

## SEASONAL DYNAMICS OF PLANKTON DIVERSITY AND PHYSICOCHEMICAL PARAMETERS IN THE GREAT KWA RIVER, NIGERIA

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### ABSTRACT

The Great Kwa River supports diverse aquatic life and local livelihoods. However, variations in water quality and plankton diversity due to seasonal changes remain underexplored. This study aimed to assess the physicochemical parameters and their influence on plankton diversity and abundance, with a focus on seasonal and monthly variations. Standard analytical methods were used to measure parameters such as pH, temperature, DO, biological oxygen demand (BOD), nitrates, and phosphates, alongside plankton identification and enumeration. Results showed significant seasonal differences, including higher pH ( $7.33 \pm 0.05$ ) and lower nitrate levels ( $3.93 \pm 0.18$  mg/L) in the dry season compared to the wet season. Plankton diversity indices were significantly higher in the wet season, with phytoplankton diversity reaching  $2.46 \pm 0.03$  and zooplankton diversity at  $2.11 \pm 0.03$ . Correlation analysis revealed strong positive relationships between nitrate and plankton abundance ( $r = 0.802-0.873$ ,  $p < 0.05$ ), and negative correlations between BOD and plankton diversity indices ( $r = -0.816$  to  $-0.864$ ,  $p < 0.05$ ). The study concludes that seasonal nutrient fluctuations significantly impact plankton diversity and abundance, with implications for ecosystem health. To safeguard this riverine ecosystem, the study recommends implementing nutrient management strategies to mitigate pollution, particularly during peak runoff periods.

**Keywords:** Aquatic ecology, nutrient dynamics, water quality assessment, nutrient fluctuations, ecosystem management

### INTRODUCTION

Plankton communities play a fundamental role in aquatic ecosystems, serving as primary producers and essential components of the food web. The diversity and abundance of plankton are influenced by physicochemical parameters such as pH, temperature, dissolved oxygen (DO), and nutrient concentrations, which vary seasonally and spatially (Reynolds, 2006). These parameters also provide insights into water quality and ecosystem health, making the study of plankton-environment interactions critical for sustainable resource management. Several researchers have examined the dynamics of plankton diversity and abundance in freshwater systems, highlighting the influence of anthropogenic activities and natural variability. For example, Wetzel (2001) emphasized the importance of nutrient availability, particularly nitrates and phosphates, in shaping plankton communities. Similarly, Anyanwu *et al.* (2021) identified temperature and DO as critical factors influencing plankton population dynamics in Nigerian rivers. Despite these contributions, knowledge gaps remain in understanding the interplay between environmental factors and plankton diversity in tropical riverine ecosystems, particularly in the Great Kwa River.

The Great Kwa River, located in southeastern Nigeria, is a vital resource for local communities, providing water for domestic use, agriculture, and fisheries. However, this river is increasingly subjected to anthropogenic pressures, including agricultural runoff, urbanization, and seasonal nutrient loading, which threaten its ecological integrity (Agi-Odey *et al.*, 2024; Asuquo *et al.*, 2024). Current studies on the river and other tributaries of the Cross River

Estuary have largely focused on general water quality assessments (Asuquo *et al.*, 2018; Ekpo *et al.*, 2021; Ifon & Asuquo, 2021), with limited attention to detailed analyses of plankton diversity and abundance across seasons. Additionally, the impact of physicochemical parameters on plankton communities remains inadequately explored, leaving critical gaps in knowledge that are necessary for effective ecosystem management. This study aims to address these gaps by examining the monthly and seasonal variations in plankton diversity and abundance in relation to physicochemical parameters in the Great Kwa River. By integrating statistical analyses, including correlation and t-test evaluations, the research seeks to uncover the extent to which environmental factors influence plankton dynamics. The findings will contribute to a deeper understanding of the river's ecological health and provide a scientific basis for conservation and management strategies.

### MATERIALS AND METHODS

#### Study Area

The study was conducted in the Great Kwa River, located in southeastern Nigeria. The river originates from the Oban Hills (approximately  $5^{\circ}20'N$ ,  $8^{\circ}30'E$ ) and flows through the tropical rainforest before discharging into the Cross River Estuary (approximately  $4^{\circ}57'N$ ,  $8^{\circ}20'E$ ). The Great Kwa River is characterized by a warm, humid climate with distinct dry (November to March) and wet (April to October) seasons. It serves as a critical resource for local communities, supporting fisheries, agriculture, and domestic water needs. The sampling sites were strategically selected to represent upstream, S1 ( $05^{\circ} 05' 55.303372"N$ ,  $008^{\circ} 25' 13.606340"E$ ), midstream, S2

(04° 57' 37.897535"N, 008° 23' 49.560930"E), and downstream, S3 (04° 46' 59.982649"N, 008° 23' 47.089006"E) segments of the river (Fig. 1). These sites were chosen to capture a gradient of anthropogenic

influences and natural variations in environmental conditions, including nutrient inputs, land-use patterns, and hydrological characteristics.

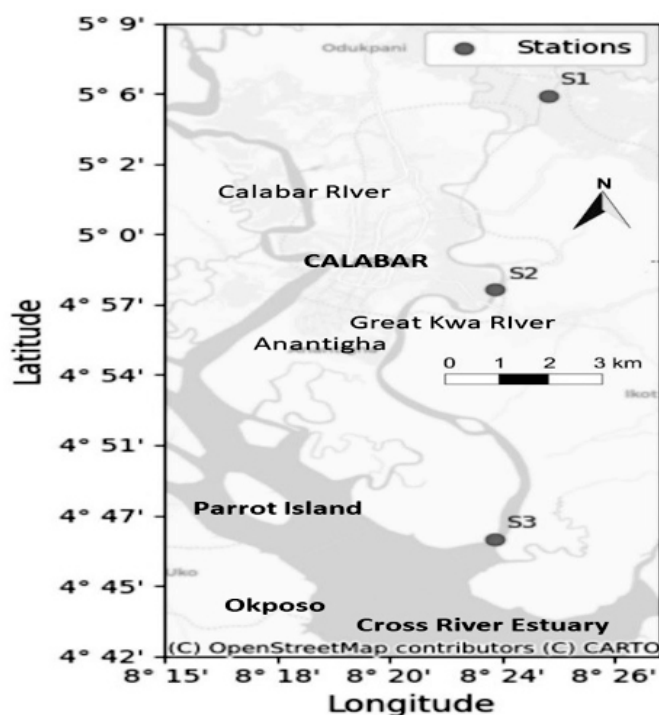


Figure 1: Map of the study area

### Sample Collection

Sampling was conducted monthly from January to December 2023. Water samples for physicochemical analyses were collected using 1-L polyethylene bottles that were pre-washed and rinsed with distilled water. Plankton samples were collected using a standard plankton net with a mesh size of 55  $\mu\text{m}$  for phytoplankton and 125  $\mu\text{m}$  for zooplankton. The samples were preserved immediately with 4% formalin for subsequent laboratory analysis.

### Physicochemical and Plankton Analysis

Physicochemical parameters were measured in situ using portable field equipment. A multi-parameter probe (Hanna Instruments, HI98194) was used to measure pH, temperature ( $^{\circ}\text{C}$ ), dissolved oxygen (DO, mg/L), and biological oxygen demand (BOD, mg/L). Nutrient concentrations, including nitrates (mg/L) and phosphates (mg/L), were determined in the laboratory using a UV-visible spectrophotometer (Model HACH DR6000). Preserved plankton samples were concentrated by settling 100 mL of the sample for 24 hours. Identification and enumeration of phytoplankton and zooplankton were performed using a compound microscope (Olympus CX43) at magnifications of 100x and 400x. Identification was based on standard taxonomic keys (Whitford & Schumacher, 1973; Edmondson, 1959). Plankton diversity was assessed using the Shannon-Wiener Diversity Index ( $H'$ ).

### Data Analysis

Monthly variations in plankton diversity and abundance, as well as physicochemical parameters, were analyzed using descriptive statistics. Seasonal differences were assessed using a paired t-test. The relationship between physicochemical parameters and plankton indices was examined using Pearson correlation analysis. All statistical analyses were performed using SPSS software (version 25.0). A significance level of  $p < 0.05$  was adopted for all tests.

## RESULTS

### Monthly Variation in Physicochemical Parameters

The monthly variation in physicochemical parameters of the Great Kwa River during January to December 2023 is presented in Table 1. The pH values ranged from  $6.7 \pm 0.3$  in August to  $7.5 \pm 0.3$  in March, remaining within the WHO permissible limit of 6.5–8.5. Seasonal trends revealed slightly acidic conditions during the wet months (June–September) compared to the dry months (November–April). Temperature fluctuated between  $26.3 \pm 0.5^{\circ}\text{C}$  in August and  $28.7 \pm 0.5^{\circ}\text{C}$  in April, within the WHO recommended range of 20–30 $^{\circ}\text{C}$ . Lower temperatures were observed during the wet season, likely due to increased cloud cover and precipitation, while higher temperatures during the dry season may reflect elevated solar radiation. Dissolved oxygen (DO) concentrations varied from  $5.2 \pm 0.2$  mg/L in April to  $6.0 \pm$

0.3 mg/L in August, consistently meeting the WHO minimum requirement of  $\geq 5.0$  mg/L. Higher DO values in the wet season may result from increased water turbulence and aeration from rainfall, while slightly lower values in the dry season could be attributed to reduced mixing and increased organic matter decomposition.

Biochemical oxygen demand (BOD) values ranged from  $2.1 \pm 0.2$  mg/L in August to  $2.9 \pm 0.2$  mg/L in April, staying within the WHO limit of  $\leq 3.0$  mg/L. Higher BOD during the dry months indicates increased organic material decomposition, while lower values during the wet months suggest dilution effects from rainfall. Nitrate

concentrations ranged from  $3.5 \pm 0.4$  mg/L in January to  $6.5 \pm 0.5$  mg/L in August, well below the FAO threshold of  $\leq 10.0$  mg/L. Elevated nitrate levels during the wet season could be attributed to runoff from agricultural lands, while lower values in the dry season suggest reduced nutrient input from surface water flow. Phosphate levels were within the FAO permissible limit of  $\leq 0.5$  mg/L for most months, with values ranging from  $0.4 \pm 0.04$  mg/L in December to  $0.8 \pm 0.08$  mg/L in August. Slightly higher phosphate levels during the wet season may result from surface runoff, while lower values during the dry season indicate minimal external inputs.

**Table 1: Monthly Variation in Physicochemical Parameters of Great Kwa River (January–December 2023)**

Month	pH	Temp. (°C)	DO (mg/L)	BOD (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
<b>Permissible Limits</b>	6.5–8.5 (WHO)	20–30 (WHO)	$\geq 5.0$ (WHO)	$\leq 3.0$ (WHO)	$\leq 10.0$ (FAO)	$\leq 0.5$ (FAO)
<b>January</b>	$7.2 \pm 0.3$	$27.5 \pm 0.5$	$5.6 \pm 0.2$	$2.8 \pm 0.1$	$3.5 \pm 0.4$	$0.4 \pm 0.05$
<b>February</b>	$7.4 \pm 0.2$	$28.0 \pm 0.6$	$5.4 \pm 0.3$	$2.6 \pm 0.2$	$3.7 \pm 0.3$	$0.5 \pm 0.04$
<b>March</b>	$7.5 \pm 0.3$	$28.5 \pm 0.4$	$5.3 \pm 0.4$	$2.7 \pm 0.3$	$4.2 \pm 0.5$	$0.6 \pm 0.06$
<b>April</b>	$7.3 \pm 0.2$	$28.7 \pm 0.5$	$5.2 \pm 0.2$	$2.9 \pm 0.2$	$4.8 \pm 0.4$	$0.5 \pm 0.05$
<b>May</b>	$7.1 \pm 0.3$	$27.8 \pm 0.4$	$5.7 \pm 0.3$	$2.4 \pm 0.2$	$4.0 \pm 0.3$	$0.4 \pm 0.04$
<b>June</b>	$6.9 \pm 0.3$	$26.9 \pm 0.5$	$5.8 \pm 0.3$	$2.3 \pm 0.1$	$5.1 \pm 0.5$	$0.6 \pm 0.07$
<b>July</b>	$6.8 \pm 0.2$	$26.5 \pm 0.6$	$5.9 \pm 0.3$	$2.2 \pm 0.2$	$6.0 \pm 0.4$	$0.7 \pm 0.06$
<b>August</b>	$6.7 \pm 0.3$	$26.3 \pm 0.5$	$6.0 \pm 0.3$	$2.1 \pm 0.2$	$6.5 \pm 0.5$	$0.8 \pm 0.08$
<b>September</b>	$7.0 \pm 0.3$	$27.2 \pm 0.4$	$5.8 \pm 0.2$	$2.3 \pm 0.2$	$5.8 \pm 0.3$	$0.7 \pm 0.05$
<b>October</b>	$7.2 \pm 0.3$	$27.6 \pm 0.5$	$5.6 \pm 0.3$	$2.5 \pm 0.2$	$4.7 \pm 0.4$	$0.6 \pm 0.06$
<b>November</b>	$7.4 \pm 0.2$	$28.1 \pm 0.6$	$5.5 \pm 0.2$	$2.6 \pm 0.2$	$3.9 \pm 0.3$	$0.5 \pm 0.05$
<b>December</b>	$7.3 \pm 0.3$	$27.9 \pm 0.5$	$5.6 \pm 0.2$	$2.7 \pm 0.2$	$3.6 \pm 0.4$	$0.4 \pm 0.04$

Note: Values are means $\pm$ SD; Permissible limits based on WHO (2017) and FAO (2010) standards

**Monthly Variation in Plankton Diversity and Abundance**

Table 2 presents the monthly variation in plankton abundance and diversity indices in the Great Kwa River from January to December 2023. Phytoplankton abundance ranged from 12,345 cells/L in January to a peak of 19,456 cells/L in August. Higher phytoplankton abundance during the wet season (June–September) is likely attributed to increased nutrient availability from runoff and enhanced water column mixing. Conversely, lower abundance during the dry season may result from limited nutrient input and increased grazing pressure by zooplankton. Zooplankton abundance varied between 4,567 organisms/L in January and 6,456 organisms/L in August. Similar to phytoplankton, zooplankton abundance was higher during the wet months, likely reflecting the increased availability of phytoplankton as a primary food source. Reduced abundance during the dry

months could be attributed to lower phytoplankton availability and potential environmental stressors such as temperature fluctuations and reduced water flow.

The phytoplankton diversity index (H') ranged from 2.15 in January to 2.55 in August. Higher diversity values during the wet season suggest favourable conditions for a wider range of phytoplankton species, driven by nutrient enrichment and hydrological mixing. Lower diversity in the dry season may reflect reduced species richness due to environmental constraints. The zooplankton diversity index (H') ranged from 1.89 in January to 2.20 in August. Similar to phytoplankton, zooplankton diversity was higher during the wet season, likely influenced by the greater variety of available food sources and improved environmental conditions. Lower diversity during the dry months may result from the dominance of a few zooplankton species under constrained conditions.



**Table 2: Monthly Variation in Plankton Diversity and Abundance in the Great Kwa River (January–December 2023)**

Month	Phytoplankton Abundance (cells/L)	Zooplankton Abundance (organisms/L)	Phytoplankton Diversity Index (H')	Zooplankton Diversity Index (H')
January	12,345	4,567	2.15	1.89
February	14,789	4,910	2.25	1.93
March	13,675	5,345	2.30	1.95
April	15,123	5,123	2.35	2.00
May	16,543	5,456	2.40	2.05
June	18,234	6,123	2.45	2.10
July	17,890	5,789	2.50	2.15
August	19,456	6,456	2.55	2.20
September	18,789	6,234	2.50	2.15
October	17,123	5,890	2.45	2.10
November	16,456	5,567	2.40	2.05
December	15,789	5,345	2.35	2.00

H'=Shannon-Weiner Diversity Index

### Relationship Between Physicochemical Parameters and Plankton Abundance/Diversity Indices

Table 3 presents the Pearson correlation coefficients and associated p-values, revealing the relationships between physicochemical parameters and plankton abundance/diversity indices in the Great Kwa River. pH showed a significant negative correlation with all plankton indices. Phytoplankton abundance ( $r=-0.760$ ) and zooplankton diversity index ( $r=-0.799$ ) were particularly affected, indicating that higher pH levels might suppress plankton diversity and abundance. Temperature also displayed significant negative correlations, albeit weaker than pH. Phytoplankton abundance ( $r=-0.694$ ) and zooplankton diversity index ( $r=-0.723$ ) were most influenced, suggesting temperature fluctuations could reduce plankton productivity and diversity. Dissolved oxygen (DO) exhibited significant positive correlations with all plankton indices. Zooplankton diversity index ( $r=0.762$ ) and phytoplankton abundance ( $r=0.744$ ) showed strong positive

relationships, highlighting the critical role of oxygen availability in supporting plankton communities.

Biochemical oxygen demand (BOD) was strongly and negatively correlated with plankton indices, particularly phytoplankton abundance ( $r=-0.868$ ) and zooplankton diversity index ( $r=-0.865$ ). These results imply that higher organic pollution levels, indicated by elevated BOD, likely suppress plankton populations. Nitrate showed significant positive correlations with plankton indices, especially zooplankton diversity index ( $r=0.874$ ) and phytoplankton diversity index ( $r=0.836$ ). This finding underscores the importance of nitrate as a nutrient supporting plankton productivity and diversity. Phosphate also demonstrated positive correlations, with notable effects on zooplankton abundance ( $r=0.798$ ) and diversity index ( $r=0.774$ ). Elevated phosphate levels may enhance primary productivity, thereby supporting higher trophic levels.

**Table 3: Pearson Correlation Between Physicochemical Parameters and Plankton Abundance/Diversity Indices in the Great Kwa River**

Parameter	Index	Correlation Coefficient	P-Value
pH	Phytoplankton Abundance (cells/L)	-0.76037	0.004094
pH	Zooplankton Abundance (organisms/L)	-0.69575	0.011982
pH	Phytoplankton Diversity Index (H')	-0.70751	0.010057
pH	Zooplankton Diversity Index (H')	-0.79913	0.001818
Temperature (°C)	Phytoplankton Abundance (cells/L)	-0.69364	0.012353
Temperature (C)	Zooplankton Abundance (organisms/L)	-0.65329	0.021241
Temperature (C)	Phytoplankton Diversity Index (H')	-0.61189	0.034467
Temperature (C)	Zooplankton Diversity Index (H')	-0.72329	0.007849
DO (mg/L)	Phytoplankton Abundance (cells/L)	0.744256	0.005503
DO (mg/L)	Zooplankton Abundance (organisms/L)	0.697095	0.011749
DO (mg/L)	Phytoplankton Diversity Index (H')	0.665045	0.018283

DO (mg/L)	Zooplankton Diversity Index (H')	0.761659	0.003995
BOD (mg/L)	Phytoplankton Abundance (cells/L)	-0.86762	0.000255
BOD (mg/L)	Zooplankton Abundance (organisms/L)	-0.83668	0.000691
BOD (mg/L)	Phytoplankton Diversity Index (H')	-0.81677	0.001185
BOD (mg/L)	Zooplankton Diversity Index (H')	-0.86475	0.000283
Nitrate (mg/L)	Phytoplankton Abundance (cells/L)	0.802447	0.001683
Nitrate (mg/L)	Zooplankton Abundance (organisms/L)	0.816385	0.001197
Nitrate (mg/L)	Phytoplankton Diversity Index (H')	0.835695	0.000711
Nitrate (mg/L)	Zooplankton Diversity Index (H')	0.873825	0.000203
Phosphate (mg/L)	Phytoplankton Abundance (cells/L)	0.705837	0.010316
Phosphate (mg/L)	Zooplankton Abundance (organisms/L)	0.797916	0.00187
Phosphate (mg/L)	Phytoplankton Diversity Index (H')	0.745598	0.005374
Phosphate (mg/L)	Zooplankton Diversity Index (H')	0.774091	0.003126

**Seasonal Variation in Physicochemical Parameters and Plankton Abundance**

The seasonal variation in physicochemical parameters and plankton abundance in the Great Kwa River revealed notable differences between the dry and wet seasons (Table 4). The pH was significantly higher during the dry season (7.33±0.05) compared to the wet season (6.97±0.09), indicating a marked influence of seasonal water chemistry on pH levels. However, other parameters such as temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), and phosphate concentrations did not show significant seasonal variation (p>0.05). In contrast, nitrate concentrations were significantly elevated in the wet season (5.37±0.37) compared to the dry season (3.93±0.18, p<0.05). This increase in nitrate levels during the wet season is likely attributed to enhanced nutrient input from surface runoff and other hydrological processes.

Phytoplankton abundance was significantly higher in the wet season (17,672.5 cells/L) compared to the dry season (15,029.5 cells/L), reflecting favorable growth conditions during the wet season, possibly driven by increased nutrient availability (p<0.05). Zooplankton abundance also increased in the wet season (5,863.5 organisms/L) relative to the dry season (5,270.67 organisms/L), though this difference was not statistically significant (p>0.05). The diversity indices further highlight the influence of seasonal variations on the river's ecological dynamics. The phytoplankton diversity index (H') was significantly higher in the wet season (2.46) than in the dry season (2.32, p<0.025), suggesting greater species richness and evenness during periods of higher water flow and nutrient input. Similarly, the zooplankton diversity index (H') was higher in the wet season (2.11) compared to the dry season (1.99, p<0.05), highlighting the indirect effects of seasonal hydrological processes on zooplankton diversity through their reliance on phytoplankton as a food source.

**Table 4: Seasonal Variation in Physicochemical Parameters and Plankton Abundance: Results of t-Test Analysis**

Parameter	Season		t-Statistic	P-Value	Significant (p<0.05)
	Dry	Wet			
pH	7.33 ± 0.05	6.97 ± 0.09	3.626593	0.006921	Yes
Temperature (°C)	27.93 ± 0.15	27.23 ± 0.36	1.778639	0.121157	No
DO (mg/L)	5.5 ± 0.05	5.73 ± 0.11	-1.85761	0.105866	No
BOD (mg/L)	2.65 ± 0.04	2.37 ± 0.11	2.317703	0.057152	No
Nitrate (mg/L)	3.93 ± 0.18	5.37 ± 0.37	-3.46055	0.009842	Yes
Phosphate (mg/L)	0.5 ± 0.04	0.62 ± 0.06	-1.65916	0.134524	No
Phytoplankton Abundance (cells/L)	15029.5 ± 732.43	17672.5 ± 647.19	-2.70411	0.022436	Yes
Zooplankton Abundance (organisms/L)	5270.67 ± 192.15	5863.5 ± 206.2	-2.10332	0.061867	No
Phytoplankton Diversity Index (H')	2.32 ± 0.04	2.46 ± 0.03	-2.65495	0.02671	Yes
Zooplankton Diversity Index (H')	1.99 ± 0.03	2.11 ± 0.03	-2.76666	0.019978	Yes

Note: Values for both dry and wet seasons are means ± SE



## DISCUSSION

The monthly variation in physicochemical parameters in the Great Kwa River highlights seasonal and temporal fluctuations that are consistent with findings from similar aquatic ecosystems. The observed pH values showed slight fluctuations across the months, with values generally falling within the neutral to slightly alkaline range. These findings align with those reported by Jimoh *et al.* (2019), who observed similar pH stability in the Ologe Lagoon, Lagos State, Nigeria attributing the trends to buffering capacity and the presence of dissolved salts. In contrast, the slight decline in pH during the wet season could be linked to increased surface runoff, which introduces acidic organic matter into the water (Okon *et al.*, 2021; Xu *et al.*, 2022).

Water temperature showed relatively minimal monthly variation, with higher values recorded in the dry months and slightly lower values in the wet months. This pattern agrees with observations by Nimma *et al.* (2024) in freshwater bodies, where temperature variation was influenced primarily by seasonal solar radiation. The stability in temperature is significant for aquatic life, as most species in tropical rivers thrive within these consistent thermal conditions (Asuquo & Ifon, 2019). Dissolved oxygen (DO) concentrations exhibited higher values during the wet months, possibly due to increased aeration from rainfall and surface flow, which promotes gas exchange. Similar findings were reported by Okoye and Ogbebor (2024) in Edo River, where DO peaked during the wet season, supporting increased biological activity. Conversely, biochemical oxygen demand (BOD) was relatively higher in the dry months, reflecting reduced dilution of organic pollutants during periods of lower flow. This observation is consistent with Obiuto *et al.* (2022), who emphasized the role of reduced hydrodynamic activities in concentrating organic matter and microbial activity. Nutrient concentrations, particularly nitrates and phosphates, demonstrated marked monthly variations, with higher levels recorded during the wet season. This aligns with studies by Tafangenyasha and Dube (2007), who attributed elevated nutrient levels during the rainy season to surface runoff and leaching from agricultural lands. The availability of these nutrients is critical for primary production, and their seasonal dynamics are closely linked to phytoplankton abundance and diversity.

The monthly variation in plankton diversity and abundance observed in the Great Kwa River highlights significant temporal changes driven by physicochemical parameters and seasonal factors. Phytoplankton abundance peaked during the wet season months, coinciding with elevated nutrient levels such as nitrates and phosphates. This is consistent with findings by Jimoh *et al.* (2019), who reported that nutrient influx during the rainy season promotes phytoplankton growth in tropical aquatic systems. The Shannon-Wiener diversity index for phytoplankton also showed higher values during the wet months, suggesting a more favorable environment for diverse algal communities due to increased nutrient availability and optimal light penetration. Zooplankton

abundance followed a similar seasonal trend, with higher counts recorded during the wet months. These findings align with Obiuto *et al.*, (2022), who observed a strong correlation between zooplankton abundance and primary productivity in Nigerian freshwater bodies. The wet season likely provides an enriched environment for zooplankton growth by supporting phytoplankton blooms, their primary food source (Eteng & Ifon, 2019). However, the diversity index for zooplankton exhibited less fluctuation compared to phytoplankton, suggesting that the zooplankton community structure may be less sensitive to environmental changes or may consist of resilient taxa adapted to seasonal variability. Comparatively, the dry season months showed a decline in both phytoplankton and zooplankton abundance, potentially due to reduced nutrient inputs and lower water volumes, leading to increased competition for limited resources. Similar observations were made by Okoye and Ogbebor (2024) in the Edo River, where lower plankton abundance during the dry season was attributed to nutrient limitation and increased predation pressure. The higher phytoplankton and zooplankton diversity indices during the wet season also suggest improved habitat conditions that support a broader range of species. This seasonal pattern aligns with Xu *et al.* (2022), who noted that the influx of freshwater during the wet season dilutes pollutants, reduces stressors, and creates conditions conducive to diverse plankton communities.

The correlation analysis between physicochemical parameters and plankton abundance and diversity indices in the Great Kwa River highlights the influence of environmental variables on plankton dynamics. The study revealed a strong negative correlation between pH and both phytoplankton abundance ( $r = -0.76$ ) and diversity ( $r = -0.71$ ), as well as zooplankton abundance ( $r = -0.70$ ) and diversity ( $r = -0.80$ ). These findings align with the results of Jimoh *et al.* (2019), who reported that a decline in pH, associated with increased acidity, inhibits phytoplankton photosynthesis and subsequently impacts zooplankton populations that depend on phytoplankton as their primary food source. Similarly, temperature exhibited a negative correlation with plankton abundance and diversity indices, with the strongest effect observed on zooplankton diversity ( $r = -0.72$ ). This supports the findings of Obiuto *et al.* (2022), who observed that elevated temperatures in tropical waters could stress plankton communities, reduce metabolic efficiency, and increase the decomposition of organic matter, leading to unfavorable conditions for plankton survival. Conversely, dissolved oxygen (DO) showed a strong positive correlation with all plankton metrics, indicating its critical role in supporting plankton communities. For instance, the correlation with phytoplankton abundance ( $r = 0.74$ ) highlights how adequate oxygen levels enhance photosynthesis, while the relationship with zooplankton diversity ( $r = 0.76$ ) reflects the dependency of higher trophic levels on oxygen availability. These results mirror findings by Xu *et al.* (2022) and Inyang-Etoh *et al.* (2024a), who emphasized the importance of DO in maintaining the ecological balance of aquatic ecosystems.

Biochemical oxygen demand (BOD) negatively correlated with plankton metrics, with a particularly strong relationship observed with phytoplankton abundance ( $r = -0.87$ ) and diversity ( $r = -0.82$ ). Elevated BOD often indicates organic pollution, which reduces DO levels and creates hypoxic conditions detrimental to plankton. This observation is consistent with studies by Okoye and Ogbebor (2024), who found that high BOD levels led to reduced plankton abundance in polluted river systems in Edo State, Nigeria. Nutrients such as nitrates and phosphates showed significant positive correlations with plankton abundance and diversity indices. Nitrates, for example, had the highest correlation with zooplankton diversity ( $r = 0.87$ ), suggesting that nutrient enrichment supports plankton growth by promoting primary productivity. Phosphates exhibited a strong positive correlation with phytoplankton diversity ( $r = 0.75$ ), corroborating findings by Reintl *et al.* (2022) and Inyang-Etoh *et al.* (2024b), who highlighted the role of phosphorus as a limiting nutrient in tropical aquatic systems. The seasonal variation in physicochemical parameters and plankton abundance in the Great Kwa River reflects the dynamic interaction between environmental conditions and aquatic biota. The t-test analysis revealed significant differences in pH, nitrate levels, phytoplankton abundance, and plankton diversity indices between the dry and wet seasons, which aligns with findings from previous studies in similar tropical ecosystems (George & Opeh, 2016; Ma *et al.*, 2019; Nwinyimagu *et al.*, 2021; Xu *et al.*, 2023; Job *et al.*, 2025).

The significantly higher pH during the dry season ( $7.33 \pm 0.05$ ) compared to the wet season ( $6.97 \pm 0.09$ ) reflects reduced freshwater input and dilution during the dry season. Increased water retention and reduced rainfall during this period may concentrate alkalinity, as noted by Odewade *et al.* (2021), who observed elevated pH values in the dry season of Nigerian inland waters. In contrast, the wet season pH reduction may be attributed to acidic runoff and increased organic matter decomposition. Nitrate levels were significantly higher in the wet season ( $5.37 \pm 0.37$  mg/L) compared to the dry season ( $3.93 \pm 0.18$  mg/L), likely due to increased runoff from agricultural and urban areas during the rainy season. This pattern is consistent with the findings of Xu *et al.* (2022), who reported higher nitrate concentrations in wet seasons across the Niger Delta region. Elevated nutrient input during the wet season supports enhanced phytoplankton growth, which in turn influences zooplankton populations.

Plankton abundance exhibited a marked seasonal trend, with phytoplankton abundance significantly higher during the wet season ( $17,672.5 \pm 647.19$  cells/L) compared to the dry season ( $15,029.5 \pm 732.43$  cells/L). This seasonal peak aligns with the nutrient enrichment during the wet season, particularly from nitrates and phosphates, which fuel primary productivity. Zooplankton abundance, although higher in the wet season, did not exhibit a statistically significant difference ( $p > 0.05$ ), potentially due to delayed population response to phytoplankton blooms. Similar trends were reported by Reintl *et al.* (2022), who found that nutrient-driven

phytoplankton blooms in wet seasons supported increased zooplankton abundance, albeit with a temporal lag. The diversity indices for both phytoplankton and zooplankton were significantly higher in the wet season. Phytoplankton diversity ( $H' = 2.46$ ) was higher than in the dry season ( $H' = 2.32$ ), suggesting that wet season conditions promote a more diverse assemblage of phytoplankton species. This finding corroborates Chea *et al.* (2020), who observed increased diversity indices in the wet season due to reduced competition among species and favorable environmental conditions. Similarly, zooplankton diversity ( $H' = 2.11$ ) was higher in the wet season compared to the dry season ( $H' = 1.99$ ), reflecting enhanced food availability and habitat complexity.

## CONCLUSION

This study investigated the seasonal and monthly variations in physicochemical parameters and plankton diversity in the Great Kwa River, emphasizing the relationship between environmental factors and plankton abundance. Significant seasonal differences were observed, with the wet season characterized by higher nitrate levels, plankton diversity, and abundance due to increased nutrient runoff. Correlation analysis revealed strong associations between physicochemical parameters such as pH, dissolved oxygen (DO), and nitrate concentrations with plankton diversity and abundance indices. The findings highlight the critical role of seasonal nutrient inputs in shaping plankton communities, underscoring the importance of continuous monitoring and sustainable management practices to preserve aquatic ecosystems. A key recommendation is the establishment of integrated water quality management programs, focusing on reducing nutrient pollution from agricultural and urban runoff, particularly during the wet season, to prevent eutrophication and maintain ecological balance in the river system.

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