FRESHWATER FISH DIVERSITY AND CONSERVATION IN NIGERIA

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ABSTRACT

Freshwater ecosystems support a disproportionately high share of global biodiversity despite occupying only a small fraction of the Earth's surface. Nigeria possesses extensive freshwater resources, including the Niger and Benue river systems, Lake Chad, floodplains, wetlands, reservoirs, and numerous streams that sustain a diverse assemblage of fish species. These ecosystems provide critical ecological functions and support food security, livelihoods, and cultural values for millions of people. However, freshwater fish biodiversity in Nigeria is increasingly threatened by habitat degradation, pollution, overexploitation, invasive species, hydrological alterations, and climate change. This review synthesises current knowledge on the diversity, distribution, ecological significance, and conservation status of freshwater fish species in Nigeria. Available evidence indicates that Nigerian inland waters harbour more than 260 freshwater fish species distributed across several taxonomic groups, with families such as Cichlidae, Clariidae, Mormyridae, Mochokidae, and Claroteidae being particularly prominent. Despite this richness, many species are experiencing population declines, while others are categorised as threatened, endangered, or near-threatened due to increasing anthropogenic pressures. The review further examines the ecological and socioeconomic consequences of biodiversity loss, including disruptions to ecosystem functioning, reduced fisheries productivity, and threats to rural livelihoods and food security. Existing conservation measures are assessed, and key knowledge gaps limiting effective biodiversity management are identified. The study highlights the need for integrated conservation strategies that combine habitat protection, sustainable fisheries management, community participation, policy reforms, and emerging monitoring technologies. Strengthening biodiversity assessment and conservation efforts is essential for safeguarding Nigeria's freshwater fish resources and ensuring the long-term sustainability of inland aquatic ecosystems.

KEYWORDS: Freshwater biodiversity; Fish diversity; Inland waters; Conservation; Threatened species.

INTRODUCTION

Freshwater ecosystems are among the most biologically diverse and economically valuable environments on Earth. Although they occupy only a small proportion of the global surface area, they support a disproportionately large share of the world's biodiversity, including approximately half of all known fish species (Fricke et al., 2023; Albert et al., 2020). Rivers, lakes, wetlands, reservoirs, floodplains, and streams perform essential ecological functions such as nutrient cycling, energy transfer, water purification, and habitat provision, while simultaneously supporting fisheries, agriculture, transportation, recreation, and other ecosystem services that contribute directly to human well-being.

Fish constitute the most diverse group of vertebrates, with more than 33,000 species described globally. Recent estimates indicate that over 18,000 fish species inhabit freshwater environments, accounting for approximately 51% of global fish diversity despite freshwater ecosystems representing only a fraction of the Earth's aquatic habitats (Fricke et al., 2023). This remarkable concentration of biodiversity highlights the ecological importance of freshwater systems and underscores the need for their effective conservation and sustainable management.

Beyond their taxonomic richness, freshwater fishes perform critical ecological functions that contribute to ecosystem stability and resilience. As predators, herbivores, detritivores, and prey organisms, fishes regulate trophic interactions, facilitate nutrient cycling, influence primary productivity, and support energy flow within aquatic food webs (Albert et al., 2020). Changes in fish community composition can therefore have cascading ecological consequences that extend beyond individual species to affect overall ecosystem functioning and service provision.

Nigeria possesses one of the most extensive networks of inland waters in Africa, encompassing the Niger and Benue river systems, the Cross River basin, the Lake Chad basin, extensive wetlands, floodplains, reservoirs, and numerous smaller rivers and streams. These freshwater ecosystems support a rich assemblage of fish species that contribute substantially to national fisheries production, food security, employment generation, and rural livelihoods (Nazeef & Abubakar, 2013; Akindele et al., 2022; Saba et al., 2024). Current records indicate that Nigeria harbours more than 260 freshwater fish species distributed across diverse ecological zones and aquatic habitats, making the country an important centre of freshwater biodiversity in West Africa (Nazeef & Abubakar, 2013; Ude et al., 2020).

The ecological and socioeconomic importance of freshwater fish biodiversity extends beyond fisheries production alone. Inland fisheries provide an affordable source of high-quality animal protein for millions of people, particularly in rural communities where dependence on aquatic resources remains high (Akintola & Fakoya, 2017; Saba et al., 2024). Freshwater ecosystems also support cultural traditions, local economies, and ecosystem services that are fundamental to sustainable development. Consequently, the conservation of freshwater biodiversity is intrinsically linked to food security, poverty alleviation, and environmental sustainability.

Despite their importance, freshwater ecosystems worldwide are experiencing unprecedented rates of biodiversity decline. Freshwater species are increasingly threatened by habitat destruction, pollution, overexploitation, hydrological alteration, invasive species, and climate change, resulting in population declines and elevated extinction risks across many regions of the world (Albert et al., 2020; Spiller et al., 2025). The growing freshwater biodiversity crisis has prompted calls for urgent conservation action and stronger integration of biodiversity considerations into environmental management and development planning (Albert et al., 2020; Larentis et al., 2022).

Nigeria is not exempt from these challenges. Rapid urbanisation, agricultural expansion, industrial development, oil exploration activities, sand mining, dam construction, and unsustainable fishing practices have intensified pressure on freshwater ecosystems across the country (Andem et al., 2023; Ugboju et al., 2023). These pressures have contributed to habitat degradation, declining water quality, reduced ecological connectivity, and increasing stress on fish populations. In addition, climate variability and long-term climatic changes are altering hydrological regimes, water availability, and habitat suitability, thereby increasing the vulnerability of freshwater ecosystems and their associated biodiversity (Rajamani & Iyer, 2023; Spiller et al., 2025).

Importantly, biodiversity loss should not be viewed solely as a conservation concern. Declines in freshwater fish diversity can reduce fisheries productivity, disrupt ecosystem processes, weaken ecological resilience, and compromise the livelihoods of communities that depend on inland aquatic resources (Sayer et al., 2018; Saba et al., 2024). The ecological and socioeconomic consequences of biodiversity decline therefore extend well beyond species conservation and have implications for sustainable development at local, regional, and national scales.

Although numerous studies have investigated aspects of freshwater fish diversity within specific rivers, lakes, wetlands, and reservoirs in Nigeria, available knowledge remains fragmented across geographical regions and research disciplines (Akindele et al., 2022; Ude et al., 2020). Consequently, a comprehensive synthesis of biodiversity patterns, conservation status, emerging threats, and management priorities remains necessary to support evidence-based conservation planning and policy development.

This review critically synthesises current knowledge on freshwater fish biodiversity in Nigeria by examining ecosystem diversity, species richness, distribution patterns, ecological significance, conservation status, major threats, and management interventions. Rather than merely cataloguing species records, the review evaluates the ecological and anthropogenic processes shaping biodiversity patterns and conservation outcomes. It further identifies critical knowledge gaps, emerging research priorities, and policy directions required to promote the sustainable management and long-term conservation of Nigeria's freshwater ecosystems and fisheries resources.

Review Methodology

This review adopted a narrative evidence-synthesis approach to evaluate the current state of freshwater fish biodiversity in Nigeria, with emphasis on ecosystem diversity, species composition, distribution patterns, ecological significance, conservation status, major threats, and management interventions. Given the multidisciplinary nature of freshwater biodiversity research, a comprehensive review framework was employed to integrate findings from fisheries science, aquatic ecology, biodiversity conservation, environmental management, and freshwater ecosystem studies.

Relevant literature was obtained from major scientific databases, including Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar. Additional information was sourced from reports and publications produced by international organisations and conservation agencies, including the Food and Agriculture Organization (FAO), the International Union for Conservation of Nature (IUCN), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Government reports, technical documents, conference proceedings, and peer-reviewed journals were also consulted to ensure broad coverage of available information on freshwater biodiversity and fisheries resources in Nigeria (Albert et al., 2020; Ugboju et al., 2023; Spiller et al., 2025).

The literature search employed combinations of keywords such as freshwater fish biodiversity, fish diversity in Nigeria, freshwater ecosystems, inland fisheries, threatened fish species, aquatic conservation, fish distribution, wetland biodiversity, and biodiversity conservation in Nigeria. Priority was given to studies conducted within major freshwater ecosystems, including the Niger River Basin, Benue River Basin, Cross River system, Lake Chad Basin, Niger Delta wetlands, reservoirs, lakes, floodplains, and associated freshwater habitats (Nazeef & Abubakar, 2013; Akindele et al., 2022).

Studies were selected based on their relevance to freshwater fish diversity, ecological functions, species composition, conservation status, environmental threats, fisheries sustainability, and biodiversity management. Particular attention was given to peer-reviewed studies that provided empirical evidence on fish assemblages, biodiversity assessments, ecological processes, anthropogenic impacts, and conservation interventions within Nigerian freshwater ecosystems. Recent publications were prioritised to ensure that the review reflects current scientific understanding and emerging conservation concerns, while seminal studies were retained where they provided important baseline information on freshwater biodiversity and ecosystem dynamics (Albert et al., 2020; Saba et al., 2024).

Information extracted from the selected literature was synthesised into five thematic areas: (i) (i) freshwater ecosystem diversity and fish assemblages, (ii) ecological and socioeconomic significance of freshwater biodiversity, (iii) biodiversity status and conservation concerns, (iv) major drivers of biodiversity loss, and (v) conservation and management strategies. Comparative evaluation of findings across different freshwater ecosystems was undertaken to identify

recurring patterns, regional variations, emerging threats, and priority conservation needs.

Rather than providing a descriptive inventory of species records, this review adopts a critical synthesis perspective that evaluates the ecological, environmental, and anthropogenic factors shaping biodiversity patterns and conservation outcomes. The review further examines the interactions among habitat degradation, pollution, overexploitation, invasive species, hydrological alteration, and climate change, recognising that freshwater biodiversity decline is often driven by multiple interacting stressors rather than isolated environmental pressures (Larentis et al., 2022; Rajamani & Iyer, 2023; Spiller et al., 2025).

By integrating evidence from diverse freshwater ecosystems and research disciplines, this review provides a comprehensive assessment of freshwater fish biodiversity in Nigeria while identifying knowledge gaps, research priorities, and policy directions required to strengthen conservation planning and sustainable management of inland aquatic resources.

Freshwater Ecosystems, Fish Diversity and Ecological Importance in Nigeria

Major Freshwater Ecosystems in Nigeria

Nigeria possesses one of the most extensive freshwater networks in Africa, comprising rivers, streams, wetlands, floodplains, lakes, reservoirs, and estuarine transition zones that support diverse aquatic communities. These ecosystems provide critical habitats for freshwater fishes and play fundamental roles in maintaining ecological processes, supporting fisheries production, and sustaining the livelihoods of millions of people (Nazeef & Abubakar, 2013; Akindele et al., 2022).

The country's major freshwater systems (Table 1) include the Niger and Benue rivers, the Cross River Basin, the Lake Chad Basin, the Niger Delta wetlands, and numerous natural and artificial lakes and reservoirs. Each ecosystem possesses distinct hydrological and ecological characteristics that influence fish diversity, species composition, and ecosystem productivity. Habitat heterogeneity, hydrological connectivity, seasonal flooding patterns, and climatic conditions collectively determine the ecological structure and biodiversity of these freshwater environments (Albert et al., 2020; Sayer et al., 2018; Adeyemi et al., 2010).

Fish Species Richness and Diversity

Current records indicate that Nigeria harbours more than 260 freshwater fish species distributed across numerous taxonomic groups and ecological guilds (Nazeef & Abubakar, 2013; Ude et al., 2020). Dominant families commonly reported include Cichlidae, Mormyridae, Clariidae, Mochokidae, Claroteidae, Cyprinidae, Alestidae, Schilbeidae, and Bagridae (Alamba et al., 2016; Ude et al., 2020).

Several species, including *Clarias gariepinus, Heterobranchus bidorsalis, Oreochromis niloticus, Coptodon zillii, Heterotis niloticus, Gymnarchus niloticus,* and *Chrysichthys nigrodigitatus*, contribute substantially to fisheries production and aquaculture development in Nigeria (Akintola & Fakoya, 2017; Saba et al., 2024). However, biodiversity significance extends beyond commercially important species, as many indigenous fishes contribute to ecological stability and ecosystem functioning.

Recent molecular studies have further demonstrated that freshwater biodiversity may be underestimated in several Nigerian ecosystems. DNA barcoding has improved species identification and revealed the importance of integrating molecular approaches into biodiversity assessments and conservation planning (Ude et al., 2020).

Distribution Patterns and Biodiversity Hotspots

The distribution of freshwater fishes in Nigeria is influenced by habitat complexity, ecological connectivity, hydrological regimes, and environmental quality. Species richness varies considerably among ecosystems, reflecting differences in habitat availability, productivity, and levels of anthropogenic disturbance.

The Niger-Benue river system supports one of the most diverse freshwater fish assemblages in the country because of its extensive drainage network and ecological connectivity. Similarly, the Cross River Basin is recognized as a major biodiversity hotspot due to its relatively intact habitats and high species richness (Akindele et al., 2022). Other important biodiversity centres include the Lake Chad Basin, the Niger Delta wetlands, and major reservoirs such as Jebba Reservoir and Dadin Kowa Dam (Oladipo et al., 2021; Yerima et al., 2023).

These biodiversity patterns demonstrate that ecosystem quality and connectivity are often more important determinants of fish diversity than ecosystem size alone. Consequently, the maintenance of habitat integrity remains fundamental to biodiversity conservation.

Ecological and Socioeconomic Importance of Freshwater Fishes

Freshwater fishes perform essential ecological functions that sustain ecosystem productivity and resilience. Through predation, herbivory, detritivory, nutrient recycling, and trophic interactions, fish communities regulate energy transfer and ecosystem functioning within aquatic environments (Albert et al., 2020).

Fish assemblages also serve as valuable indicators of ecosystem health. Changes in species composition and abundance often reflect broader environmental changes, including habitat degradation, pollution, and hydrological alteration (Tamuno & Smith, 2013; Andem et al., 2023).

Beyond their ecological roles, freshwater fishes contribute significantly to food security, nutrition, employment, and economic development. Inland fisheries provide affordable animal protein for millions of Nigerians and support extensive value chains involving harvesting, processing, transportation, and marketing (Akintola & Fakoya, 2017; Bradley et al., 2020; Saba et al., 2024).

The conservation of freshwater fish biodiversity is therefore essential not only for maintaining ecosystem integrity but also for supporting sustainable livelihoods and national development objectives.

Table 1: Major Freshwater Ecosystems and Biodiversity Characteristics of Nigeria

Freshwater Ecosystem	Geographic Location	Biodiversity Characteristics	Ecological Importance
Niger River Basin	Central and Western Nigeria	High species richness; diverse riverine and floodplain fish assemblages	Supports inland fisheries, nutrient cycling, and aquatic biodiversity
Benue River Basin	North-Central Nigeria	Important habitat for migratory and commercially important fishes	Provides breeding and feeding grounds for fish populations
Cross River Basin	South-Eastern Nigeria	One of the richest freshwater biodiversity hotspots in Nigeria	Supports endemic and conservation-important fish species
Lake Chad Basin	North-Eastern Nigeria	Seasonal fish diversity influenced by hydrological fluctuations	Supports fisheries and livelihoods in semi-arid regions
Niger Delta Wetlands	Southern Nigeria	High habitat heterogeneity and aquatic productivity	Functions as nursery and spawning grounds for numerous species
Reservoirs and Artificial Lakes	Nationwide	Variable species composition influenced by management practices	Contribute to fisheries production and water resource management

Source: Adapted from Abubakar (2013), Akindele et al. (2022), and Oladipo et al. (2021).

Current Status and Conservation Concerns of Freshwater Fish Biodiversity in Nigeria

Current Status of Freshwater Fish Biodiversity

Despite the considerable diversity of freshwater fishes recorded in Nigeria, growing evidence indicates that many freshwater ecosystems are experiencing progressive ecological degradation and biodiversity decline. Biodiversity changes are increasingly reflected in reductions in population abundance, shifts in species composition, and alterations in ecosystem functioning (Akindele et al., 2022; Andem et al., 2023).

In many freshwater systems, sensitive species are declining while environmentally tolerant species become increasingly dominant. Such changes may occur before substantial reductions in overall species richness become evident, thereby masking underlying ecological deterioration.

Threatened and Vulnerable Freshwater Fish Species

The conservation status of freshwater fishes in Nigeria has become an increasing concern. Available assessments indicate that a significant proportion of freshwater fish species face varying levels of extinction risk due to habitat degradation, pollution, overexploitation, and other anthropogenic pressures (IUCN, 2022; Akindele et al., 2022).

Species characterized by restricted distributions, specialized habitat requirements, or high commercial values are particularly vulnerable. Population declines among such species may reduce genetic diversity, disrupt ecological interactions, and compromise ecosystem resilience (Alexander et al., 2015; Albert et al., 2020).

Table 2 shows some of the threatened freshwater fish species. The continued decline of threatened species underscores the need for targeted conservation measures, including habitat protection, population monitoring, and species recovery programmes.

Table 2: Selected Threatened Freshwater Fish Species and Major Conservation Concerns in Nigeria

Species	Common Name	Conservation Status	Major Threats
Heterotis niloticus	African bonytongue	Endangered	Overfishing, habitat degradation, pollution
Gymnarchus niloticus	Aba fish	Endangered	Habitat loss, hydrological alteration, excessive exploitation
Labeo parvus	Small labeo	Endangered	Habitat modification and pollution
Schilbe mystus	Butter catfish	Vulnerable	Water pollution and habitat degradation
Chrysichthys nigrodigitatus	Silver catfish	Locally threatened	Overexploitation and habitat disturbance
Protopterus annectens	African lungfish	Vulnerable in some locations	Wetland loss and environmental degradation

Source: Adapted from Andem et al. (2016), Bassey and Udo (2017), and related literature.

Emerging Conservation Concerns

Several emerging environmental challenges are increasing pressure on freshwater biodiversity. Climate change, biological invasions, microplastic pollution, pharmaceutical contaminants, and other novel stressors are increasingly recognised as important drivers of ecological change in freshwater ecosystems (Reid et al., 2019; Rajamani & Iyer, 2023; Spiller et al., 2025).

Climate-induced changes in temperature, rainfall patterns, and hydrological regimes may alter habitat availability, reproductive success, migration patterns, and species distributions. Similarly, invasive species can modify community structure through competition, predation, and habitat alteration (Carosi et al., 2023; Costantini et al., 2023).

Although the impacts of many emerging stressors remain insufficiently studied in Nigeria, their potential interactions with traditional threats may accelerate biodiversity decline and increase ecosystem vulnerability.

Challenges to Freshwater Biodiversity Conservation

Effective conservation is constrained by several scientific, institutional, and governance challenges. Existing biodiversity information remains fragmented, with many freshwater ecosystems lacking comprehensive surveys and long-term monitoring programmes (Ude et al., 2020; Miqueleiz et al., 2020).

Institutional limitations, including inadequate funding, weak regulatory enforcement, and limited coordination among environmental agencies, further reduce conservation effectiveness (Ugboju et al., 2023). In addition, biodiversity considerations are often insufficiently integrated into broader sectors such as water resource management, agriculture, infrastructure development, and climate adaptation planning.

Addressing these challenges will require stronger scientific capacity, improved governance frameworks, enhanced biodiversity monitoring, and greater integration of conservation objectives into national development policies. Without such interventions, continued biodiversity decline may undermine both ecosystem integrity and the socioeconomic benefits derived from Nigeria's freshwater resources.

Major Threats to Freshwater Fish Biodiversity in Nigeria

Freshwater fish biodiversity in Nigeria is increasingly threatened by a combination of anthropogenic and environmental pressures that operate across multiple spatial and temporal scales. Although individual threats may affect species and ecosystems differently, their cumulative and often synergistic effects have emerged as the primary drivers of biodiversity decline in freshwater environments (Albert et al., 2020; Spiller et al., 2025). Understanding the mechanisms through which these threats influence fish populations is essential for developing effective conservation and management strategies.

Habitat Degradation and Ecosystem Fragmentation

Habitat degradation remains one of the most significant threats to freshwater biodiversity in Nigeria. Rapid urbanisation, agricultural expansion, deforestation, wetland conversion, sand mining, and infrastructure development have altered the structure and ecological integrity of many freshwater ecosystems (Andem et al., 2023; Larentis et al., 2022). These activities often result in habitat simplification, increased sedimentation, reduced water quality, and the loss of critical breeding, feeding, and nursery habitats required by freshwater fishes.

The ecological consequences of habitat degradation extend beyond the physical loss of habitat. Many fish species depend on habitat heterogeneity and hydrological connectivity to complete different stages of their life cycles. The fragmentation of

rivers, floodplains, and wetlands can disrupt migration routes, reduce genetic exchange among populations, and increase vulnerability to local extinction (Alexander et al., 2015; Albert et al., 2020). Furthermore, habitat simplification frequently favours opportunistic species while reducing the abundance of specialist species that contribute to ecosystem complexity and resilience.

Particularly important is the degradation of floodplain ecosystems, which serve as critical nursery and feeding grounds for numerous fish species. Alterations to floodplain dynamics can significantly reduce recruitment success and fisheries productivity, thereby affecting both biodiversity conservation and food security (Sayer et al., 2018).

Water Pollution and Environmental Contamination

Water pollution has become a pervasive threat across many Nigerian freshwater systems. Agricultural runoff, industrial effluents, domestic wastewater, mining activities, and petroleum-related operations introduce a wide range of contaminants into aquatic environments, affecting water quality and ecosystem health (Andem et al., 2023; Rajamani & Iyer, 2023).

Nutrient enrichment from agricultural activities often promotes eutrophication, resulting in excessive algal growth, oxygen depletion, and altered ecological conditions that can negatively affect fish survival and reproduction (Rajamani & Iyer, 2023). Industrial pollutants, including heavy metals and toxic chemicals, may accumulate within aquatic organisms and food webs, causing physiological stress, reduced reproductive performance, and increased mortality.

In regions affected by petroleum exploration and oil-related activities, contamination by hydrocarbons presents an additional threat to freshwater biodiversity. Such pollutants can impair habitat quality, reduce species abundance, and alter community composition, particularly within sensitive wetland ecosystems. Emerging contaminants such as pharmaceuticals, personal care products, endocrine-disrupting compounds, and microplastics are also receiving increasing attention globally because of their potential ecological effects, although their impacts remain poorly understood in many Nigerian freshwater ecosystems (Spiller et al., 2025).

Overexploitation and Unsustainable Fishing Practices

Freshwater fisheries provide substantial socioeconomic benefits throughout Nigeria; however, increasing fishing pressure has contributed significantly to biodiversity decline in many inland waters. Population growth, rising demand for fish, and limited livelihood alternatives have intensified exploitation of freshwater resources, often beyond sustainable levels (Akintola & Fakoya, 2017; Saba et al., 2024).

Unsustainable fishing practices, including the use of small mesh nets, indiscriminate harvesting of juvenile fishes, destructive fishing methods, and fishing during breeding seasons, can reduce population abundance and disrupt natural recruitment processes. Species characterised by slow growth, delayed maturation, or high commercial value are particularly susceptible to overexploitation because

their populations require longer periods to recover following disturbance (Wangboje, 2022).

The impacts of overfishing extend beyond target species. The removal of large-bodied predators and commercially important taxa can alter food-web dynamics, modify species interactions, and reduce ecosystem stability. Such ecological changes may ultimately affect the productivity and sustainability of freshwater fisheries themselves (Albert et al., 2020).

Hydrological Modification and River Regulation

Hydrological processes play a fundamental role in shaping freshwater biodiversity. Consequently, alterations to natural flow regimes through dam construction, water abstraction, channel modification, and flood-control infrastructure can have profound ecological consequences (Larentis et al., 2022).

Many freshwater fish rely on seasonal flooding as a cue for spawning, migration, and habitat utilisation. River regulation can disrupt these ecological processes by altering water flow, reducing floodplain connectivity, modifying sediment transport, and restricting access to critical habitats. Such changes may reduce reproductive success, alter species distributions, and diminish ecosystem productivity (Sayer et al., 2018).

The ecological effects of hydrological modification are often cumulative. Multiple water-resource developments within a river basin may collectively reduce ecological resilience and compromise the ability of freshwater ecosystems to support diverse fish communities. Balancing water-resource development with biodiversity conservation therefore remains a major challenge for sustainable freshwater management in Nigeria.

Invasive Species and Biological Invasions

The introduction and establishment of non-native species represent an increasingly important threat to freshwater biodiversity. Invasive species can affect native fish populations through competition, predation, habitat alteration, disease transmission, and hybridisation (Alexander et al., 2015; Amadi et al., 2017).

Evidence from freshwater ecosystems indicates that non-native fishes usually compete with indigenous species for food and habitat resources, resulting in declines in native biodiversity. Habitat degradation often exacerbates these impacts because disturbed ecosystems tend to be more vulnerable to biological invasions. In some freshwater systems, aquaculture-related introductions have been associated with alterations in community composition and reductions in native fish diversity (Amadi et al., 2017).

The ecological effects of invasive species are frequently amplified when combined with other environmental stressors. Consequently, effective management of biological invasions requires consideration of broader ecosystem conditions rather than focusing solely on individual invasive species.

Climate Change and Emerging Environmental Stressors

Climate change has emerged as one of the most significant long-term threats to freshwater biodiversity globally and is expected to have substantial implications for Nigerian freshwater ecosystems (Albert et al., 2020; Spiller et al., 2025). Changes in temperature, rainfall patterns, hydrological regimes, and the frequency of extreme weather events can influence fish physiology, reproduction, migration, and habitat availability. As shown in Table 3, major threats to freshwater biodiversity are highlighted.

Altered rainfall patterns may affect river discharge, floodplain inundation, and water availability, thereby disrupting ecological processes that support fish populations. Increased temperatures can influence metabolic rates, dissolved oxygen concentrations, and species distributions, potentially favouring some species while placing others under increased physiological stress (Rajamani & Iyer, 2023; Ahme et al., 2022).

Climate change also interacts with existing environmental pressures, including habitat degradation, pollution, and overexploitation. Such interactions may amplify ecological impacts and reduce the adaptive capacity of freshwater ecosystems. Consequently, climate change should be viewed not as an isolated threat but as a factor capable of intensifying other drivers of biodiversity loss.

Table 3: Major Threats to Freshwater Fish Biodiversity in Nigeria and Recommended Management Responses

Threat	Ecological Impacts	Recommended Management Responses
Habitat degradation	Loss of spawning and nursery habitats; reduced biodiversity	Habitat restoration, wetland protection, riparian vegetation management
Water pollution	Fish mortality, reduced reproductive success, biodiversity decline	Pollution control, wastewater treatment, routine monitoring
Overfishing	Population decline and altered community structure	Sustainable fisheries management and fishing regulations
Dam construction and river regulation	Habitat fragmentation and disrupted migration routes	Environmental flow management and fish passage facilities
Invasive species	Competition, predation, and displacement of native species	Early detection, monitoring, and control programmes

Climate change	Altered hydrology, habitat loss, and species redistribution	Climate adaptation planning and ecosystem-based management
Sand mining and dredging	Habitat destruction and increased turbidity	Regulation and environmental impact assessments

Source: Adapted from Dudgeon (2019), Reid et al. (2019), Koehnken et al. (2020), Ahmed et al. (2022), and Lynch et al. (2023).

Multiple Stressors and Biodiversity Decline

Although individual threats are often examined separately, freshwater biodiversity loss is increasingly driven by the interaction of multiple stressors operating simultaneously. Habitat degradation may increase vulnerability to invasive species; pollution can reduce physiological tolerance to climatic stress; and overfishing may weaken ecosystem resilience to environmental disturbances (Spiller et al., 2025).

These cumulative effects often produce ecological impacts that exceed those associated with individual stressors acting independently. As a result, conservation approaches focused exclusively on single threats may be insufficient to halt biodiversity decline. Effective management requires integrated strategies that recognise the interconnected nature of environmental pressures and address the underlying drivers of ecosystem degradation.

Overall, the major threats affecting freshwater fish biodiversity in Nigeria reflect complex interactions among environmental change, resource exploitation, and human development activities. Their cumulative effects have contributed to declining fish populations, altered community structure, reduced ecosystem resilience, and increasing conservation concern. Addressing these challenges will require coordinated interventions that integrate habitat protection, pollution control, sustainable fisheries management, climate adaptation, and ecosystem-based conservation approaches.

Conservation Strategies and Management Framework for Freshwater Fish Biodiversity in Nigeria

The accelerating decline of freshwater biodiversity in Nigeria highlights the urgent need for conservation strategies that address both the ecological drivers of biodiversity loss and the socioeconomic factors influencing resource use. While numerous conservation initiatives have been implemented across different freshwater ecosystems, their effectiveness has often been constrained by inadequate funding, weak institutional capacity, fragmented governance structures, poor enforcement of environmental regulations, and limited stakeholder participation (Ugboju et al., 2023). Consequently, sustainable biodiversity conservation requires a comprehensive and integrated management framework that balances ecological protection with human development needs.

Habitat Protection and Ecosystem Restoration

The conservation of freshwater biodiversity depends fundamentally on the protection and restoration of aquatic habitats. Habitat degradation remains one of the primary drivers of species decline in Nigerian freshwater ecosystems, making habitat conservation a critical priority (Alexander et al., 2015; Larentis et al., 2022). Effective conservation strategies should therefore focus on protecting ecologically important rivers, wetlands, floodplains, reservoirs, and biodiversity hotspots such as the Cross River Basin, Niger Delta wetlands, and Hadejia-Nguru wetland complex.

Habitat restoration initiatives should complement habitat protection efforts. Restoring degraded wetlands, re-establishing riparian vegetation, controlling erosion, reducing sedimentation, and improving hydrological connectivity can enhance habitat quality and support the recovery of fish populations (Nayaya & Ibrahim, 2015; Ugboju et al., 2023). Such interventions are particularly important in ecosystems where habitat fragmentation has disrupted ecological processes essential for migration, feeding, and reproduction.

An ecosystem-based approach to habitat management is especially relevant because freshwater fishes depend on interconnected aquatic and terrestrial environments. Protecting entire watersheds rather than isolated water bodies can therefore provide more sustainable conservation outcomes by maintaining ecological processes operating across larger spatial scales (Albert et al., 2020).

Sustainable Fisheries Management

Maintaining viable fish populations requires fisheries management approaches that balance resource utilisation with biodiversity conservation. Overexploitation remains a significant threat to freshwater biodiversity in Nigeria, necessitating stronger regulation of fishing activities and improved compliance with fisheries legislation (Akintola & Fakoya, 2017; Wangboje, 2022).

Science-based fisheries management should include the regulation of fishing effort, protection of spawning grounds, enforcement of minimum mesh-size requirements, seasonal fishing closures, and restrictions on destructive fishing methods. These measures can reduce pressure on vulnerable populations while promoting sustainable harvest levels. Protecting breeding habitats and reproductive periods is particularly important because recruitment success largely determines the long-term sustainability of fish populations.

Adaptive fisheries management approaches that incorporate ecological monitoring and stakeholder participation are likely to be more effective than rigid regulatory systems. Such approaches enable management strategies to respond to changing environmental conditions, biodiversity trends, and socioeconomic realities while promoting greater stakeholder compliance and ownership.

Pollution Control and Water Quality Management

Improving water quality is essential for maintaining freshwater biodiversity and ecosystem health. Effective pollution control requires stronger regulation of industrial discharges, agricultural runoff, domestic wastewater, mining activities,

and petroleum-related operations that introduce contaminants into freshwater ecosystems (Andem et al., 2023; Rajamani & Iyer, 2023).

Integrated watershed management offers a practical framework for reducing pollutant inputs while maintaining ecosystem integrity. Such approaches recognise the close relationship between land-use activities and aquatic ecosystem health and encourage coordinated management across sectors. Investments in wastewater treatment infrastructure, improved environmental monitoring, and stricter enforcement of pollution-control regulations are necessary to minimise environmental degradation and protect aquatic habitats.

Routine monitoring of water quality parameters, sediment contamination, and emerging pollutants can provide early warning of ecological deterioration and support evidence-based management decisions. Such monitoring programmes are particularly important given the growing concern regarding microplastics, pharmaceutical residues, and other emerging contaminants whose ecological impacts remain poorly understood in many Nigerian freshwater systems (Spiller et al., 2025).

Species Conservation and Biodiversity Monitoring

Although ecosystem-based conservation should remain the primary management approach, targeted interventions may be necessary for species facing elevated extinction risks. Conservation actions for threatened fishes should include population monitoring, habitat protection, captive breeding programmes where appropriate, conservation stocking, and species recovery initiatives (Altowairqi & Shafi, 2024; Ugboju et al., 2023).

Effective species conservation depends on accurate information regarding species distribution, abundance, ecological requirements, and conservation status. Unfortunately, biodiversity monitoring remains limited in many Nigerian freshwater ecosystems. Establishing long-term monitoring programmes would improve understanding of population trends and facilitate the evaluation of conservation outcomes.

Regular biodiversity assessments are also essential for identifying species at risk and prioritising conservation interventions. Such assessments should utilise internationally recognised conservation criteria while incorporating local ecological knowledge and region-specific environmental conditions.

Community Participation and Co-management Approaches

The long-term success of biodiversity conservation depends heavily on the participation of local communities. Freshwater ecosystems provide food, employment, income, and cultural benefits for millions of people, making community engagement an essential component of conservation planning (Sayer et al., 2018; Saba et al., 2024).

Conservation initiatives that exclude local stakeholders frequently experience implementation challenges because they fail to address the socioeconomic realities influencing resource use. In contrast, community-based conservation and co-

management approaches can improve compliance, strengthen local stewardship, and enhance conservation effectiveness (Ugboju et al., 2023). These approaches encourage collaboration among government agencies, local communities, fishers, and conservation organisations while promoting shared responsibility for resource management.

Indigenous ecological knowledge can also contribute valuable insights regarding species behaviour, seasonal ecological changes, and historical ecosystem conditions. Integrating such knowledge with scientific research may improve conservation outcomes and strengthen local support for biodiversity protection.

Environmental Education and Public Awareness

Public awareness and environmental education play important roles in promoting sustainable resource use and biodiversity conservation. Many drivers of biodiversity decline, including overfishing, habitat destruction, and pollution, are influenced by human behaviour and decision-making. Consequently, increasing public understanding of the ecological and socioeconomic importance of freshwater biodiversity can contribute to positive behavioural change (Nayaya & Ibrahim, 2015).

Educational programmes targeting fishers, students, policymakers, community leaders, and resource managers can improve awareness of conservation challenges and encourage sustainable environmental practices. Such initiatives may also strengthen public support for conservation policies and facilitate broader stakeholder participation in biodiversity management.

Strengthening Governance and Policy Implementation

Effective conservation requires strong institutions, coherent policies, and effective regulatory enforcement. Although Nigeria possesses environmental legislation and fisheries regulations relevant to biodiversity conservation, implementation challenges continue to limit their effectiveness (Ugboju et al., 2023).

Strengthening governance requires improved coordination among environmental agencies, fisheries authorities, research institutions, conservation organisations, and local governments. Biodiversity considerations should be integrated into water resource development, agriculture, infrastructure planning, climate adaptation strategies, and environmental impact assessment processes to minimise conflicts between development objectives and ecosystem conservation.

Policy frameworks should also promote ecosystem-based management, precautionary decision-making, and adaptive governance approaches capable of responding to environmental uncertainty and emerging conservation challenges.

Technological Innovation and Future Conservation Opportunities

Recent technological advances offer significant opportunities for strengthening biodiversity conservation and ecological monitoring. Environmental DNA (eDNA), DNA barcoding, remote sensing, Geographic Information Systems

(GIS), artificial intelligence, and machine learning are increasingly transforming biodiversity assessment and conservation planning worldwide (Ude et al., 2020).

These technologies can improve species detection, habitat mapping, ecological forecasting, and biodiversity monitoring while reducing the costs and logistical challenges associated with conventional survey methods. The integration of such technologies into national biodiversity monitoring programmes could significantly improve data availability and support evidence-based conservation decisions.

Furthermore, digital biodiversity databases, ecological information systems, and automated monitoring platforms can facilitate information sharing among researchers, conservation practitioners, and policymakers. Such innovations may play a crucial role in addressing current knowledge gaps and improving conservation effectiveness in Nigerian freshwater ecosystems.

Towards an Integrated Conservation Framework

Given the interconnected nature of biodiversity loss, conservation strategies should not be implemented in isolation. Habitat protection, fisheries management, pollution control, species conservation, community participation, policy reform, and technological innovation are most effective when integrated within a coordinated ecosystem-based management framework (Albert et al., 2020; Spiller et al., 2025).

An effective national conservation framework should therefore pursue four complementary objectives: protecting critical freshwater habitats, promoting sustainable fisheries utilisation, strengthening governance and institutional capacity, and improving scientific knowledge through research and monitoring. Achieving these objectives will require long-term investment, political commitment, stakeholder collaboration, and adaptive management approaches capable of responding to changing environmental conditions.

Ultimately, the conservation of freshwater fish biodiversity in Nigeria depends not only on protecting individual species but also on maintaining the ecological processes and social systems that support sustainable freshwater ecosystems. Integrated conservation strategies that recognise the linkages among biodiversity, ecosystem services, fisheries productivity, and human well-being offer the greatest potential for securing the long-term sustainability of Nigeria's inland aquatic resources.

Knowledge Gaps, Research Priorities and Policy Directions

Despite increasing research attention on freshwater ecosystems and fisheries resources in Nigeria, substantial knowledge gaps continue to hinder effective biodiversity conservation and sustainable management. Existing information on freshwater fish diversity is often fragmented, geographically uneven, and derived from short-term studies, limiting the ability to develop comprehensive conservation strategies and evidence-based management interventions (Ude et al., 2020; Ugboju et al., 2023). Addressing these limitations will require coordinated scientific research, technological innovation, institutional strengthening, and policy reforms capable of responding to emerging environmental challenges.

Knowledge Gaps in Freshwater Biodiversity Research

One of the most significant challenges facing freshwater biodiversity conservation in Nigeria is the absence of comprehensive national biodiversity inventories. Although numerous studies have documented fish assemblages within specific rivers, lakes, wetlands, and reservoirs, many freshwater ecosystems remain poorly studied, resulting in incomplete understanding of species distributions and conservation status (Akindele et al., 2022; Ude et al., 2020). Consequently, national estimates of biodiversity may underestimate the true extent of freshwater fish diversity.

Taxonomic uncertainty also remains an important limitation. Most biodiversity assessments rely heavily on morphological identification methods, which may fail to distinguish closely related or cryptic species. Molecular studies have demonstrated the value of DNA barcoding for improving species identification and revealing previously unrecognised biodiversity (Ude et al., 2020). Expanding molecular approaches would enhance taxonomic resolution and strengthen biodiversity assessments across Nigerian freshwater ecosystems.

Another major knowledge gap relates to long-term ecological monitoring. Most available studies provide snapshots of biodiversity at particular points in time, making it difficult to evaluate population trends, ecological resilience, and responses to environmental change. The absence of continuous monitoring programmes limits the ability to distinguish natural ecological fluctuations from persistent biodiversity decline and constrains the evaluation of conservation effectiveness (Albert et al., 2020).

Furthermore, significant information gaps exist regarding the ecological impacts of emerging environmental stressors. While the effects of habitat degradation, pollution, and overfishing have received considerable attention, the consequences of microplastic contamination, pharmaceutical residues, endocrine-disrupting compounds, invasive species, freshwater salinisation, and other emerging pollutants remain poorly understood in most Nigerian freshwater systems (Rajamani & Iyer, 2023; Spiller et al., 2025).

Priority Areas for Future Research

Future research should prioritise comprehensive biodiversity assessments across major river basins, wetlands, reservoirs, and understudied freshwater habitats. National-scale biodiversity surveys would provide critical baseline information for conservation planning, species protection, and fisheries management. Such surveys should integrate traditional ecological methods with molecular tools to improve species detection and taxonomic accuracy (Ude et al., 2020).

Research is also needed to improve understanding of ecological processes that influence biodiversity patterns and ecosystem functioning. Studies examining species interactions, trophic dynamics, habitat connectivity, reproductive ecology, and ecosystem resilience would provide valuable insights into the mechanisms sustaining freshwater biodiversity. Such information is essential for developing

ecosystem-based management approaches capable of maintaining ecological integrity under increasing environmental pressure (Albert et al., 2020).

Climate change represents another critical research priority. Although its potential impacts on freshwater biodiversity are increasingly recognised, substantial uncertainty remains regarding species-specific responses, ecosystem vulnerability, and long-term ecological consequences within Nigerian freshwater systems. Future studies should integrate climate modelling, ecological forecasting, and vulnerability assessments to identify ecosystems and species most at risk from changing environmental conditions (Spiller et al., 2025).

Greater emphasis should also be placed on interdisciplinary research that integrates ecological, social, economic, and governance dimensions of biodiversity conservation. Understanding how biodiversity loss influences fisheries productivity, food security, livelihoods, and community resilience will facilitate the development of management strategies that simultaneously address conservation and development objectives (Saba et al., 2024; Sayer et al., 2018).

Technological Innovations for Biodiversity Assessment and Conservation

Emerging technologies offer significant opportunities for advancing freshwater biodiversity research and conservation in Nigeria. Environmental DNA (eDNA) analysis, DNA barcoding, remote sensing, Geographic Information Systems (GIS), artificial intelligence, machine learning, and automated monitoring systems are increasingly transforming ecological research globally (Ude et al., 2020).

Environmental DNA techniques enable the detection of species from genetic material present in water samples, providing a highly sensitive approach for biodiversity assessment, species monitoring, and early detection of invasive species. Similarly, remote sensing and GIS technologies facilitate large-scale habitat mapping, environmental monitoring, and conservation planning, particularly in remote or inaccessible freshwater environments.

Artificial intelligence and machine learning technologies have demonstrated considerable potential for analysing large ecological datasets, predicting biodiversity patterns, identifying environmental risks, and supporting adaptive management decisions. The integration of these technologies into freshwater biodiversity monitoring programmes could substantially improve conservation efficiency and decision-making capacity.

The establishment of national biodiversity databases and digital information platforms would further enhance data accessibility, facilitate information sharing, and support collaborative research among scientists, conservation practitioners, and policymakers.

Policy Priorities for Freshwater Biodiversity Conservation

Scientific knowledge alone is insufficient to achieve biodiversity conservation without effective policy implementation and institutional support. Strengthening the science-policy interface is therefore a major priority for freshwater biodiversity management in Nigeria (Ugboju et al., 2023). Improved communication between

researchers, government agencies, conservation organisations, and resource managers can facilitate the translation of scientific evidence into practical management actions.

Biodiversity conservation should be more effectively integrated into national development planning, water resource management, agricultural policies, climate adaptation strategies, and infrastructure development programmes. Environmental impact assessment procedures should explicitly consider freshwater biodiversity and ecosystem services to minimise adverse ecological consequences associated with development projects (Larentis et al., 2022).

Improved enforcement of existing environmental regulations is equally important. Many conservation challenges persist not because of the absence of policies but because of inadequate implementation, insufficient institutional capacity, and limited financial resources. Strengthening regulatory institutions and enhancing interagency coordination would significantly improve conservation effectiveness.

Towards a National Freshwater Biodiversity Conservation Strategy

The complexity of freshwater biodiversity challenges requires a coordinated and long-term conservation framework. A National Freshwater Biodiversity Conservation Strategy would provide an important mechanism for integrating scientific research, policy implementation, ecosystem management, and stakeholder participation.

Such a strategy should establish clear conservation objectives, biodiversity monitoring standards, habitat restoration priorities, species recovery programmes, and institutional responsibilities. It should also promote ecosystem-based management, adaptive governance, stakeholder engagement, and sustainable financing mechanisms capable of supporting long-term conservation efforts (Albert et al., 2020; Ugboju et al., 2023).

Furthermore, the strategy should encourage collaboration among government agencies, universities, research institutions, conservation organizations, local communities, and the private sector. Such partnerships are essential for improving biodiversity knowledge, strengthening conservation capacity, and ensuring that management interventions remain scientifically informed and socially relevant.

Ultimately, the future of freshwater fish biodiversity in Nigeria will depend on the extent to which scientific research, technological innovation, effective governance, and community participation can be integrated into a coherent conservation framework. Addressing existing knowledge gaps while strengthening policy implementation and institutional capacity will be critical for safeguarding freshwater ecosystems and ensuring the sustainable use of aquatic resources for future generations.

CONCLUSION

Freshwater ecosystems represent one of Nigeria's most important natural resources, supporting a rich diversity of fish species that contribute significantly to

ecosystem functioning, fisheries productivity, food security, and socioeconomic development. The country's extensive network of rivers, lakes, wetlands, floodplains, and reservoirs provides habitats for a diverse ichthyofauna and serves as a critical component of West Africa's freshwater biodiversity. However, increasing anthropogenic pressures and environmental changes are threatening the ecological integrity of these ecosystems and the sustainability of the biodiversity they support.

This review demonstrates that freshwater fish biodiversity in Nigeria is shaped by complex interactions among habitat characteristics, hydrological processes, ecological connectivity, and human activities. Although many freshwater ecosystems continue to support considerable species diversity, mounting evidence indicates that habitat degradation, pollution, overexploitation, hydrological modification, invasive species, and climate change are progressively altering fish communities and ecosystem functioning. The cumulative impacts of these stressors have contributed to biodiversity decline, population reductions, changes in community composition, and increasing conservation concern for numerous freshwater fish species.

Importantly, the consequences of biodiversity loss extend beyond ecological considerations. Freshwater fishes provide essential ecosystem services and support livelihoods for millions of people through fisheries, employment opportunities, income generation, and nutritional security. Consequently, the conservation of freshwater biodiversity is inseparable from broader goals of sustainable development, poverty reduction, and environmental sustainability. Declining fish diversity therefore represents both an ecological challenge and a socioeconomic concern requiring coordinated and long-term management responses.

The review further highlights critical deficiencies in biodiversity knowledge, long-term ecological monitoring, taxonomic resolution, and conservation implementation. Addressing these challenges will require greater investment in scientific research, improved biodiversity assessment programmes, stronger institutional coordination, and more effective integration of conservation objectives into environmental governance and development planning. Emerging technologies, including environmental DNA, remote sensing, geographic information systems, artificial intelligence, and ecological modelling, offer significant opportunities for improving biodiversity monitoring, conservation planning, and evidence-based decision-making.

Recommendations

1. Future conservation efforts should move beyond reactive species protection towards proactive, ecosystem-based management approaches that address the underlying drivers of biodiversity loss.

2. Habitat restoration, sustainable fisheries management, pollution control, climate adaptation, community participation, and effective policy implementation should be pursued within an integrated conservation framework capable of maintaining ecosystem resilience and supporting the sustainable use of freshwater resources.

3. Ultimately, the long-term conservation of freshwater fish biodiversity in Nigeria will depend on the collective commitment of government institutions, research organisations, conservation practitioners, local communities, and development stakeholders.

4. Through the integration of sound science, effective governance, technological innovation, and sustainable resource management, it is possible to safeguard freshwater ecosystems while maintaining the ecological and socioeconomic benefits they provide.

5. Protecting freshwater biodiversity should therefore be regarded not only as an environmental responsibility but also as a strategic investment in Nigeria's sustainable future.

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