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Conservation of Freshwater Fish Biodiversity in the Face of Global Change: A Study of Species Diversity, Seasonal Population Dynamics, and Habitat Use of Fish in Qua River, Calabar, Nigeria

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ABSTRACT

The conservation of freshwater fish biodiversity is increasingly threatened by global environmental changes. This study investigates species diversity, seasonal population dynamics, and habitat use of fish in the Qua River, Calabar, Nigeria, to inform conservation strategies. Fish species were monitored over four months to assess the influence of environmental factors such as temperature, turbidity, and pH on seasonal variations during the dry and rainy seasons. Results revealed that *Chrysichthys nigrodigitatus* was the most abundant species during the rainy season, whereas *Pellonula leonensis* dominated the dry season. Morphometric analysis demonstrated significant seasonal effects on fish attributes, although head length and width remained consistent. A statistically significant correlation ($p < 0.01$, two-tailed) indicated the strong influence of seasonal variations on fish population dynamics.

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These findings underscore the importance of adaptive management strategies for conserving freshwater ecosystems, particularly in the face of climate change and habitat alterations. Implementing evidence-based conservation measures will be crucial in maintaining fish biodiversity and ensuring the sustainability of aquatic resources in the Qua River and similar freshwater systems.

Keywords: Biodiversity, Freshwater ecosystems, Conservation, Global change.

1. INTRODUCTION

Freshwater ecosystems are among the planet's most diverse and productive habitats, providing essential human livelihood and biodiversity resources. However, these ecosystems are increasingly threatened by global environmental changes, including climate change, habitat degradation, and pollution, significantly impacting aquatic species' biodiversity and population dynamics (Ekpo *et al.,* 2017). Understanding the factors influencing fish biodiversity and their seasonal dynamics is crucial for developing effective conservation strategies.

The Qua River in Calabar, Nigeria, serves as a vital freshwater resource, supporting numerous fish species that contribute to local fisheries and ecological balance. Freshwater fish are particularly sensitive to environmental changes, which can alter their distribution, abundance, and reproductive cycles (Ekpo *et al*., 2022). The seasonal variation in tropical regions, characterized by distinct dry and rainy seasons, plays a crucial role in shaping the habitat conditions and availability of resources for aquatic species. This study aims to investigate the species diversity, seasonal population dynamics, and habitat use of fish in the Qua River, emphasizing the impacts of environmental factors such as temperature, turbidity, and pH on their distribution.

Previous studies have demonstrated that temperature is a critical determinant of fish distribution and metabolic processes. For instance, temperature fluctuations influence the reproductive cycles and growth rates of many freshwater fish species. In the Qua River, it is hypothesized that the rainy season, with cooler temperatures and increased water flow, provides favorable conditions for species like *Chrysichthys nigrodigitatus* and *Macrobrachium vollenhoven*, leading to their higher abundance. Conversely, during the dry season, reduced water levels and higher temperatures create a different ecological niche, favoring species such as *Pellonula leonensis* and *Clarias lazera*.

Turbidity, another key environmental factor, affects light penetration and subsequently the availability of food and habitat for fish. High turbidity levels, often associated with the rainy season, can limit the growth of aquatic plants and reduce visibility for predatory fish, influencing their feeding efficiency and habitat selection. The fluctuating turbidity levels in the Qua River are expected to impact the habitat use and spatial distribution of different fish species, contributing to seasonal shifts in community composition.

PH levels also play a significant role in determining the suitability of freshwater habitats for various fish species. Extreme pH levels can lead to physiological stress and reduced survival rates in fish, while optimal pH ranges promote healthy metabolic functions and reproduction (Ekerette *et al*., 2024). In tropical rivers like the Qua, seasonal changes in pH, influenced by rainfall and runoff, may affect the species composition and abundance, particularly for sensitive species with narrow tolerance ranges.

Research on the seasonal dynamics of fish populations in African rivers has highlighted the importance of understanding local ecological processes for conservation efforts (Asuquo *et al*., 2021). Studies on the Zambezi River and the Amazon have shown that seasonal flooding and drying cycles create diverse habitats that support high fish biodiversity. These findings underscore the need for region-specific studies that consider the unique environmental conditions and species interactions in each river system.

The present study builds on this body of knowledge by examining the species diversity, population dynamics, and habitat use of fish in the Qua River over four months, encompassing both the dry and rainy seasons. By assessing the influence of temperature, turbidity, and pH on fish distribution, this research aims to provide insights into the ecological processes that govern freshwater fish biodiversity in tropical rivers. The findings are expected to inform conservation strategies that address the challenges posed by global environmental changes, ensuring the sustainable management of freshwater resources in Nigeria and beyond.

2. MATERIALS AND METHODS

2.1. Description of Study Area

This study was conducted at the Great Kwa River, with Esuk Atu Beach, located off University Teaching Hospital Road, Calabar, Cross River State, serving as the sampling station. The Great Kwa River, also known as the Kwa Ibo River or Kwa River, flows through Cross River State, Nigeria, and drains the eastern side of Calabar city. The river's ecology is under threat from human activities, including pollution and habitat destruction.

2.2. Geographic Location and Features

The Great Kwa River originates in the Oban Hills, within the Cross River National Park, Akamkpa, and flows southwards to the Cross River estuary in Cross River State, Nigeria, with its coordinates approximately 4.957°N latitude and 8.337°E longitude. This estuary is a vital ecological zone where the Great Kwa River meets the Atlantic Ocean, forming a diverse and productive wetland system. The estuary is characterized by brackish waters, with significant influences from both freshwater inflows and tidal oceanic processes (Ekpo *et al*., 2021). The river features dramatic landscapes, including the Kwa Falls, and its lower reaches are tidal, with broad mudflats.

2.3. Human Activities and Pollution Threats

Historically, human activities in the Great Kwa basin have been limited to small-scale farming, aquaculture, and artisanal fisheries. However, the rapid growth of Calabar's population, driven by the establishment of the Calabar Free Trade Zone, has led to increased urbanization and industrialization along the river's coastline and mangrove swamps. This has resulted in significant pollution threats, including the discharge of human and industrial waste into the river, particularly during heavy rainfall events. The lack of sewage treatment facilities and the increasing human population in Calabar municipality further exacerbate the pollution threat to the river's ecology.

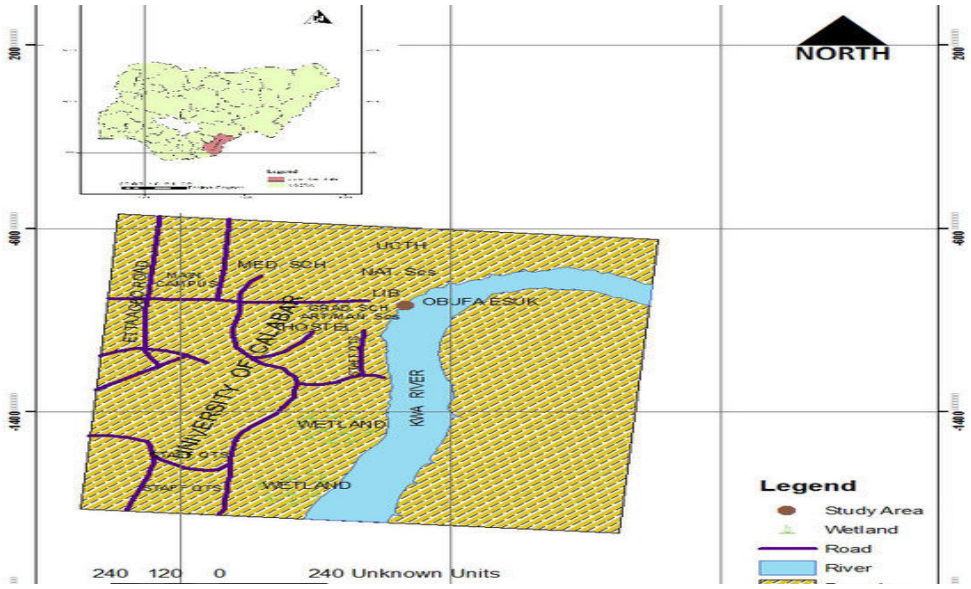


Figure 1. Map of the study area, (Ekpo *et al*., 2021).

2.4. Sampling Procedure

A four-month sampling period (March to August) was conducted at Esuk Atu Beach, where fish species were collected from subsistence fishermen's landings. A variety of fishing gear was employed to ensure a representative sample of the fish population, including:

- Basket traps

- Gill nets with stretched meshes of 10 to 3mm

- Cast nets with mesh sizes of 10 to 25mm

- Hook and net

- Bait (earthworms and fingerlings)

- Local wooden boats and engine boats

2.5. Laboratory Analysis of Fish Samples

Fish species were collected seasonally (dry and rainy) at different locations (upper and lower) and their:

- Measurements (length, width, and weight)

- Abundance (number of each species on landing)

- Names (identified and recorded), were documented before being transported to the laboratory for further analysis.

In the laboratory, each fish species was confirmed for identity from family to species using common and scientific names and was measured to the nearest 0.1cm using a meter rule for:

- Full-length (FL)

- Head length (HL)

- Tail length (TL)

- Head width (HW)

- Abdomen (A)

- Tail width (TW)

- Weighed using an electronic weighing balance (Scout Pro 600g) with a range of 0.00 to 600g according to the protocol by Ekpo *et al*, 2024: Asuquo *et al*., 2019. Water quality was tested and confirmed to be stable during the study period using the method described by ALPHA (1987).

3. RESULT AND DISCUSSION

3.1. Fish Composition and Diversity

The taxonomic composition of fish species in the Great Kwa River is presented in Table 1a.
A total of 21 fish species, representing 18 genera, 17 families, and 8 orders, were identified in the Great Kwa River ecosystem.

However, as shown in Table 1b, 10 out of the 21 species were not available for sampling during this study. This absence may be attributed to various factors, including seasonal fluctuations, migratory patterns influenced by climate change, overfishing, and exploitation of fish resources leading to stock depletion. Additionally, local fishermen reported that some of these species are present in the Great Kwa River, albeit in limited quantities, suggesting possible rare or endangered species.

Table 1a. Classification of Fish In Great Kwa River.

Order	**Family**	**Species**	**Genus**	**Common Name**	**Efik Name**
Siluriformes	Bagridae	*Chrysichthys nigrodigitatus*	Chrysichthys	Silver cat fish	Inagha
Decapoda	Palaemonidae	*Macrobrachium vollenhovenii*	Macrobrachium	Prawn	Obu
Perciformes	Polynemidae	*Polydactylus quadrifilis*	Polydactylus	-	Eden
Perciformes	Eleotridae	***Eleotris daganensis***	Eleotris	-	Nkukwori

Clupeiformes	Clupeidae	***Pellonula leonensis***	Pellonula	-	Odudukudu
Mugiliformes	Mugilidae	***Mugil cephalus***	Mugil	-	Imin
Pleuronectiformes	Cynoglossidae	***Cynoglossus senegalensis***	Cynoglossus	Senegalese tonguesole	Ukpeg
		Lycodontis niricans			Idogo
Perciformes	Sciaenidae	***Pseudotolithus elongatus***	Pseudotolithus	-	Aniok
Siluriformes	Clariidae	***Clarias lazera***	Clarias	-	Afot
Siluriformes	Schilbeidae	***Schilbe mystus***	Schilbe		Unan

Table 1b. List of Fish Species That Were Not Available For Measurements But Inhabit Great Kwa River.

Order	**Family**	**Species**	**Genus**	**Common Name**	**Efik Name**
Myliobatiformes	Dasyatidae	***Dasyatis margarita***	Dasyatis	-	Ukpan
Perciformes	Cichlidae	***Oreochromis niloticus***	Oreochromis	Tilapia	Asad
Perciformes	Cichlidae	***Gobiocichla ethelwynnae***	Gobiocichla	-	Tabtabonko
Perciformes	Haemulidae	***Pomadasys jubelini***	Pomadasys		Okono
Perciformes	Sphyraenidae	***Sphyraena afra***	Sphyraena	-	Akpanata
Perciformes	Trichiuridae	***Trichurus lepturus***	Trichurus		Adido

Siluriformes	Clariidae	***Clarias anguillaris***	Clarias	-	Oford
Siluriformes	Mochokidae	***Synodontis obesus***	Synodontis	-	Mpikuikuk
Pleocyemata	Portunidae	*Callinectes amnicola*	Callinectes	Crab	Isobu
		Sydodontis nigrita		-	Ngbekuiku

3.2. Length, Width, and Weight of Fish Species

Table 2a presents the mean, sample size, standard deviation, minimum, and maximum values for the full length, head length, tail length, head width, tail width, abdomen, and weight of 11 sampled fish species.

3.3. Seasonal Variations in Fish Length and Weight During the dry season

Clarias lazera exhibited the widest range of full length (32.00-55.00 cm) and weight (262.60-1300.00 g), followed by *Chrysichthys nigrodigitatus* (full length: 9.00-47.50 cm; weight: 6.30-1000.00 g). Other notable species included *Pellonula leonensis* (full length: 4.60-7.10 cm; weight: 0.50-2.20 g) and *Macrobrachium vollenhovenii* (full length: 2.80-9.00 cm; weight: 0.40-21.30 g).

In contrast, the rainy season saw *Chrysichthys nigrodigitatus* attain the highest full length (20.00-71.00 cm) and weight (46.80-2900.00 g). *Cynoglossus senegalensis* followed with a full length range of 35.00-61.00 cm, while *Polydactylus quadrifilis* exhibited a weight range of 1.88-112.00 g.

3.4. Comparing both seasons

Fish species from the rainy season generally displayed greater full length (5.90-71.00 cm) and weight (1.80-2900.00 g) ranges than those from the dry season (full length: 2.80-55.00 cm; weight: 0.40-1300.00 g).

3.5. Range/Abundance of Fish Species

Tables 2b and Figure 2 illustrate the range and abundance of various fish species in the Great Kwa River. The results reveal distinct seasonal patterns in species abundance.

3.6. Rainy Season

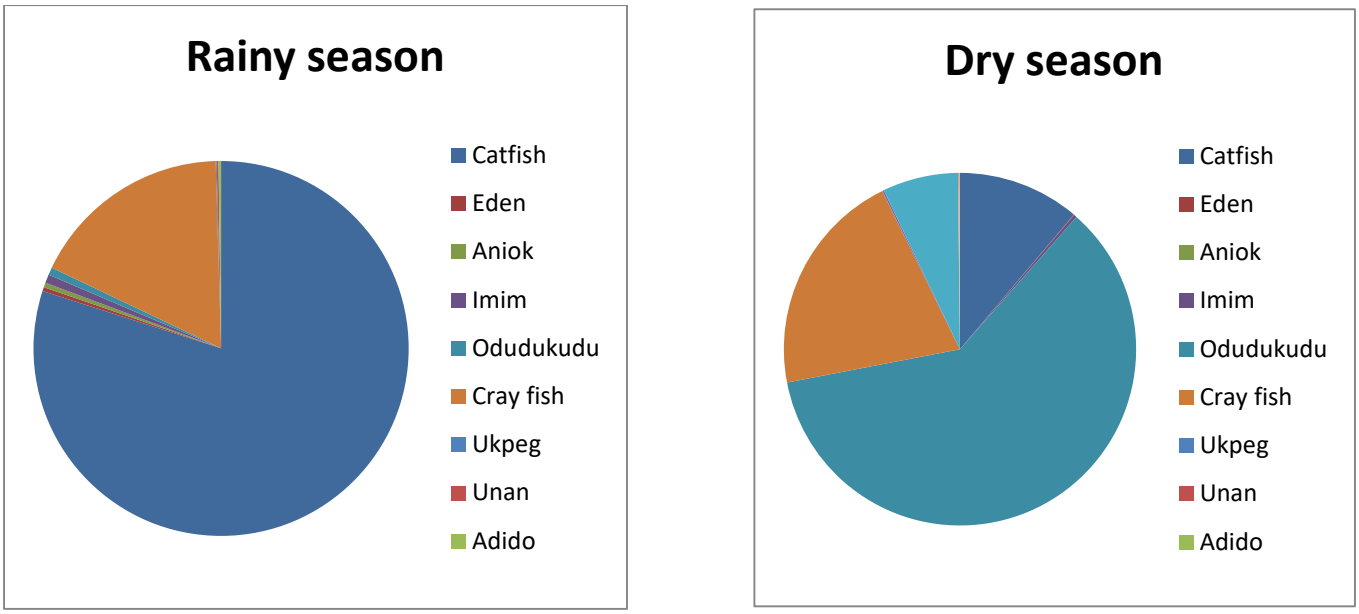
During the rainy season, *Chrysichthys nigrodigitatus* (Silver catfish) was the most abundant species, with a total abundance of 3954 individuals (range: 897-7000). *Macrobrachium vollenhovenii* (Crayfish) followed with an abundance of 863 individuals. Other species, such as *Mugil cephalus* (Imin), *Pellonula leonensis* (Odudukudu), and *Polydactylus quadrifilis* (Edeng), exhibited lower abundances. *Cynoglossus senegalensis* (Ukpeg) was the least abundant species, with only 4 individuals recorded.

3.7. Dry Season

In contrast, the dry season saw *Pellonula leonensis* emerge as the most abundant species, with a total abundance of 4362.5 individuals (range: 3944-4781). *Macrobrachium vollenhovenii* and *Chrysichthys nigrodigitatus* followed with abundances of 1498.5 and 957 individuals, respectively. *Cynoglossus senegalensis* remained the least abundant species, with only 1 individual recorded.

3.8. Seasonal Variations

Notably, some species exhibited marked seasonal variations in abundance. *Clarias lazera* (Ofot), *Eleotris daganensis* (Ngukurwri), and *Lycodontis nigricans* (Idogo) were absent during the rainy season but present during the dry season, suggesting environmental factors influenced their distribution. Conversely, *Pseudotolithus elongatus* (Oniok) and *Schilbe mystus* (Unan) were found during the rainy season but not during the dry season, indicating their diversity was also affected by environmental factors.



Fish species abundance varied between rainy and dry seasons. *Chrysichthys nigrodigitatus* dominated during the rainy season, while *Pellonula leonensis* was most abundant in the dry season, with some species shifting in abundance seasonally.

Figure 2. Distribution of fish species during the dry and rainy season in Great Kwa River.

3.9. Seasonal Variations in Fish Body Characteristics

The results presented in Table 3a indicate that seasonal changes significantly impacted various body characteristics of fish species, including full length, tail length, abdomen size, tail width, and weight. However, head length and head width remained unaffected by seasonal variations (Table 2a).

A case in point is *Chrysichthys nigrodigitatus*, which exhibited significant differences in full length, tail length, abdomen size, tail width, and weight between the dry and rainy seasons (Table 2a). Furthermore, correlation analysis revealed a significant relationship at the 0.01 level (2-tailed), as shown in Table 3b.

Table 3a. Effect of Season (Dry and Rainy) On Body Characteristics Of Some Fish Species.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Full length	Equal variances assumed	.021	.885	-3.348	227	.001	-6.0734890	1.8142324	-9.6483786	-2.4985994
	Equal variances not assumed			-3.345	225.386	.001	-6.0734890	1.8158566	-9.6517165	-2.4952615
Head length	Equal variances assumed	.176	.675	-1.957	227	.052	-1.0116606	.5168636	-2.0301245	.0068034
	Equal variances not assumed			-1.952	220.315	.052	-1.0116606	.5183475	-2.0332147	.0098935
Tail length	Equal variances assumed	.914	.340	-3.027	227	.003	-1.6048993	.5301408	-2.6495255	-.5602730
	Equal variances not assumed			-3.031	226.974	.003	-1.6048993	.5295077	-2.6482787	-.5615199
Head width	Equal variances assumed	6.684	.010	-1.470	227	.143	-.4763126	.3239840	-1.1147132	.1620880
	Equal variances not assumed			-1.462	209.012	.145	-.4763126	.3257718	-1.1185321	.1659070
Abdomen	Equal variances assumed	.200	.655	-6.022	218	.000	-1.6760601	.2783312	-2.2246246	-1.1274956
	Equal variances not assumed			-5.964	202.529	.000	-1.6760601	.2810128	-2.2301460	-1.1219741
Tail width	Equal variances assumed	1.897	.170	-2.675	227	.008	-.9881792	.3694282	-1.7161262	-.2602322
	Equal variances not assumed			-2.666	218.668	.008	-.9881792	.3706606	-1.7187038	-.2576546
Weight	Equal variances assumed	8.902	.003	-2.176	227	.031	-102.0559676	46.9044148	-194.4796870	-9.6322483
	Equal variances not assumed			-2.153	177.257	.033	-102.0559676	47.4124482	-195.6214717	-8.4904635

Results showed there is a significant effect of season on full length, tail length, abdomen size, tail width, and weight. The seasonal effect was not significant on head length and head width (Table 2a). For instance, in *Chrysichthys nigrodigitatus,* there is a significant difference between the full length during the dry and rainy season.

Table 3b. Correlations.

		Full length	Head length	Tail length	Head width	Abdomen	Tail width	Weight
Full length	Pearson Correlation	1	.927**	.906**	.944**	.904**	.889**	.811**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000
	N	229	229	229	229	220	229	229
Head length	Pearson Correlation	.927**	1	.874**	.920**	.828**	.870**	.783**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000
	N	229	229	229	229	220	229	229
Tail length	Pearson Correlation	.906**	.874**	1	.861**	.759**	.887**	.713**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000
	N	229	229	229	229	220	229	229
Head width	Pearson Correlation	.944**	.920**	.861**	1	.845**	.861**	.837**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000
	N	229	229	229	229	220	229	229
Abdomen	Pearson Correlation	.904**	.828**	.759**	.845**	1	.781**	.745**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000
	N	220	220	220	220	220	220	220
Tail width	Pearson Correlation	.889**	.870**	.887**	.861**	.781**	1	.789**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	229	229	229	229	220	229	229
Weight	Pearson Correlation	.811**	.783**	.713**	.837**	.745**	.789**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	229	229	229	229	220	229	229

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Results of the Physiochemical Analysis.

PARAMETER/UNIT	DRY	RAINY
Temperature (^{0}C)	20.9	21.6
pH	4.52	6.66
Colour (HU)	>70	70
Turbidity (NTU)	184	10.68
Dissolved Oxygen (mg/l)	2.66	4.8

4. DISCUSSION

The abundance and distribution of fish species in the Great Kwa River ecosystem are significantly influenced by various environmental factors. Only a limited number of species can thrive in conditions with fluctuating temperatures, salinity, or turbidity (Gibson *et al*., 1993: Asuquo *et al*., 2012). Estuarine fish typically exhibit varying abilities to cope with salinity fluctuations, which directly impacts their distribution (Blaber, 2000: Andem *et al*., 2013). In the Kwa River, the fluctuation of environmental factors such as salinity is primarily influenced by the balance between freshwater inflow (long-term, seasonal changes) and tidal regime (short-term changes). Freshwater intrusion increases during the rainy season and decreases during the dry season, affecting salinity levels (Ekpo *et al*., 2021: Whitfield, 1998).

High turbidity in the river is another crucial environmental factor affecting fish species diversity. Turbidity levels are significantly higher in the dry season (184 NTU) compared to the rainy season (10.68 NTU). Turbidity impacts estuarine fishes by providing protection for juvenile fish from predators, indicating areas with abundant food, and aiding in migration orientation to and from the estuary (Blaber, 2000). However, excessively high turbidity negatively impacts fish egg survival, hatching success, feeding efficiency, growth rate, and population size (Whitfield, 1998). For instance, during turbid conditions, fish rely more on smell than sight for hunting. This is reflected in the abundance of certain species like *Pellonula leonensis*, which showed significantly higher abundance in the dry season (4362.5, range: 3944-4781) compared to the rainy season (32.5, range: 15-50).

Temperature is another critical factor influencing fish availability in the Kwa River. Warmer water temperatures accelerate the growth of young fish and larvae due to increased food availability. Analysis of water samples indicated higher water temperatures during the rainy season (21.6°C) compared to the dry season (20.9°C). This temperature difference contributed to the higher yields of fish species such as *Chrysichthys nigrodigitatus* during the rainy season. pH variations also play a role in fish growth, with the river's pH being 6.66 during the rainy season and 4.52 in the dry season. Increased acidity can hinder the ability of marine organisms to extract necessary calcium carbonate from the water, potentially affecting their survival and growth.

Although these changes in river acidity are slight, they can significantly impact freshwater fish populations. Water color, influenced by rainfall, is another factor affecting fish abundance. During the dry season, the color range exceeded 70, while it was around 70 during the rainy season. This difference impacts species such as *Pellonula leonensis* and *Polydactylus quadrifilis*, with *Pellonula leonensis* showing greater abundance in the clearer waters of the dry season. However, *Polydactylus quadrifilis*, which is more active at night, exhibited higher yields during the rainy season (17.5, range: 10-25) compared to the dry season (3.5, range: 2-5), likely due to reduced predator visibility. In summary, the abundance and distribution of fish species in the Great Kwa River is influenced by a complex interplay of environmental factors, including salinity, turbidity, temperature, pH, and water color. Understanding these factors is essential for the effective management and conservation of the river's aquatic ecosystem (Ekpo *et al*, 2024)

4.1. Species Richness and Diversity

The species richness observed in this study, comprising 11 species, 11 genera, 11 families, and 7 orders, surpasses that recorded in most African streams. For instance, Leke (1968) documented only 6 species from 3 families in the Ebo streams of Ghana. The species count in this study aligns with White's (1975) findings, where he recorded 11 species from streams flowing into Lake Bosumtwi. The species *Chrysichthys nigrodigitatus* emerged as the most abundant in both seasons, with a remarkable count of 7,000 individuals, significantly higher than the 113 recorded by J.-J. Albaret *et al*. (2004). This difference may be attributed to environmental variations during the rainy season. *Pellonula leonensis* followed as the next most abundant species, with 4,781 individuals compared to 79 recorded by Albaret *et al*. (2004). This species showed higher abundance during the dry season, which could also be linked to environmental factors. The distribution of *Cynoglossus senegalensis* and *Mugil cephalus* showed minimal seasonal variation, reflecting their generally low abundance in the Kwa River. While J.-J. Albaret *et al*. (2004) recorded only 2 individuals of *Mugil cephalus*, this study found 60.

Conversely, *Cynoglossus senegalensis* had a significant decrease, with only 4 individuals recorded here compared to 216 in Albaret's study. *Eleotris daganensis*, *Lycodontis nigricans*, and *Schilbe mystus* were among the least abundant species, likely due to environmental variations. *Polydactylus quadrifilis* and *Pseudotolithus elongatus* also showed low abundance, with Albaret *et al.* (2004) reporting much higher counts of 162 and 19,336 respectively. Summary and

5. CONCLUSIONS

This study highlights the seasonal variations in environmental factors in the Great Kwa River and their impact on the distribution and abundance of fish species. Key factors influencing fish populations include water temperature, turbidity, and pH levels. *Chrysichthys nigrodigitatus* was identified as the most abundant species during the rainy season, while *Pellonula leonensis* dominated during the dry season. In contrast, *Cynoglossus senegalensis* was the least abundant species across both seasons. The study found that seasonal changes significantly affect fish metrics such as full length, tail length, abdomen size, tail width, and weight, while head length and head width remained unaffected. Correlation analysis showed significance at the 0.01 level (2-tailed). Conclusively, environmental factors influence fish populations by: • Shifting fish distribution patterns, possibly leading to migration. • Affecting river temperatures, which impact the growth and survival of juvenile fish. • Determining dominant currents that influence the growth and survival of young fish. • Shifting the timing of crucial ecosystem events necessary for fish survival and reproduction.

Recommendations

Further studies are needed to assess the extent of the potential extinction of fish species prevalent in our rivers. Strategies should be devised to preserve the remaining species that may be at risk of extinction. Additionally, the government should implement and strictly enforce fishing regulations to conserve aquatic resources and protect the riverine environment.

References

[1] Albaret, J.-J., Simier, M., Darboe, F. S., Ecoutin, J. M., Raffray, J., & De Morais, L. T. (2004). Fish diversity and distribution in the Gambia Estuary, West Africa, in relation to environmental variables. *Aquatic Living Resources, 17*(1), 35-46.

[2] American Public Health Association. (1987). *Standard methods for the examination of water and wastewater* (16th ed.). American Public Health Association.

[3] Andem, A. B., Ekpo, P. B., Etta, S. E., Usoh, A. G., & Eyo, V. O. (2013). Effect of different feed application rates on the growth performance and body composition of African catfish, *Clarias gariepinus* fingerlings. *International Journal of Scientific Research and Management, 1*(9), 471-475.

[4] Asuquo, P. E., & Ifon, H. T. (2019). Morphometric adaptation of Bobo Croaker, *Pseudotolithus elongatus* (Bowdich, 1825) (Sciaenidae) in Cross River Estuary, Nigeria. *International Journal of Natural and Applied Sciences (IJNAS, 12*(Special Edition), 87-92.

[5] Asuquo, P. E., & Ifon, H. T. (2021). Morphological discreteness of the estuarine croaker *Pseudotolithus elongatus* (Teleostei: Sciaenidae). *Journal of Fish Biology*, 1-6.

[6] Asuquo, P. E., Ekanem, A. P., Eyo, V. O., & Pedro, E. J. (2012). Effects of diet with cassava leaf meal (CLM), *Manihot utilissima*, on the growth and fecundity of *Clarias gariepinus*. *African Journal of Biosciences, 5*(1), 1-5.

[7] Blaber, S. J. M. (2000). *Tropical estuarine fishes: Ecology, exploitation, and conservation*. Blackwell Science.

[8] Ekerette, E. E., Etukudo, O. M., Efienokwu, J. N., Etta, H. E., Henry, I., & Ekpo, P. B. (2024). Mi am at annexEvaluation of genetic variation in Oreochromis tilapia species from South-South Nigeria using mitochondrial DNA hypervariable region. *Tropical Journal of Natural Product Research, 8*(9).

[9] Ekpo, P. B., Etangetuk, N. A., Chinyere, O. A., Effiong, N. M., & Ekpo, I. P. (2024). Effects of municipal waste discharge and its re-suspension on water quality in the Great Kwa River estuary, Cross River State, Nigeria. *International Journal of Research and Innovation in Applied Science*.

[10] Ekpo, P. B., Umoyen, A. J., Akpan, N. G., Ekpo, I. P., Sunday, C. J., Abu, G., & Ekpenyong, B. B. (2022). The distribution and seasonal variation of zooplankton species of the Great Kwa River, Calabar, Nigeria: A reassessment approach. *Annual Research and Review in Biology, 37*(8), 10-20.

[11] Ekpo, P. B., Umoeyen, A., Akpan, N., Ekpo, I. P., Abu, G., & Sunday, C. (2021). Evaluation of pollution load: Heavy metals contents and physiochemical properties of the Great Kwa River, Calabar, Cross River State, Nigeria. *International Journal of Environmental and Climate Change, 11*(2), 19-31.

[12] Ekpo, P. B., Uno, U. U., Okolo, C. M., Agu, R. B., & Onwudike, C. F. (2017). Acute toxicity of *Adenia cissampeloides* in farmed African catfish (*Clarias gariepinus*). *Annual Research and Review in Biology, 20*(5), 1-5.

[13] Gibson, R. N., Yin, M. C., & Robb, L. (1993). The behavioural ecology of flatfishes. *Journal of Fish Biology, 45*(1), 57-79.

[14] Leke, A. W. (1968). A preliminary survey of the fish fauna of Ebo streams, Ghana. *Ghana Journal of Science*.

[15] Whitfield, J. (1998). The effects of climate change on crop yields. Journal of Agricultural Science, 131(2), 133-144.

[16] White, R. (1975). Ecological issues in agricultural development. Journal of Environmental Management, 3(2), 131-144.