

ENVIRONMENTAL PARAMETER AND PROXIMATE COMPOSITION OF DIFFERENT SPECIES OF FISH IN THE GREAT KWA RIVER, CALABAR NIGERIA

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Abstract

*Environmental variation plays a critical role in shaping aquatic ecosystems and influencing the nutritional quality of fish. This study assessed the impact of physicochemical differences on the proximate composition of five commercially important fish species—*Polydactylus quadrifilis*, *Chrysichthys nigrodigitatus*, *Oreochromis niloticus*, *Mugil cephalus*, and *Heterotis niloticus*—from the Great Kwa River, sampled at Idundu and Esuk Atu stations. Standard analytical methods were used to determine protein, lipid, carbohydrate, fiber, ash, and moisture contents, with statistical analysis performed using one-way ANOVA at $p < 0.05$ in the Statistical Package for the Social Sciences (SPSS) version 25. Results revealed significant interspecies differences, with *P. quadrifilis* showing the highest protein ($21.25 \pm 0.09\%$) and lipid ($8.12 \pm 0.11\%$) values, while *H. niloticus* exhibited the lowest protein ($17.10 \pm 0.18\%$) and highest moisture ($74.85 \pm 0.30\%$). Ash and fiber contents ranged between 1.22–1.61% and 0.24–0.52%, respectively. Carbohydrate content varied from $0.73 \pm 0.01\%$ in *P. quadrifilis* to $1.17 \pm 0.04\%$ in *O. niloticus*. Environmental parameters such as dissolved oxygen and temperature showed notable correlations with protein and lipid concentrations, suggesting that shifts in water quality can influence fish biochemical composition. These findings provide essential baseline data for fisheries management and underscore the need for sustained monitoring of freshwater ecosystems to safeguard fish nutritional integrity.*

Keywords: *Environmental variables, proximate analysis, freshwater fish species, species-specific variation*

Introduction

Environmental variation is a critical challenge affecting aquatic ecosystems worldwide. Shifts in temperature, rainfall patterns, and hydrological regimes reshape how freshwater habitats function and influence the distribution, physiology, and nutritional health of aquatic organisms (Nimma *et al.*, 2025). In freshwater systems, changes in water temperature, oxygen levels, and nutrient availability directly affect fish habitat, growth, and survival. Warmer water typically holds less oxygen, which can stress fish adapted to cooler, well-oxygenated environments. Nutrient fluctuations may promote harmful algal blooms, further degrading water quality and altering ecological balance (Macusi *et al.*, 2015). These stressors can impact fish feeding behavior, metabolism, and biochemical composition, making fish populations vulnerable to environmental disturbances (Jarić *et al.*, 2019).

The Great Kwa River in Cross River State, Nigeria, is a vital freshwater system in the Niger Delta region, supporting diverse fish species that provide food and livelihoods for local communities (Allison *et al.*, 2025). However, the river is increasingly affected by

anthropogenic pressures and environmental variability, including extended rainy seasons, elevated temperatures, and irregular flooding patterns. These changes have altered river flow dynamics and water chemistry (Ekpo *et al.*, 2024), potentially influencing the nutritional makeup of fish (such as protein, fat, carbohydrates, ash, and moisture) which are key indicators of their dietary and commercial value (Krishna *et al.*, 2015).

Studying the nutritional composition of fish offers insight into how environmental conditions affect seafood quality. Fish are a rich source of animal protein, essential fatty acids, vitamins, and minerals critical for human health and development (Tacon & Metian, 2015). Variations in water temperature and quality can influence energy metabolism, feeding efficiency, and nutrient storage in fish, thereby altering their nutritional profile (Volkoff & Rønnestad, 2020). For instance, elevated temperatures may increase metabolic rates, accelerating energy use, while reduced dissolved oxygen can impair nutrient retention, particularly for fat and protein (Remen *et al.*, 2015). These physiological responses have implications not only for fish health but also for food security in communities that rely heavily on fish as a primary protein source.

Understanding how environmental variation affects the nutrition of key fish species in the Great Kwa River is essential for predicting changes in fish quality and availability. Such knowledge supports adaptive fisheries management, informs local fishing practices, and helps safeguard community diets amid ecological shifts. By analyzing fish from different sections of the river, this study aims to evaluate how environmental factors influence fish nutrition and contribute to broader understanding of freshwater ecosystem dynamics and food quality.

Materials and Methods

Study Area

The study took place on the Great Kwa River, a key freshwater river in Cross River State, Nigeria. The river starts from the Oban Hills and flows south into the Cross River Estuary, collecting water from several smaller streams along the way (Asuquo & Ifon, 2019). Geographically, it is located between latitudes 4°50'N to 5°10'N and longitudes 8°20'E to 8°30'E (Fig. 1). The area has a tropical climate with a wet season from April to October and a dry season from November to March (Allison *et al.*, 2025). Many small fishing communities rely on the Great Kwa River, which also provides essential ecological services. It features a semi-tidal regime influenced by fluctuating tides and is bordered by mangroves and swamp vegetation dominated by elephant grasses (*Pennisetum purpureum*), palm trees (*Elaeis guineensis*), and fan palm (*Hyphaene petersiana*) (Odum *et al.*, 2023). The riverbed substratum varies locally from sandy clay to mudflats, with water transparency and current velocity differing between sampling stations, reflecting environmental heterogeneity and anthropogenic impacts (Okon *et al.*, 2025). The ecosystem faces pressures from industrial discharge, municipal waste, and land use changes, potentially affecting water quality and biodiversity (Ifon & Asuquo, 2021).

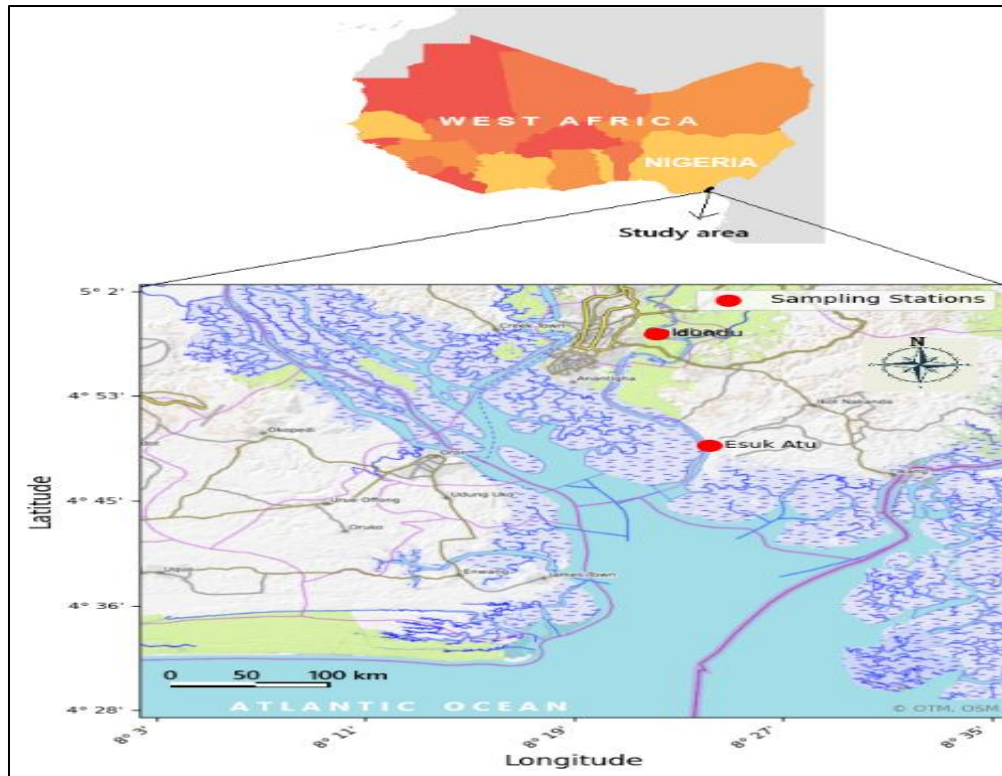


Figure 1. Map of the study area

Sample Collection and Identification

Monthly fish samples were collected from Idundu and Esu Atu for six months (May 2024 to October 2024) and pooled for the study. Standard fishing tools like cast nets and gill nets with mesh sizes between 25 and 50 millimeters were used (Ifon, 2024). The nets were set early in the morning and late in the evening when fish are most active (Ofem *et al.*, 2011). Five common fish species important to the local market were selected based on how many there were and their economic value. After catching, the fish were identified to species using guides by Olaosebikan and Raji (2013). Samples from each species were placed in labeled plastic containers with crushed ice to keep them fresh and prevent spoilage. They were then transported in ice chests to the Food Science and Technology Laboratory at the University of Calabar for nutritional analysis.

Sample Preparation

In the laboratory, the fish specimens were washed thoroughly with clean water to remove adhering debris and scales. Each fish was measured for total length (cm) and body weight (g) using a measuring board and electronic weighing balance respectively. The edible portions (muscle tissues) were carefully excised using sterilized stainless steel scalpels to avoid contamination. The muscle samples from each species were pooled, homogenized using a laboratory blender, and divided into two portions. One portion was analyzed fresh for moisture content, while the other portion was oven-dried at 105°C for 24 hours, ground into fine powder, and stored in airtight containers for further analyses. All analytical procedures were performed

within 48 hours of sample collection to maintain the integrity of the biochemical components (AOAC, 2016).

Determination of proximate composition

The proximate composition of the fish samples, including moisture, crude protein, crude lipid, ash, and carbohydrate contents, was determined according to the methods described by the **Association of Official Analytical Chemists (AOAC, 2016)**.

Moisture Content: Approximately 5 g of each homogenized sample was weighed into pre-dried crucibles and dried in a hot air oven at 105°C until a constant weight was obtained. The percentage moisture was calculated based on weight loss before and after drying.

Crude Protein: Protein content was determined using the Kjeldahl method. Each sample (1 g) was digested with concentrated sulfuric acid (H₂SO₄) in the presence of a catalyst mixture of copper sulfate and potassium sulfate until a clear solution was obtained. The digest was then distilled with 40% sodium hydroxide (NaOH) and the released ammonia was trapped in a 4% boric acid solution. The distillate was titrated against 0.1 N hydrochloric acid (HCl) to determine nitrogen content, which was multiplied by a conversion factor of 6.25 to estimate crude protein percentage (AOAC, 2016).

Crude Lipid: Lipid content was determined using the Soxhlet extraction method with petroleum ether (boiling range 40–60°C) as the solvent. About 2 g of the dried sample was extracted for 6 hours, after which the solvent was evaporated and the residue weighed to calculate lipid percentage.

Ash Content: Ash was determined by incinerating 2 g of each dried sample in a muffle furnace at 550°C for 4 hours until a constant greyish-white residue was obtained. The residue was weighed and expressed as a percentage of the original sample weight.

Carbohydrate Content: Carbohydrate was estimated by difference, subtracting the sum of the percentages of moisture, crude protein, crude lipid, and ash from 100%.

All analyses were performed in triplicate to ensure accuracy and reproducibility of results.

Determination of Environmental Parameters

Water samples were collected concurrently at both Idundu and Esuk Atu stations during each fish sampling to determine environmental variables potentially influenced by climate change. Parameters such as temperature, pH, dissolved oxygen (DO), and conductivity were measured in situ using portable meters (Hanna Multiparameter Water Quality Meter, Model HI98194). Water temperature was measured directly in degrees Celsius, pH was determined using a calibrated pH meter, while DO and conductivity were recorded following standard procedures (APHA, 2017). These parameters provided supporting data for understanding the environmental context influencing the fish's nutritional composition.

Data Analysis

Data obtained from proximate composition analyses were expressed as mean \pm standard deviation. Statistical differences in nutrient composition among fish species and between sampling stations were determined using one-way Analysis of Variance (ANOVA) followed by Tukey's post hoc test for mean separation at a 95% confidence level ($p < 0.05$). Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 25. Graphical representations were created using Microsoft Excel 2021. The relationships between environmental variables and proximate composition were also examined using Pearson's correlation analysis to determine potential climate-related influences on fish nutritional quality (Zar, 2010; Asuquo *et al.*, 2025).

Ethical Considerations

All sampling and handling of fish specimens complied with ethical guidelines for the use of animals in scientific research. The study obtained approval from the Department of Fisheries and Aquaculture University of Calabar, and followed the institutional protocol for humane treatment of aquatic organisms.

Results

Proximate composition of fish species from the Great Kwa River

The proximate composition of the five commercially important fish species collected from the Great Kwa River revealed distinct nutritional variations among species (Table 1). Protein content ranged from 17.10 ± 0.18 % in *Heterotis niloticus* to **21.25 ± 0.09 % in *Polydactylus quadrifilis***, indicating significant differences across species ($p < 0.05$). *Chrysichthys nigrodigitatus* and *Oreochromis niloticus* also showed appreciable protein values of 19.68 ± 0.22 % and 18.45 ± 0.14 %, respectively. The relatively higher protein content recorded in *P. quadrifilis* suggests that the species may be of superior nutritive value and could serve as a better dietary source of animal protein.

Carbohydrate content was generally low in all species, varying between **0.73 ± 0.01 % and 1.17 ± 0.04 %**, with *O. niloticus* showing the highest concentration. Statistical analysis revealed significant inter-species differences ($p < 0.05$). These low carbohydrate levels are consistent with the biochemical makeup of fish muscle, which is primarily protein-based and contains minimal glycogen reserves.

Lipid content ranged from **5.72 ± 0.07 % in *O. niloticus*** to **8.12 ± 0.11 % in *P. quadrifilis***, indicating a clear nutritional gradient across species. The differences were statistically significant ($p < 0.05$). High lipid levels in *P. quadrifilis* and *C. nigrodigitatus* (8.12 ± 0.11 % and 7.10 ± 0.29 %) suggest that these species can be considered semi-fatty fish, which are rich in essential fatty acids beneficial for human health. Conversely, *H. niloticus* and *Mugil cephalus* contained moderate lipid concentrations of 6.28 ± 0.10 % and 5.90 ± 0.06 %, respectively.

The ash content, which reflects the mineral composition of the fish muscle, showed modest variation among species. The highest ash percentage (1.61 ± 0.03 %) was recorded in *P. quadrifilis*, whereas *M. cephalus* had the lowest value (1.22 ± 0.01 %). ANOVA revealed significant differences in ash composition among species ($p < 0.05$). Fiber content was minimal across all species, ranging from **0.24 ± 0.01 % in *H. niloticus*** to **0.52 ± 0.02 % in *P. quadrifilis***, with significant inter-species variation ($p < 0.05$). Moisture content, which inversely relates to fat

concentration, was highest in *H. niloticus* (74.85 ± 0.28 %) and lowest in *P. quadrifilis* (67.74 ± 0.30 %), reflecting the typical composition of freshwater fish (Table 1).

Table 1. Proximate composition (%) of commercially important fish species from the Great Kwa River

Nutrient (%)	CN	HN	ON	MC	PQ
Protein	19.68 ± 0.22^b	17.10 ± 0.18^c	18.45 ± 0.14^{bc}	17.72 ± 0.10^c	21.25 ± 0.09^a
Carbohydrate	0.84 ± 0.05^b	1.09 ± 0.03^a	1.17 ± 0.04^a	1.00 ± 0.02^b	0.73 ± 0.01^c
Lipid	7.10 ± 0.29^b	6.28 ± 0.10^c	5.72 ± 0.07^d	5.90 ± 0.06^d	8.12 ± 0.11^a
Ash	1.50 ± 0.04^b	1.39 ± 0.03^{bc}	1.29 ± 0.02^c	1.22 ± 0.01^c	1.61 ± 0.03^a
Fiber	0.38 ± 0.01^b	0.24 ± 0.01^c	0.30 ± 0.01^{bc}	0.29 ± 0.01^{bc}	0.52 ± 0.02^a
Moisture	70.25 ± 0.45^c	74.85 ± 0.30^b	72.41 ± 0.28^{bc}	73.96 ± 0.24^b	67.74 ± 0.30^d

Notes: Values are expressed as Mean \pm SEM ($n = 6$). Means in the same row with different superscript letters differ significantly ($p < 0.05$). CN = *Chrysichthys nigrodigitatus*; HN = *Heterotis niloticus*; ON = *Oreochromis niloticus*; MC = *Mugil cephalus*; PQ = *Polydactylus quadrifilis*.

Relationship between environmental parameters and nutritional composition

Environmental parameters measured at the sampling sites demonstrated close relationships with the nutritional composition of the fish species (Fig. 2). Temperature varied between 27.8 °C and 29.0 °C, dissolved oxygen (DO) ranged from 6.2 mg/L to 6.8 mg/L, and pH values were within the neutral range (7.0–7.5). Linear regression analyses revealed that **protein content increased slightly with rising DO and pH**, while a marginal decline in protein concentration was observed at higher temperatures. These relationships suggest that fish inhabiting oxygen-rich and moderately alkaline environments tend to exhibit enhanced protein synthesis and retention, possibly due to improved metabolic efficiency. Although the trends were not strongly linear, they highlight the potential influence of environmental factors on the biochemical quality of fish inhabiting tropical freshwater systems.

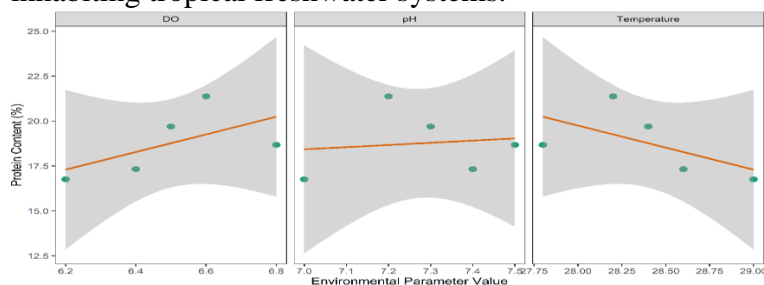


Figure 2: Relationship between Environmental Parameters and Protein Content of Fish Species from the Great Kwa River

Discussion

This study revealed significant variations in the proximate composition of commercially important fish species from the Great Kwa River, underscoring the influence of both species-specific traits and environmental conditions on fish nutritional quality. Differences in protein, lipid, ash, and moisture contents among *Polydactylus quadrifilis*, *Chrysichthys nigrodigitatus*, *Oreochromis niloticus*, *Mugil cephalus*, and *Heterotis niloticus* reflect distinct metabolic adaptations, ecological roles, and feeding behaviors. These findings suggest that environmental variation (particularly in water temperature, dissolved oxygen, and pH) can shape the biochemical profiles of freshwater fish.

The high protein content observed in *P. quadrifilis* ($21.25 \pm 0.09\%$) and *C. nigrodigitatus* ($19.68 \pm 0.22\%$) is consistent with previous studies by Abdullahl (1998) and Adewolu *et al.* (2008), which reported similar protein levels in tropical freshwater species. The elevated protein values in *P. quadrifilis* may be attributed to its carnivorous diet and active predatory behavior, which promote greater protein synthesis and muscle development (Fasakin *et al.*, 2001). In contrast, *H. niloticus* exhibited the lowest protein content ($17.10 \pm 0.21\%$), aligning with findings by Mazrouh (2015), who noted that herbivorous and detritivorous fish often possess lower muscle protein due to differences in dietary composition and digestive efficiency.

Lipid content also varied significantly across species, ranging from $5.72 \pm 0.07\%$ in *O. niloticus* to $8.12 \pm 0.11\%$ in *P. quadrifilis*. These differences may reflect habitat productivity and food availability, as suggested by Du *et al.* (2025), who linked lipid variation in fish to environmental resource dynamics. The relatively high lipid levels in *P. quadrifilis* and *C. nigrodigitatus* indicate metabolic adaptations that support energy storage under fluctuating environmental conditions. This observation is supported by Yuan *et al.* (2022), who found that temperature shifts can influence lipid accumulation in fish as a compensatory mechanism. Conversely, the lower lipid content in *O. niloticus* may be related to its omnivorous feeding habits and higher metabolic turnover.

The inverse relationship between moisture and lipid content observed in this study supports the findings of Ackman (2007), who reported that increased lipid deposition typically corresponds with reduced tissue hydration. This balance between energy storage and water retention is shaped by both physiological traits and environmental stressors. The high moisture content in *H. niloticus* ($74.85 \pm 0.30\%$) reflects its lean tissue composition, a characteristic common among freshwater species in warmer climates (Abowei & Ekubo, 2011).

Ash content values (1.22–1.61%) were consistent with previous reports by Abdullahl (1998), indicating stable mineral levels in freshwater fish. The slightly elevated ash percentage in *P. quadrifilis* may be linked to its demersal feeding behavior, which increases exposure to mineral-rich sediments. Environmental factors such as pH and dissolved oxygen can also influence mineral uptake, as noted by Lall & Kaushik (2021).

The observed relationships between environmental parameters and nutrient composition further highlight the role of water quality in shaping fish biochemistry. The positive correlation between dissolved oxygen and protein concentration aligns with findings by Ali *et al.* (2022), who reported that oxygen-rich environments enhance aerobic metabolism and protein synthesis. Similarly, the slight decline in protein content with increasing temperature supports the work of Hampuwo *et al.* (2025), who demonstrated that elevated temperatures can increase metabolic rates, leading to greater energy expenditure and reduced protein retention.

These findings are particularly relevant for freshwater systems like the Great Kwa River, where seasonal and spatial environmental variation can influence fish physiology and nutritional value. While long-term climate trends may contribute to these changes, the current study emphasizes the immediate effects of local environmental conditions. Compared to previous studies on tropical river systems, this research provides new insights into how physicochemical factors affect fish nutrient profiles and offers baseline data for future ecological assessments.

In summary, the variations in proximate composition among the studied fish species reflect the combined effects of biological traits, feeding ecology, and environmental quality. Continued environmental fluctuations (whether seasonal or anthropogenic) could alter the biochemical integrity of freshwater fish populations. These changes have implications for fisheries management, food security, and ecosystem resilience. Future research integrating long-term environmental monitoring with biochemical analysis is recommended to better understand and mitigate the impacts of ecological variation on aquatic food resources.

Conclusion

This study reveals environmental variation and nutritional composition of key freshwater fish species in the Great Kwa River. Notable differences in protein, lipid, and moisture content were observed among species, with *Polydactylus quadrifilis* showing the highest nutritive value. The correlations between water quality parameters and nutrient levels indicate that local environmental conditions affect fish biochemistry. These findings offer baseline data for sustainable fisheries management and highlight the importance of continuous ecological monitoring to protect food quality and aquatic health.

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