill nets 30 m each, 10 cast net throws, and 5 traps were set for 12 h, providing standardized effort. Gear effort was maintained as consistently as possible among stations and sampling occasions. Because the fishing gears differ in size and species selectivity, catches were retained and recorded by gear type before being pooled for the description of overall fish composition.

Fish Sampling, Preservation and Identification

Various fishing gears, including monofilament gill nets (mesh sizes 30–70 mm), cast nets, and traditional traps, were employed. Fish were preserved in 10% neutral buffered formalin for 48 h then transferred to 70% ethanol. Identification followed Olaosebikan and Raji (2013). Voucher specimens were deposited at Dennis Osadebay University Fisheries Laboratory. Each fish was measured (standard length in cm) and weighed (g) using a Metre rule and the Camry Analogue Fish Scale.

Data Analysis

Species diversity indices such as Shannon-Wiener Index (H′), Simpson's Index (D) and Evenness (E) were calculated using the following:

Species Richness (S): total number of different species

Shannon-Wiener Index (H′):

$$H' = -\sum_{i=1}^{S} Pi \ln Pi \quad (1)$$

where *pi* is the proportion of individuals belonging to species *i*

Simpson's Diversity Index (D):

$$D = 1 - \sum_{i=1}^{S} Pi^2 \quad (2)$$

Evenness (E):

$$E = \frac{H'}{\ln S} \quad (3)$$

Abundance was calculated as the total number of individuals per species

Relative abundance (%):

$$RA_i = \left(\frac{n_i}{N}\right) \times 100 \quad (4)$$

where n_i is the number of individuals of species *i*, and *N* is the total number of individuals.

Mean Biometric Parameters of Fish by Station and Months in Ona Lake were subjected to a Two-way analysis of variance, Feb–Apr 2025. Tukey Post-hoc Test was use to separate the means, and Pearson correlation coefficient was used to assess the relationship between length and weight.

LWR was modeled as $W = aL^b$ using log-transformed data. Parameter b was tested against 3 using t-test. Pearson correlation was reported to show strength of length-weight association.

RESULTS

A total of 2,811 fish representing 18 species and 14 families. Cichlidae accounted for 815 individuals, Clariidae for 507 and Mochokidae for 185. The two most abundant species were *Oreochromis niloticus* (363) and *Clarias gariepinus* (344). The species with the lowest relative abundance was *Hepsetus odoe* (n = 10, 0.78%). S3 (open water) had highest richness S = 18, which may be related to greater habitat heterogeneity in open water, though direct habitat data were not collected.

Spatial Distribution

Station S3 (open water) had the highest species richness (n = 18), while Station S1 (inlet zone) recorded the highest abundance. Figure 2 shows the relative species distribution by station. Mean species richness ranged from 4.0 to 8.0, while mean Shannon diversity ranged from 1.341 to 2.044 (Table 2). These metrics demonstrate spatial variation in the observed assemblage but do not independently establish ecological health or habitat heterogeneity.

S1 (Inlet) displays the most compromised water quality profile with elevated nutrient levels (Nitrate average ~1.81 mg/L), high sediment loads (TSS average ~34.5 mg/L), and depressed Dissolved Oxygen (~4.72 mg/L). S3 (Open Water) functions as the healthiest section of the system, achieving optimal Dissolved Oxygen levels (~6.80 mg/L) alongside minimal algal levels (Chla ~4.43 µg/L). As water travels from the Inlet (S1) through the Vegetated zone (S2) toward the Open Water (S3), both Nitrate and TSS show sharp drops, indicating active ecological filtration (Figure 3).

Table 1: Summary of fish species composition in Ona Lake

Species	Family	Abundance	Relative abundance (%)
Oreochromis niloticus	Cichlidae	363	12.91
Clarias gariepinus	Clariidae	344	12.24
Hemichromis fasciatus	Cichlidae	232	8.25
Tilapia zillii	Cichlidae	220	7.83
Heterobranchus bidorsalis	Clariidae	163	5.80
Gymnarchus niloticus	Gymnarchidae	159	5.66
Malapterurus electricus	Malapteruridae	157	5.59
Heterotis niloticus	Arapaimidae	154	5.48
Labeo coubie	Cyprinidae	140	4.98
Alestes baremose	Alestidae	135	4.80
Citharinus citharius	Citharinidae	123	4.38
Mormyrus rume	Mormyridae	118	4.20
Parachanna africana	Channidae	116	4.13
Synodontis nigrita	Mochokidae	115	4.09
Polypterus senegalus	Polypteridae	77	2.74
Distichodus niloticus	Distichodontidae	75	2.67
Synodontis clarias	Mochokidae	70	2.49
Bagrus bajad	Bagridae	50	1.78

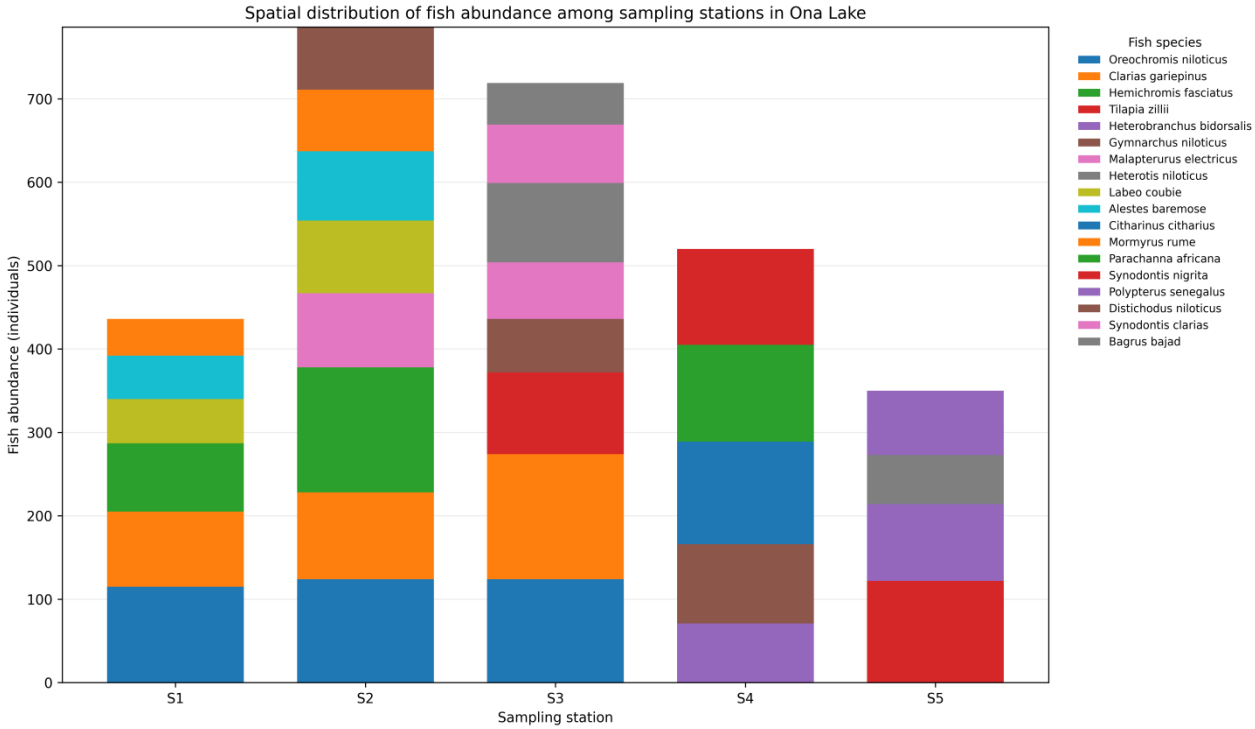


Figure 2: Spatial distribution of fish abundance among the five sampling stations of Ona Lake, Asaba, Delta State, Nigeria

Table 2: Station-Level Fish Diversity Indices of Ona Lake

Station	Mean abundance	Mean richness	Shannon H′	Simpson 1−D	Evenness
S1	72.67	6.00	1.725	0.811	0.963
S2	131.00	8.00	2.044	0.866	0.983
S3	119.83	8.00	2.015	0.858	0.969
S4	86.67	5.00	1.582	0.790	0.983
S5	58.33	4.00	1.341	0.727	0.967

Where: S1=Inlet, S2=Vegetated, S3= Open Water, S4= Shallow, and S5= Outlet.

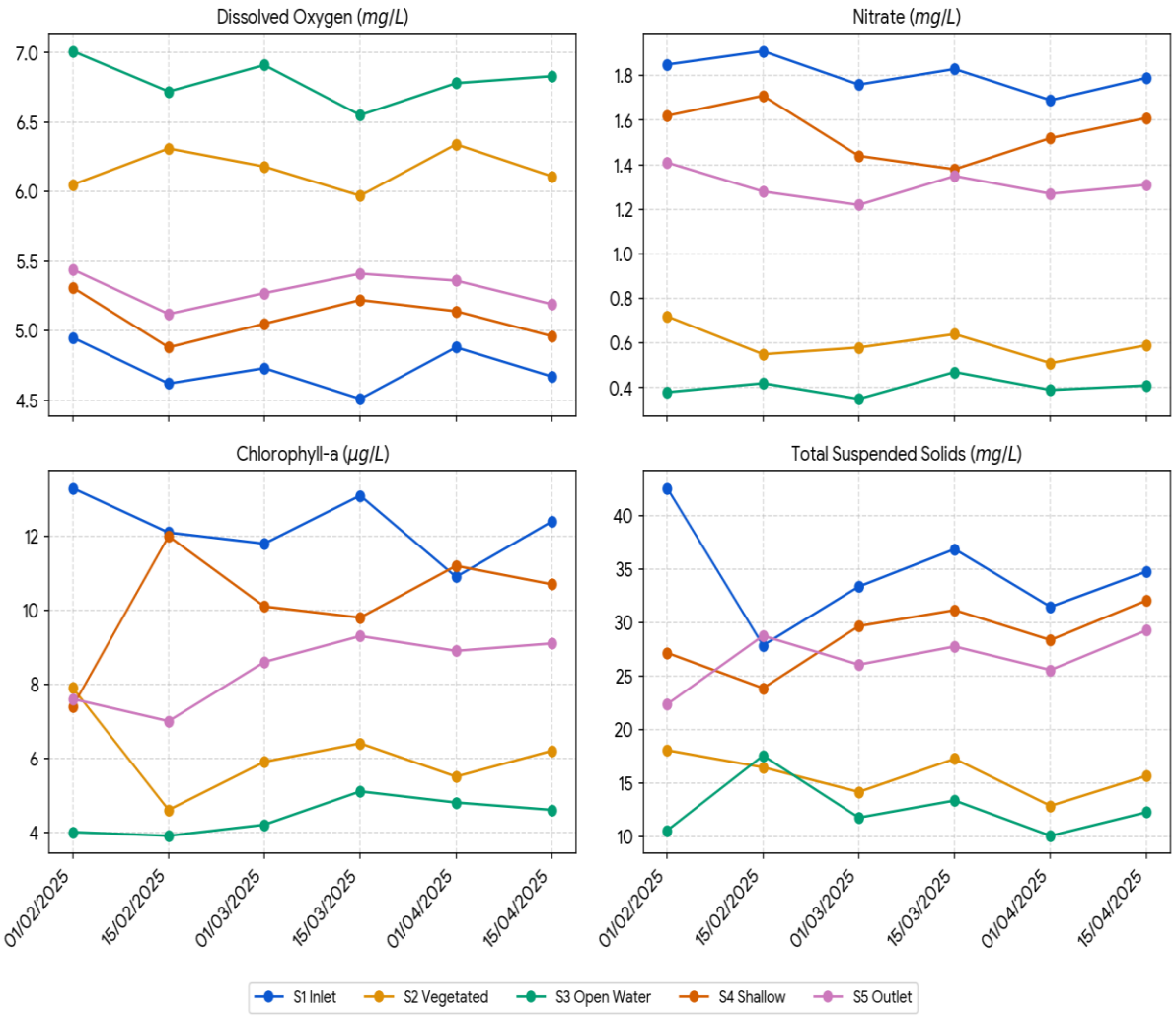


Figure 3: Multi-panel visualization tracking water quality trends across sampling stations (S1-S5)

DISCUSSION

The Moderate diversity indices suggest Ona Lake has a moderately structured assemblage, but do not independently confirm ecosystem health. This is consistent with the report of Magurran (2004) on tropical freshwater systems. Comparable dominance of Cichlidae has been reported in Nigerian freshwater systems (Ataguba *et al*., 2014; Dan-kishiya *et al*., 2013). Cichlidae and Clariidae were dominant. This pattern is consistent with literature reports of their tolerance to eutrophic conditions, though trophic data were not collected in this study. Dan-kishiya *et al* (2013) reported that family Cichlidae is the most dominant in quite a number of Nigeria reservoirs and attributed this dominance to their ability to tolerate wide range of environments and ability to utilize a wide range of foods in the lower trophic level as herbivores, as well as their high fecundity and prolific nature (Awiti, 2011; Ataguba *et al*., 2014). This position also aligns with the views of Offem *et al*.

(2009) that fish community of the Cross River is dominated by juvenile size classes of fish species from the families Bagridae, Cichlidae, and Clariidae, with Bagridae and Cichlidae specially adapted to living in the river stretch in the forest area and Clariidae in grassland savanna. and Komolafe & Arawomo (2008) report that family Cichlidae, comprising four species (*Hemichromis faciatus*, *Pelmatochromis taeniatus*, *Sarotherodon galilaeus* and *Tilapia zillii*) constituted the largest percentage (59.6%) of fish caught in the recently impounded Osinmo reservoir in Ejigbo Local Government area of Osun State, followed by families Clariidae, Channidae and Hepsetidae.

The prevalence of *Oreochromis niloticus* and *Clarias gariepinus* may be attributed to ecological plasticity, broad dietary range, and high fecundity. These species are known to tolerate fluctuating environmental conditions (Awiti, 2011).

Spatial variation in diversity likely reflects habitat heterogeneity and anthropogenic influence. Reduced diversity at Station S5 may indicate localized disturbance, possibly from shoreline activities. According to Shi and Czerniawski (2025), Habitat heterogeneity has long been recognized as a major driver of biodiversity patterns in aquatic ecosystems because heterogeneous environments provide a greater variety of microhabitats, niches, and resources, supporting more species and functional groups. Research shows that variation in abiotic factors such as substrate complexity, vegetative cover, and water quality creates spatial variation in fish communities, often resulting in distinct assemblages in structurally diverse areas. For example, environmental heterogeneity was found to significantly influence fish community composition and species distribution patterns in riverine ecosystems, where sites with complex physical habitats supported more diverse fish assemblies than simplified environments (Shi and Czerniawski 2025). Also, Adeogun *et al*. (2020) and Xie *et al*. (2025) are of the view that more heterogeneous habitats sustain higher diversity because they offer more ecological niches and reduce competitive exclusion. In aquatic systems, this trend is evident where differences in shoreline structure, submerged vegetation, and littoral features correspond with variation in fish richness and assemblage composition.

Although moderate diversity indices suggest a moderately structured assemblage, on-going urban expansion around Asaba presents long-term risks. Similar declines in freshwater biodiversity due to anthropogenic pressure have been reported in other Nigerian water bodies (Essien-Ibok & Isemin, 2020; Obiyor *et al*., 2017). Direct human alterations of shoreline and littoral habitats such as shoreline armouring, removal of vegetation, bank stabilization, or construction have been empirically associated with decreases in fish species richness and diversity. A watershed-scale analysis demonstrated that residential development features (docks, boathouses, break walls) correlated negatively with species richness and altered local fish assemblages, even at small spatial scales, indicating that anthropogenic disturbance can reduce diversity at impacted sites (Lange, 1999). Similarly, studies in estuarine systems showed that proximity to anthropogenically modified shorelines, such as armoured or engineered banks, corresponded with reduced fish diversity compared to areas near structurally complex natural habitats such as mangroves. This pattern highlights how human shoreline modification can have pervasive ecological effects that extend into adjacent aquatic habitats by degrading habitat quality and reducing available niches for sensitive species (Henderson *et al., 2019*).

Station S3's high species richness may be attributed to greater habitat heterogeneity and lower disturbance. However, the reduced diversity in S5 could signal overfishing or pollution. This does not differ from the views of Onoja *et al*. (2026) and Adewale *et al*. (2024) on freshwater ecosystems in Nigeria being under significant pressure from urbanization, overfishing, pollution, and climate change culminating in declined fish diversity and abundance. According to Obiyor *et al*. (2017) the faunal diversity of Otamiri River (a tributary of Imo River) was obviously affected by the anthropogenic activities of the area. Essien-Ibok & Isemin (2020) also reported a decline in the fish species of Cross River, Imo River and Qua Iboe River arising from a combination of many factors including: climate change, poor management among others. Other recognised threats to freshwater biodiversity in the region include pollution, habitat loss, and overexploitation for human consumption.

Dissolved oxygen was significantly associated with species richness $r = 0.89$, $p < .0001$ in Ona Lake. Oxygen availability determines aerobic scope and metabolic performance, thereby influencing habitat occupancy. Global analyses confirm expanding hypoxia in freshwater ecosystems driven by nutrient enrichment and warming. The positive association between oxygen concentration and species richness observed in this study reinforces evidence that oxygen depletion simplifies community structure. Dissolved oxygen (DO) is a fundamental driver of fish assemblages because it governs aerobic metabolism, habitat suitability, and physiological performance (Adeogun *et al*., 2020). Hypoxic or low-oxygen conditions alter spatial distribution patterns by excluding sensitive species and favouring tolerant taxa, which in turn reduces species richness and overall community diversity. A broad review of hypoxia impacts shows that changes in DO markedly affect survival, growth, recruitment, and distribution of pelagic organisms, including fish, with profound consequences for food-web structure and ecosystem functioning (Ekau *et al*. 2010; Breitburg *et al*. 2018). Low DO thresholds commonly result in avoidance behaviour whereby mobile fish species redistribute to oxygenated waters to meet physiological requirements, restructuring assemblages spatially (Ekau *et al*. 2010). According to Zhang *et al*. (2024) and Bhandari *et al*. (2026), higher DO levels were associated with richer fish communities, reinforcing the view that oxygen availability supports coexistence of a greater number of species.

Empirical studies consistently demonstrate that hypoxic conditions lead to declines in species richness and localized reductions in fish diversity. Research on demersal fishes in

eutrophic estuaries showed that areas experiencing low dissolved oxygen (<4 mg L^{-1}) exhibited significant reductions in species richness and abundance, and fish avoided hypoxic zones altogether, underscoring how low oxygen constrains distribution (Walsh *et al*. 2023). A separate investigation using environmental DNA metrics found that fish community structure in river segments was significantly affected by DO and chemical oxygen demand, highlighting that reduced oxygen due to organic matter decomposition was a primary factor limiting the survival and activity of oxygen-demanding species (Wang *et al*. 2023).

Research in estuarine systems has revealed a threshold-dependent relationship between DO and fish diversity. In areas where bottom oxygen was reduced to hypoxic levels, species diversity indices (e.g., Shannon and Simpson) correlated positively with DO, indicating that low oxygen zones supported fewer species, while increases in DO provided conditions suitable for a broader suite of taxa. This paints a mechanistic picture of how oxygen depletion simplifies fish community structure by filtering out oxygen-intolerant species (Sun *et al*. 2023).

Nutrient enrichment constituted a secondary but highly influential environmental driver shaping fish assemblage structure in Ona Lake. Elevated nitrate concentrations were positively associated with chlorophyll *a* (Chl-a) $r = 0.78$, $p = 0.001$ across sampling events, supporting a nutrient-algal relationship. This more likely translated to enhanced primary productivity consistent with established eutrophication theory (Smith *et al*. 2006; Reid *et al*. 2019). Nitrogen enrichment stimulates phytoplankton growth, leading to higher algal biomass, which upon senescence increases organic matter deposition and microbial respiration. This pattern is consistent with the nutrient-algal-oxygen pathway described for eutrophic systems, though causality cannot be inferred from this observational study (Diaz and Rosenberg 2008; Paerl and Paul 2012). Numerous studies have demonstrated that such nutrient driven oxygen depletion acts as an ecological filter, reducing species richness and altering community composition by excluding oxygen sensitive taxa while favouring tolerant and opportunistic species (Jeppesen *et al*. 2010; Adeogun *et al*., 2020). The observed decline in diversity at stations with elevated nitrate levels in Ona Lake therefore aligns with broader empirical evidence that eutrophication induces community simplification through reinforcing feedback between nutrient loading and oxygen depletion (Breitburg *et al*. 2018). Over time, this interaction may promote assemblage homogenization and dominance by resilient taxa, thereby reducing ecological complexity and functional diversity.

The present study demonstrates that dissolved oxygen and nutrient were individually associated with assemblage metrics, suggesting they are important environmental correlates shaping fish assemblage structure in Ona Lake. Rather than acting independently, these variables interact through well-established biogeochemical processes that influence habitat suitability, community composition, and biodiversity patterns in freshwater ecosystems. The observed spatial variation in fish diversity across sampling stations reflects the combined influence of oxygen availability and nutrient loading, both of which are sensitive to catchment-level anthropogenic pressures.

The interaction between these drivers is central to understanding observed diversity patterns. Nutrient enrichment alone may initially increase productivity and support higher biomass; however, when nutrient inputs exceed ecological assimilation capacity, the system transitions toward eutrophication. Under such conditions, periodic or chronic hypoxia reduces habitat suitability for oxygen-demanding species, leading to community simplification. Reid *et al*. (2019) demonstrated that nutrient-driven eutrophication alters fish community structure by promoting dominance of opportunistic and tolerant taxa. Similarly, Conine *et al*. (2017) reported that hypoxia linked to nutrient enrichment restructures fish assemblages by reducing diversity and favouring species with physiological or behavioural adaptations to low oxygen conditions. The decline in diversity observed at stations with elevated nitrate levels in Ona Lake therefore aligns with global evidence that eutrophication-induced oxygen stress drives assemblage homogenization.

Importantly, these processes do not occur in isolation but are embedded within broader anthropogenic contexts. Shoreline modification, runoff from surrounding settlements, and agricultural inputs likely contribute to nutrient loading in Ona Lake. Such pressures are characteristic of small urban-adjacent lakes where catchment disturbances rapidly translate into altered water quality. Reduced oxygen conditions further constrain benthic invertebrate communities, alter trophic pathways, and modify predator–prey interactions, thereby amplifying biodiversity loss beyond direct physiological stress.

The combined influence of dissolved oxygen and nutrient enrichment thus provides a mechanistic explanation for spatial variation in fish distribution within Ona Lake. Stations with higher oxygen and lower nutrient concentrations maintained more balanced assemblages, whereas nutrient-enriched and oxygen-reduced areas exhibited increased dominance by resilient taxa such as cichlids and air-breathing catfishes. This pattern reflects ecological filtering processes documented in numerous freshwater systems undergoing eutrophication and highlights the vulnerability of small tropical lakes to relatively modest increases in nutrient input (Smith *et al*. 2006; Diaz and Rosenberg 2008). This baseline assessment is crucial given rapid urban expansion in Asaba, which could threaten lake integrity through effluents, agricultural runoff, and sedimentation.

CONCLUSION AND RECOMMENDATIONS

Ona Lake in Asaba supports a rich and diverse ichthyofaunal community, dominated by ecologically and economically important species. Fish diversity varied spatially among stations. The assemblage showed moderate diversity but

biometric data indicate stressed growth conditions, highlighting need for conservation in impacted zones.

Given evidence of stunted growth and dominance by tolerant species, we suggest monitoring fishing pressure and mesh sizes. However, seasonal closures cannot be recommended from this 3-month study. Community-based conservation programs should be established. Periodic biodiversity and water quality monitoring should be conducted. Local fishers should be educated and sensitized on the value of biodiversity and its sustainable practices

Acknowledgments

The authors appreciate the efforts of the 300 Level students of Fisheries and Aquaculture, Dennis Osadebay University and the local fishermen in Ona Lake in making the sampling and data collection exercise a success.

Authors Contributions

JOA developed the study methodology, carried out data analysis, interpretation of data, writing of manuscript QAJ managed data collection, material support, and wrote the first draft of the manuscript. Both authors reviewed the manuscript.

Ethical Statement

"Not applicable".

AI Declaration Statement

The authors declare that Artificial Intelligence (AI) tool- Black box.ai poe.com were used for improving manuscript structure and final polishing, respectively. All outputs were critically reviewed, verified, and approved by both authors, who accept full responsibility for the content of the manuscript.

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