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IMPACT OF SOME HUMAN INDUCED STRESSORS ON THE BENTHIC MACROINVERTEBRATE ASSEMBLAGE OF LAGOS LAGOON, NIGERIA

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Abstract: The Lagos Lagoon in Nigeria faces significant human-induced stress, impacting its biodiversity and ecosystem dynamics, notably the benthic macroinvertebrates. A study was carried out to assess the impact of human activities on the abundance and diversity of benthic macroinvertebrates in the Lagos Lagoon. Twelve stations with varying human impacts along the Lagos lagoon were investigated monthly between November 2021 and April 2022. Water and benthic macroinvertebrates were collected monthly using *Hydrobios* Water Sampler and Van-Veen grab respectively, and analysed in the laboratory using standard methods. Statistical analysis revealed significant differences ($P<0.05$) in pH and Total Suspended Solids (TSS) among study stations, while other parameters showed no significant variation ($P>0.05$). Water temperature ranged from 27.3 to 29.7°C, with spatial variability observed. pH levels ranged from 6.2 to 7.0, indicating acidic to neutral conditions, potentially influenced by industrial activities. Salinity ranged from 5.0 to 17.0 ppt, highest in March, attributed to the dry season. Conductivity, Total Dissolved Solids (TDS), and Turbidity varied spatially, influenced by land use and runoff. Dissolved oxygen levels ranged from 4.5 to 6.9 mg/L, with lowest levels in April, potentially impacting aquatic biota. Principal Component Analysis (PCA) highlighted interrelations among physicochemical parameters, emphasizing salinity, conductivity, and TDS in specific stations. Benthic macroinvertebrate analysis revealed dominance by gastropods (64%), with low biodiversity and abundance, indicating disturbed ecosystems. Human activities are key drivers of water quality degradation and macroinvertebrate community changes, emphasizing the need for management strategies to preserve ecosystem health.

Keywords: Biomonitoring; Lagos lagoon; Bioindicator; Pollution; Macroinvertebrates

Introduction

The intricate dynamics of aquatic ecosystems are increasingly subjected to the deleterious effects of anthropogenic stressors, with notable implications for benthic macroinvertebrate assemblages (Ma *et al*., 2023). These diminutive yet ecologically significant organisms constitute pivotal components of aquatic ecosystems, serving critical roles in nutrient cycling, energy transfer, and overall ecological stability. The encroachment of human activities, notably urbanization, agriculture, and industrialization, has precipitated an array of stressors, ranging from habitat degradation to pollutant influxes, profoundly influencing benthic macroinvertebrates (Keke *et al*., 2021; Onyena, 2019).

Benthic macroinvertebrates are important indicators of aquatic ecosystem health and water quality dynamics (Banda *et al*., 2023). They are sensitive to pollution and changes in their environment, making them valuable for biomonitoring and assessing the impacts of phenomena such as climate change (Nkwoji *et al*., 2020; Onyena *et al*., 2023). Macroinvertebrates play a crucial role in aquatic ecosystems by serving as reliable indicators of water quality and ecosystem health. They contribute to the circulation and recirculation of nutrients, accelerate the breakdown of organic matter, and serve as a food source for higher animal taxa (Brraich and Kaur, 2017). Additionally, they are essential for converting carbon and nitrogen from plant tissues into animal biomass, thus supporting higher-order consumers (Thakur *et al*., 2023).

Lagos Lagoon in Nigeria, as a mega city with high anthropogenic activities, is significantly impacting aquatic organisms and biodiversity (Ugwumba *et al*., 2020; Nkwoji *et al*., 2020; Adesakin *et al*., 2023). The continuous discharge of industrial and domestic inputs into the lagoon has led to the release of potentially toxic elements (PTEs) into the water, posing a serious ecological threat to the marine environment and human health (Basheeru *et al*., 2022). The proximity of the lagoon to human settlements has resulted in the disposal of wastewater from polluting activities, such as sawmills and livestock processing, further degrading the aquatic ecosystem. The physicochemical parameters and abundance of planktonic and benthic invertebrates in the lagoon are being affected by human activities, including transportation, fishing, and domestic sewage disposal. These anthropogenic stressors have led to changes in water quality, loss of certain organisms, and the thriving of tolerant benthic macroinvertebrates.

Human-induced stressors have a significant impact on the benthic macroinvertebrate assemblages of Lagos Lagoon in Nigeria. These stressors include anthropogenic activities, encroachment into aquatic environments, and pollution from industries and human settlements. The presence of toxic chemicals in the waterbodies has led to the loss of certain organisms and the thriving of tolerant benthic macroinvertebrates (Bendary *et al*., 2023; Adesakin *et al*., 2023). Studies have shown that benthic macroinvertebrates are reliable indicators of the extent of toxicity and pollution in coastal waters (Nkwoji *et al*., 2020; Onyena *et al*., 2023; Andem *et al*., 2023). The distribution and diversity of benthic macroinvertebrates in the Lagos Lagoon are influenced by the physical and chemical characteristics of the water, as well as the availability of food and the extent of human impacts and activities (Keke *et al*., 2021). It is crucial to manage the river and its surrounding ecosystem appropriately to ensure sustainable water quality and biodiversity conservation (Ugwumba *et al*., 2020). This study aims to evaluating the impact of anthropogenic activities of the macroinvertebrates the community structure in the Lagos lagoon Nigeria.

Materials and Methods

Description of Study Area and Stations

The Lagos Lagoon, situated in the mega city of Lagos, Nigeria, holds the distinction of being the largest in the Gulf of Guinea, spanning over 6,000 square kilometres (Ibe 1988). It is positioned between the Atlantic Ocean and Lagos State and forms an integral part of the lagoon system along the Gulf of Guinea. Experiencing semi-diurnal tides, with an average depth of 2 meters (maximum 5 meters), the lagoon serves as a vital habitat for diverse aquatic organisms, including various fish species (Nkwoji and Edokpayi, 2013).The Lagos Harbour serves as the sole connection to the Atlantic Ocean, boasting a water depth exceeding 25 meters. The continuous growth in human population in and around the Lagos metropolis has resulted to such tremendous increase in generated wastes of unprecedented quantities and variants. Industries of various types and nature have been birthed and in addition, recreational and tourist centres have been built. Twelve sampling stations that transverse the western axis of the lagoon (Table 1) was chosen for the study. The choice is based on their importance as sources of different forms of contaminants into the lagoon. Coordinates of the sampling stations were marked (Figure 1) using Global Positioning System (GPS) (Magellan SporTrak GPS receiver).

Table 1: Sampling Stations and their Coordinates

STATION	LOCATIONS	LATITUDE	LONGITUDE
1	IDDO JETTY	6°28’10.9095N	3°23’2.4686E
2	OYINGBO JETTY	6°28’27.3430N	3°23’8.6189E
3	OKOBABA	6°28’53.5704N	3°23’30.7090E
4	MAKOKO	6°29’45.8031N	3°23’49.1950E
5	ABULE AGEGE	6°30’33.9523N	3°24’0.4366E
6	UNILAG JETTY	6°31’6.3924N	3°24’11.7397E
7	ABULE ELEDU	6°31’25.0835N	3°24’3.0754E
8	AGBOYI CREEK	6°33’49.1934N	3°24’37.5127E
9	OGUDU CREEK	6°33’49.3608N	3°24’25.1073E
10	MAJIDUN I	6°35’14.0201N	3°27’20.4153E
11	MAJIDUN II	6°35’33.0098N	3°27’39.8852E
12	OGOLONTO	6°35’59.4204N	3°28’30.0205E

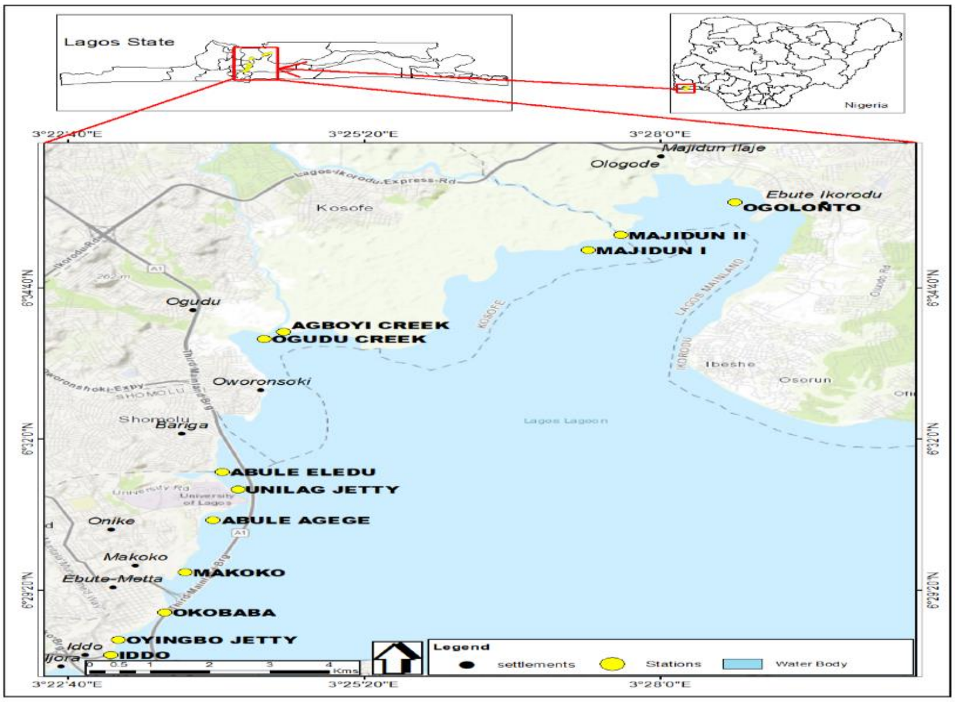

Figure 1. Lagos Lagoon showing the sampling stations of the study area

Collection and analysis of samples

Collection and analysis of water samples

Surface water samples were collected monthly using 1-liter pre-labelled plastic containers at designated study stations over a 6-month period from November 2021 to April 2022, spanning from 0800 to 1200 noon. A motorized boat equipped with an outboard engine facilitated the collection process. In-situ measurements of water temperature, dissolved oxygen (DO), and total dissolved solids (TDS) were conducted at each sampling station using a mercury-in-glass thermometer, a handheld LaMotte DO Meter (DO 6 PLUS), and a LaMotte TDS Meter (TDS 6 PLUS) respectively. The *Hydrobios* water sampler, following APHA (2002) guidelines, was employed for station-based sample collection. The samples were stored in a large, airtight plastic ice chest at 4°C to prevent deterioration. Laboratory analysis, following standard methods (APHA, 2002), included the measurement of salinity and pH using a Horiba-U10 water quality checker. Nitrate, phosphate, and sulfate were assessed through colorimetric analysis and spectroscopy utilizing a LaMotte Smart-Spectrophotometer. Additionally, separate water samples were collected in 250ml dissolved oxygen bottles at each station for dissolved oxygen estimation using iodometric Winkler's method. These samples were incubated in darkness for five days to determine biochemical oxygen demand (BOD5), following the procedures outlined in APHA (2002).

Collection and analysis of benthic samples

Benthic samples were obtained using a 0.25 m2 Van-Veen grab (weighing 25kg and standing at a height of 20cm) at every designated station while stationed on an anchored boat. The collected samples were sifted through a sieve with a mesh size of 0.55 mm. Substances remaining on the sieve were placed in appropriately labeled plastic containers and treated with 10% formalin. This preservation method facilitated the subsequent processes of sorting, grouping, classification, and further analysis of benthic macroinvertebrates, all carried out in accordance with established standard procedures.

Statistical analysis

Descriptive and inferential statistical analyses of the physicochemical parameters of water were conducted with the *Statistical Package for the Social Sciences* 21 (SPSS 21) for Windows. Diversity indices were calculated using the Paleontological statistical (PAST) program. Principal Component Analysis was employed via Originlab software to discern interrelations between the physicochemical parameters and study stations. Canonical Correspondence Analysis, carried out with PAST, aimed to estimate the relationship between the physicochemical parameters and the macroinvertebrate fauna across the study area.

Results and Discussion

Hydrochemistry variations

The P-statistics and F-distribution results of the physical and chemical parameters of the water samples measured (Table 2) indicated that only pH and Total Suspended Solids (TSS) showed significant differences (P<0.05) among study stations while Salinity, Conductivity, Total Dissolved Solids and Dissolved Oxygen, Water Temperature, Turbidity, and BOD showed no significant difference (P>0.05) across study stations.

Table 2: The Mean±SD of the Physicochemical Parameters of the Water Samples in the Study Area for the Period of Study

	Water Temperature	pH	Salinity	Conductivity	Turbidity	T.S.S	T.D.S	D.O	BOD
Iddo	28.3±0.5	6.4±0.2	14.2±1.5	16.2±1.2	13.3±1.0	11.2±1.0	16.7±5.2	6.1±0.1	7.3±0.3
Oyingbo	28.8±0.4	6.6±0.2	11.8±1.2	12.7±1.6	11.5±0.8	10.0±0.9	14.5±3.9	5.2±0.2	7.1±0.1
Okobaba	28.8±0.4	6.6±0.3	10.7±1.3	11.2±0.9	13.0±0.9	10.2±1.6	13.5±2.8	5.5±0.3	7.5±0.3
Makoko	28.3±0.8	6.7±0.1	9.3±1.2	10.7±0.5	8.5±0.8	9.8±0.8	12.7±0.8	6.2±0.2	5.9±0.6
Abule Agege	27.3±0.5	6.7±0.2	10.8±1.0	11.7±1.4	12.8±0.4	11.0±1.4	12.6±0.7	5.1±0.6	8.4±0.4
Unilag Lagoon Front	29.5±0.6	6.7±0.2	11.5±1.2	11.3±0.5	12.5±1.2	11.2± 2.4	10.3±0.4	4.7±0.1	6.7±0.6
Abule Eledu	29.0±0.3	6.9±0.1	9.3±1.4	11.0±1.4	11.8±4.0	11.0±4.1	11.4±0.9	6.3±0.4	7.0±2.0
Agboyi	29.5±0.0	6.7±0.2	8.1±1.8	10.4±0.9	15.8±4.0	14.3±3.7	12.2±1.7	5.9±0.6	7.1±2.3
Ogudu	29.3±0.3	6.7±0.2	7.3±1.4	9.9±0.7	13.4±3.0	13.2±2.1	12.7±2.0	5.9±0.6	7.3±2.7
Majidun Abule	28.5±0.5	6.8±0.1	11.3±3.4	11.4±1.5	12.0±4.0	10.8±1.7	13.7±1.9	6.2±0.5	7.4±3.5
	29.3±0.3	6.8±0.2	11.2±1.9	10.6±0.5	13.3±1.2	12.2±1.7	13.1±1.6	5.9±0.4	7.4±4.1
Ogolonto	29.7±0.4	6.8±0.2	11.5±2.7	14.3± 3.1	12.8±2.3	11.3±1.9	12.5±2.2	5.8± 0.6	8.3±5.6
F-Value	13.107	2.533	6.331	7.520	2.965	2.137	2.625	8.566	3.480
P-Stat.	P>0.05	P<0.05	P>0.05	P>0.05	P>0.05	P<0.05	P>0.05	P>0.05	P>0.05

The water temperature within the study area exhibited a consistent range of 27.3 to 29.7°C, with notable variations throughout the year. December recorded the lowest temperature, while April marked the highest. Ogolonto experienced the warmest temperatures spatially, whereas the Abule-Agege area registered the coolest temperatures. This pattern aligns with the findings of Oyeleke *et al*. (2019), who measured water temperature in Lagos Lagoon and reported a range of 28.50-30.15°C across different locations. Adewoyin *et al*. (2022) also noted temperature variations, stating that the wet season's highest mean temperature in Apapa was 30.28±1.15°C, while the lowest mean temperature of 26.41±1.15°C was observed in Okobaba. Satellite imagery analysis conducted by Alademomi *et al*. (2020) revealed an increase in mean water temperature in the Lagos Lagoon over the years—from 22.68°C in 1984 to 28.40°C in 2019. The uniformity in water temperature values across the Lagos Lagoon can be attributed to its shallowness and the regular tidal motions, facilitating complete water mixing.

The pH levels of the water samples in this study varied between 6.2 and 7.0, suggesting an acidic to neutral condition. This acidity could be influenced by several factors, including the influx of contaminants from nearby creeks (Adesalu and Nwankwo, 2008). Stations like Unilag Lagoon Front showed higher pH, possibly influenced by local factors. The presence of industrial activities and urbanization in the surrounding areas is also identified as potential contributors to the acidity of the water (Onyena and Okoro, 2019). Slight acidity may impact the aquatic biota, especially species sensitive to pH fluctuations. Salinity varied between 5.0 and 17.0 ppt, with the lowest in August and the highest in March. Iddo exhibited the highest salinity, while the lowest was found in Iddo. The relatively high salinity recorded during the period of study may be as a result of the period of the study which coincides with dry season. The reduced fresh water influx reduces dilution and increases the salinity during the period of study (Onyema and Omokanye, 2016).

Conductivity ranged from 8.7 to 20.1 µS/cm, with the highest and lowest values observed in November 2021 and January 2022, respectively. The highest conductivity occurred in Iddo, while Ogudu had the lowest. The same trends follow for conductivity which has a direct relationship with salinity. Total dissolved solids (TDS) varied from 10.0 to 22.0 mg/L, with the lowest in April and the highest in November. Unilag Lagoon Front had the lowest TDS, while Iddo had the highest. Factors such as land use and discharge from surrounding areas may contribute to the TDS variations (Sharma *et al*., 2016).

Total suspended solids (TSS) ranged from 8.0 to 18.0 mg/L, correlating with turbidity values of 8.0 to 20.0 NTU. November recorded the lowest turbidity, and April the highest. Agboyi had the highest turbidity, while Makoko had the lowest. Higher values at Agboyi and Unilag Lagoon Front may stem from increased sedimentation due to urbanization or industrial activities. The increase in turbidity and total suspended solids (TSS) in some sampling stations may be due to the increase in sediment mining as such activities lead to resuspension of sediment in the water column. The highest turbidity in April might be linked to increased rainfall, elevated runoff, and higher suspended sediment concentrations in the water (Zhou *et al*. 2015). Wet months often experience intensified weather patterns, leading to greater soil erosion and transport of sediments into water bodies, thereby increasing turbidity (Chen *et al*., 2016). Elevated salinity, conductivity, turbidity, and T.S.S may affect the habitat suitability for certain aquatic organisms.

Dissolved oxygen levels ranged from 4.5 to 6.9 mg/L, with the lowest in April and the highest in November. Biological oxygen demand (BOD) values during the study ranged from 5.1 to 10.2 mg/L, with the lowest recorded in November 2021 and the highest in March 2022. There was an observed decline in the levels of dissolved oxygen in areas with higher anthropogenic activities and organic matter decomposition. This was in consonance with the findings of Nkwoji and Awodeyi (2018).

The variation in dissolved oxygen levels observed during the study, ranging from 4.5 to 6.9 mg/L, with the lowest in April and the highest in November can be linked to seasonal changes and environmental dynamics. There was an observed decline in the levels of dissolved oxygen in areas with higher anthropogenic activities. This was in consonance with the findings of Nkwoji and Awodeyi (2018). Biological Oxygen Demand (BOD) values which ranged from 5.1 to 10.2 mg/L, was recorded lowest in November 2021 and the highest in March 2022, these variations could be linked to organic matter decomposition and microbial activity. Lower BOD in November might be associated with reduced organic inputs, while the higher BOD in March could be influenced by increased biological activities due to favourable environmental conditions, such as nutrient availability (Jaiswal *et al*., 2019). .Higher BOD, observed at Abule Agege, may signify organic pollution, potentially originating from industrial and domestic discharges. Lower dissolved oxygen levels and higher BOD in the Lagos Lagoon suggest potential stress on aquatic life, affecting their respiration and overall health.

Table 3 provides a comprehensive overview of the Principal Component Analysis (PCA) results, including the loading plot and Eigen values for the nine studied physicochemical parameters. This analysis illuminates the interrelationships among these parameters and offers insights into their contributions to overall water quality dynamics. The PCA was expressed as two components, PC1 and PC2, each providing unique perspectives on the variability within the dataset.

PC1, constituting 33.83% of the total variation, is characterized by weak positive loadings (<0.50) and prominently features salinity, conductivity, and Total Dissolved Solids (TDS) in specific stations (1, 2, 3, 5). This suggests a modest correlation among these parameters in the mentioned stations. Notably, conductivity and salinity, as well as salinity, conductivity, and TDS, exhibit nearly equal weight values, indicating a notable interrelation between these factors. PC2, representing 26.44% of the total variation, showcases moderately positive loadings for turbidity, Total Suspended Solids (TSS), and Biological Oxygen Demand (BOD) in stations 6, 8, 9, 11, and 12 (Figure 2). These findings suggest that PC2 is associated with the presence of organically polluted materials, primarily arising from anthropogenic sources.

Table 3: Loading plot and Eigen value of the nine physicochemical parameters studied

	Loading plot	
	PC 1	PC2
W/ TEMP	-0.28	**0.29**
pH	-0.41	-0.16
SAL.	**0.50**	0.08
COND	**0.49**	0.15
TUR	-0.08	**0.62**
TSS	-0.27	**0.50**
TDS	**0.43**	0.12
DO	-0.11	-0.18
BOD	0.04	**0.41**

	Eigenvalue	% Variance	Cumulative
PC1	2.85	33.83%	33.83%
PC2	2.03	26.44%	60.27%

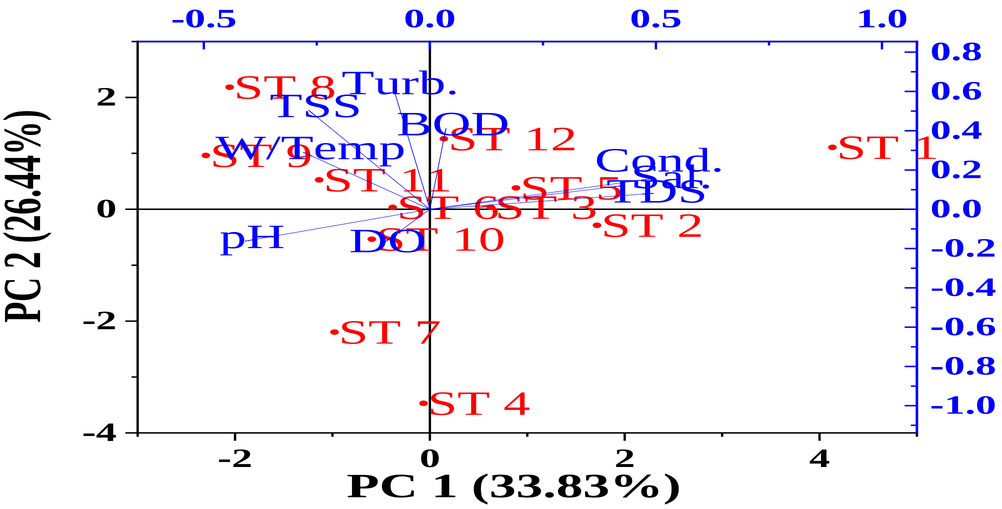

Figure 2: The Principal Component Analysis Biplot based on the correlation matrix of the water physicochemical parameters across the Sample station

The temporal PCA biplot, depicted in the Figure 3, further shows temporal variations in water quality. PC1, contributing to 54.74% of the total variation (Table 4), reveals negative and moderate loadings for salinity and conductivity during March and April 2022. This implies a potential decrease in these parameters during this period. In PC2, weakly positive loadings for turbidity, BOD, and TDS in December 2021, January, and April 2022 indicate a potential increase in these parameters during those months.

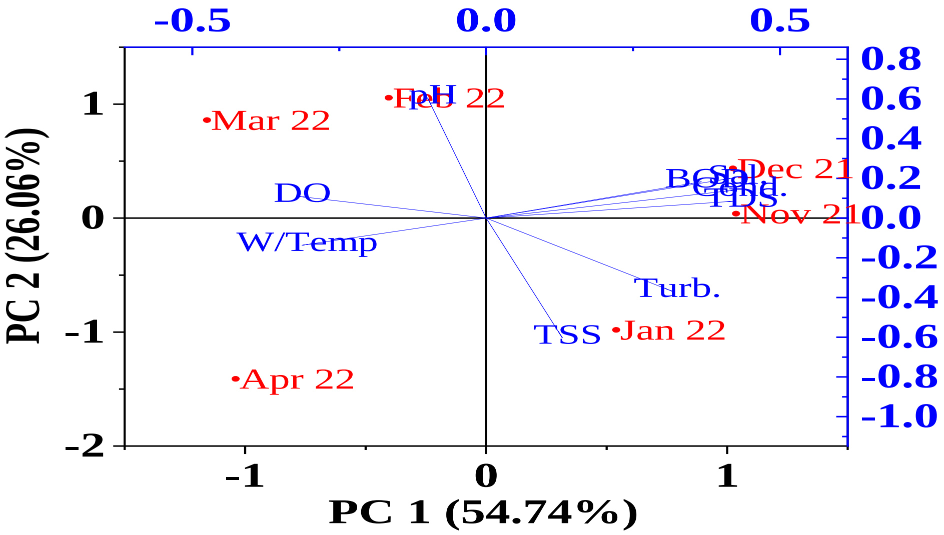

Figure 3: The Principal Component Analysis Biplot based on the correlation matrix of the water physicochemical parameters across the Sample period

Table 4: Loading plot and Eigen value of the temporal variations in the nine physicochemical parameters studied

	PC 1	PC2
W/ TEMP	-0.28	0.29
pH	-0.41	-0.16
SAL.	**0.50**	0.08
COND	**0.49**	0.15
TUR	-0.08	**0.62**
TSS	-0.27	**0.50**
TDS	**0.43**	0.12
DO	-0.11	-0.18
BOD	0.04	**0.41**
Eigenvalue	4.93	2.34
Percentage of Variance	54.74%	26.06%
Cumulative	54.74%	80.80%

Benthic macroinvertebrates composition and abundance

Figure 4 shows the percentage representative samples of the benthic macroinvertebrates collected at the sampling stations during the period of study. The overall percentage contribution of species to the benthic macroinvertebrates sampled during the study period. The gastropod *Tympanotonus fuscatus* dominated the macrobenthic assemblage, contributing 44% and followed by the bivalve, *Aloides trigona* and the gastropod *Pachymelania aurita* which contributed 23% and 13% respectively.

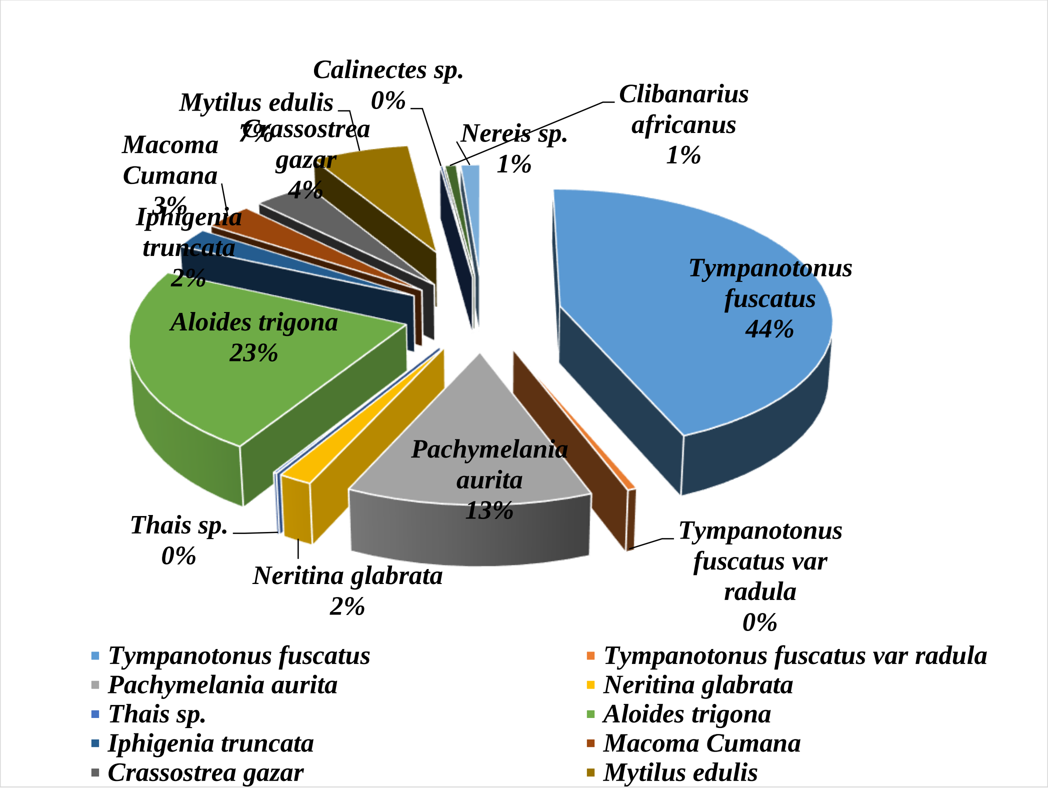

Figure 4: Percentage Species contribution to the total macrobenthic fauna abundance during the period of study

The Class Bivalvia, Polychaetea, and Crustacea accounted for 22%, 7%, and 7% respectively. The Phylum Mollusca and Class Gastropoda (64%) dominated the benthic macroinvertebrate of the study area. This study confirms the quantitative dominance of gastropoda in the Lagos lagoon and agrees with the results of previous studies in tropical zones (Figure 5).

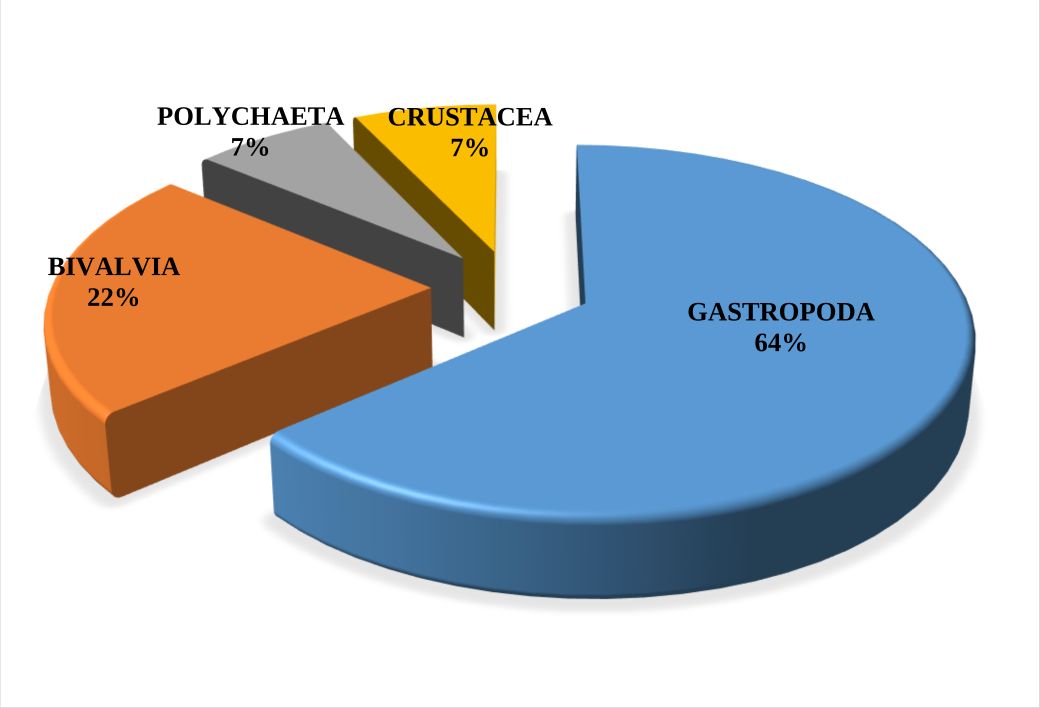

Figure 5: Percentage contribution by Class of the benthic macroinvertebrates during the period of study

Previous research on the Lagos lagoon in Nigeria has shown that gastropod molluscs make up between 86% and 95% of the macroinvertebrate community in terms of abundance (Nkwoji *et al*., 2010; 2016). Similarly, studies in Côte d'Ivoire have found that Aby lagoon has a 51% abundance of gastropod molluscs (Kouadio *et al*., 2008), while Ebrié lagoon has a 71% abundance (Kouadio *et al*., 2011). However, in Keta lagoon, Ghana, gastropod molluscs make up a lower proportion of the macroinvertebrate community (Lamptey and Armah, 2008). The low abundance of *Clibanarius africanus* and the absence of other crustaceans in these areas may be due to their sensitivity to organic pollution.

Table 5 represents the community structure of the benthic fauna in the study area during the period of study. The highest number of individuals and species were recorded in Abule-Agege sampling station. The number of species and individuals recorded in each location reflects low biodiversity and abundance of macroinvertebrates (Onyena, 2019). Lower numbers typically indicate disturbed ecosystems with low species richness. Shannon Wiener species diversity index was highest in Iddo and least in Majidun study stations while Margalef's species richness index was highest in Ogudu and least in Unilag lagoon front study stations.

Table 4: Community Structure of the Benthic Fauna in the Study Area During the of Period of Study

	Iddo	Oyigbo	Okobaba	Makoko	Abule Agege	Unilag Front	Abule Eledu	Agboyi	Ogudu	Majidun	Abule	Ogolonto
No. of Species	8	5	7	7	9	5	7	6	9	6	7	7
No. of Indiv.	112	77	92	169	218	176	201	61	101	96	193	100
Dominance	0.16	0.28	0.23	0.26	0.29	0.33	0.28	0.24	0.21	0.39	0.27	0.42
Simpson	0.84	0.72	0.77	0.74	0.71	0.67	0.72	0.76	0.79	0.61	0.73	0.58
Shannon	1.94	1.43	1.68	1.57	1.60	1.24	1.54	1.54	1.80	1.18	1.59	1.23
Evenness	0.87	0.83	0.77	0.68	0.55	0.69	0.67	0.77	0.67	0.54	0.70	0.49
Menhinick	0.76	0.57	0.73	0.54	0.61	0.38	0.49	0.77	0.90	0.61	0.50	0.70
Margalef	1.48	0.92	1.33	1.17	1.49	0.77	1.13	1.22	1.73	1.10	1.14	1.30
Equitability	0.93	0.89	0.86	0.81	0.73	0.77	0.79	0.86	0.82	0.66	0.81	0.63

The findings of this study indicate that lower levels of evenness, Simpson, and Shannon index are indicative of reduced diversity and less balanced distribution of species within the community (Onyena *et al*., 2023). Physicochemical parameters and substrate type are among the factors that contribute to the low diversity and abundance of these organisms (Onyena *et al*., 2023). Equitability values of <1 suggest that the macroinvertebrate species in the study stations were specific to the location. Differences in habitat quality across the various locations could have influenced the specificity and availability of suitable conditions for different macroinvertebrate species (Carter *et al*., 2017).

Human activities such as urbanization, industrial discharges, and agricultural runoff can introduce pollutants into water bodies, leading to changes in the diversity indices of macroinvertebrate communities (Nkwoji *et al*., 2020; Onyena *et al*., 2021). The variations in water quality, including reduced dissolved oxygen levels, nutrient concentrations, and pollution levels, may have contributed to the decreased composition and distribution of macroinvertebrate communities (Luo *et al*., 2018; Berger *et al*., 2017; Xu *et al*., 2014). Elevated levels of pollutants in the water bodies can be attributed to the low macroinvertebrate communities, which may have been influenced by human activities (Nkwoji *et al*., 2020; Onyena *et al*., 2021). Sedimentation resulting from increased turbidity may smother benthic organisms, alter substrate composition, and could have influenced macroinvertebrate composition (Dunlop *et al*., 2005). Overall, the results of this study suggest that human activities, water quality, and habitat conditions can have significant impacts on the diversity and distribution of macroinvertebrate communities in water bodies.

Conclusion

The Lagos Lagoon in Nigeria, amidst its vital ecological significance, faces significant challenges due to human-induced stressors. The hydrochemical variations observed in this study provide valuable insights into the dynamics of water quality within the Lagos Lagoon. While certain parameters such as pH and Total Suspended Solids (TSS) showed significant differences among study stations, others remained relatively consistent across the sampled locations. The uniformity in water temperature values across the lagoon, coupled with variations in pH, salinity, conductivity, turbidity, dissolved oxygen, and biological oxygen demand (BOD), underscores the complex interplay of natural and anthropogenic factors shaping the aquatic environment. The findings suggest that human activities significantly impact water quality parameters.

Elevated levels of pollutants, including organic matter and sedimentation, may pose challenges to aquatic life, affecting their habitat suitability and overall health. Furthermore, the observed variations in macroinvertebrate composition and abundance reflect the ecological responses to changes in water quality and habitat conditions. The reduced diversity and abundance of macroinvertebrates emphasize the ecological implications of anthropogenic impacts on aquatic ecosystems. Overall, this study highlights the intricate relationship between hydrochemical parameters, macroinvertebrate communities, and human activities in shaping the environmental health of the Lagos Lagoon, emphasizing the need for effective management strategies to mitigate further degradation and preserve ecosystem integrity.

References

Adesakin, T.A., Erhomosele, E.I., Ogunrinola, O.F., Oloyede, O.O., Adedeji, A.A., Odufuwa, P.T., Aimienoho, A., Aduwo, A.I. and Adewumi, E.A., 2023. Using benthic macroinvertebrates as bioindicators to evaluate the impact of anthropogenic stressors on water quality and sediment properties of a West African lagoon. *Heliyon*, *9*(9).

Adesalu, T.A. and Nwankwo, D.I., 2008. Effect of water quality indices on phytoplankton of a sluggish tidal creek in Lagos, Nigeria. *Pakistan Journal of Biological Sciences: PJBS*, *11*(6), pp.836-844.

Adewoyin, J.E., Olaifa, F.E., Akintunde-Alo, D.A., Kappo, A. and Muibi, K.H., 2022. Spatio–Temporal Variation of Chlorophyll, Nutrients and Productivity in Lagos Lagoon, Lagos Nigeria Using Remote Sensing Approach. *Asian Journal of Fisheries and Aquatic Research*, *20*(6), pp.19-28.

Alademomi, A.S., Okolie, C.J., Daramola, O.E., Agboola, R.O. and Salami, T.J., 2020. Assessing the relationship of LST, NDVI and EVI with land cover changes in the Lagos Lagoon environment. *Quaestiones Geographicae*, *39*(3), pp.111-123.

Andem, A.B., Odey, C.O., Beshel, S.B., Ojo, O.B. and Etuk, M.C., 2023. Human-Induced Impact on the Distribution and Diversity of Benthic Macroinvertebrates and Fish Fauna in the Tropical Ikang River, Nigeria. *Croatian Journal of Fisheries*, *81*(1), pp.1-12.

APHA. 2002. American Public Health Association. In: Standard Methods for the Examination of Water and Waste Water, 22nd ed., APHA, New York, 1475.

Banda, K., Ngwenya, V., Mulema, M., Chomba, I., Chomba, M. and Nyambe, I., 2023. Influence of water quality on benthic macroinvertebrates in a groundwater-dependent wetland. *Frontiers in Water*, *5*, p.1177724.

Basheeru, K.A., Adekola, F.A., Abdus-Salam, N. and Okoro, H.K., 2022. Spatio-temporal monitoring of potentially toxic elements in Lagos harbour water and its health risk implications. *SN Applied Sciences*, *4*(11), p.298.

Bendary, R.E., Ibrahim, S.M., Goher, M.E., Elsaied, H.E., El Shabrawy, G.M., El Mordy, M.A. and Khalil, M.T., 2023. Taxonomic and functional structure of macrobenthic invertebrate communities and their response to environmental variables along the subbranches of the Nile River (rayahs), Egypt. *Environmental Science and Pollution Research*, *30*(11), pp.28803-28817.

Berger, E., Haase, P., Kuemmerlen, M., Leps, M., Schaefer, R.B. and Sundermann, A., 2017. Water quality variables and pollution sources shaping stream macroinvertebrate communities. *Science of the Total Environment*, *587*, pp.1-10.

Brraich, O.S. and Kaur, R., 2017. Temporal composition and distribution of benthic macroinvertebrates in wetlands. *Current Science*, pp.116-125.

Carter, J.L., Resh, V.H. and Hannaford, M.J., 2017. Macroinvertebrates as biotic indicators of environmental quality. In *Methods in stream ecology* (pp. 293-318). Academic Press.

Chen, X., Shen, Z. and Yang, Y., 2016. Response of the turbidity maximum zone in the Yangtze River Estuary due to human activities during the dry season. *Environmental Science and Pollution Research*, *23*, pp.18466-18481.

Dunlop, J., McGregor, G. and Horrigan, N., 2005. Potential impacts of salinity and turbidity in riverine ecosystems. *National Action Plan for Salinity and Water Quality. State of Queenslands*.

Ibe, A. C. 1988. Coastline Erosion in Nigeria (p. 217). Ibadan, Nigeria: Ibadan University Press.

Jaiswal, M., Hussain, J., Gupta, S.K., Nasr, M. and Nema, A.K., 2019. Comprehensive evaluation of water quality status for entire stretch of Yamuna River, India. *Environmental monitoring and assessment*, *191*, pp.1-17.

Keke, U.N., Omoigberale, M.O., Ezenwa, I., Yusuf, A., Biose, E., Nweke, N., Edegbene, A.O. and Arimoro, F.O., 2021. Macroinvertebrate communities and physicochemical characteristics along an anthropogenic stress gradient in a southern Nigeria stream: Implications for ecological restoration. *Environmental and Sustainability Indicators*, *12*, p.100157.

Luo, K., Hu, X., He, Q., Wu, Z., Cheng, H., Hu, Z. and Mazumder, A., 2018. Impacts of rapid urbanization on the water quality and macroinvertebrate communities of streams: A case study in Liangjiang New Area, China. *Science of the Total Environment*, *621*, pp.1601-1614.

Ma, Y., Yu, Z., Jia, S., Wu, N., Yin, K., Wang, Y., Giesy, J.P. and Jin, X., 2023. Multiple anthropogenic stressors influence the taxonomic and functional homogenization of macroinvertebrate communities on the mainstream of an urban-agricultural river in China. *Journal of Environmental Management*, *341*, p.118017.

Nkwoji, J.A. and Awodeyi, S.I., 2018. Impacts of sediment mining on the hydrochemistry and macrozoobenthos community in a coastal lagoon, Lagos, Nigeria. *Archives of Agriculture and Environmental Science*, *3*(3), pp.209-215.

Nkwoji, J.A. and Edokpayi, C.A., 2013. Hydrochemistry and community structure of benthic macroinvertebrates of Lagos lagoon, Nigeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, *4*(1), pp.1119-1131.

Nkwoji, J.A., Ugbana, S.I. and Ina-Salwany, M.Y., 2020. Impacts of land-based pollutants on water chemistry and benthic macroinvertebrates community in a coastal lagoon, Lagos, Nigeria. *Scientific African*, *7*, p.e00220.

Nkwoji, J.A., Yakub, A., Ajani, G.E., Balogun, K.J., Renner, K.O., Igbo, J.K., Ariyo, A.A. and Bello, B.O., 2010. Seasonal variations in the water chemistry and benthic macroinvertebrates of a south western Lagoon, Lagos, Nigeria. *Journal of American Science*, *6*(3), pp.85-92.

Nkwoji, J.A., Yakub, A.S., Abiodun, A.O. and Bello, B.O., 2016. Hydrochemistry and community structure of benthic macroinvertebrates in Ilaje coastal waters, Ondo State, Nigeria. *Regional Studies in Marine Science*, *8*, pp.7-13.

Onyema, I.C. and Omokanye, A., 2016. The influence of environmental variables on algal pigment in the western Lagos lagoon, Nigeria. *Nigerian Journal of Life Sciences (ISSN: 2276-7029)*, *6*(2), pp.197-212.

Kouadio, K.N., Diomandé, D., Ouattara, A., Koné, Y.J. and Gourene, G., 2008. Taxonomic diversity and structure of benthic macroinvertebrates in Aby Lagoon (Ivory Coast, West Africa). *Pakistan Journal of Biological Sciences: PJBS*, *11*(18), pp.2224-2230.

Kouadio K.N., Diomandé D., Ouattara A., Koné Y.J.M. and Gourène G., 2011. Distribution of benthic macroinvertebrates communities in relation to environmental factors in the Ebrié lagoon (Ivory Coast, West Africa). Life and Environment, 61: 59-69.

Lamptey, E. and Armah, A.K., 2008. Factors affecting macrobenthic fauna in a tropical hypersaline coastal lagoon in Ghana, West Africa. *Estuaries and Coasts*, *31*, pp.1006-1019.

Onyena, A.P. and Okoro, C.A., 2019. Spatio-temporal variations in water and sediment parameters of Abule Agege, Abule Eledu, Ogbe, creeks adjoining Lagos Lagoon, Nigeria. *Journal of Ecology and The Natural Environment*, *11*(4), pp.46-54.

Onyena, A.P., 2019. Composition, distribution, and diversity of benthic Macroinvertebrate from Creeks around Lagos Lagoon, Nigeria. *Journal of Applied Sciences and Environmental Management*, *23*(5), pp.857-863.

Onyena, A.P., Nkwoji, J.A. and Chukwu, L.O., 2023. Sediment characteristics and ecological quality evaluation of a brackish creek using AZTI's Marine Biotic and Bentix Indices. *Aquatic Sciences*, *85*(4), p.108.

Oyeleke, P.O., Popoola, S.O. and Abiodun, O.A., 2019. Assessment of Some Physico-Chemical Parameters of Lagos Lagoon, Southwestern Nigeria. *Academic Journal of Chemistry*, *4*(3), pp.09-11.

Sharma, S., Roy, A. and Agrawal, M., 2016. Spatial variations in water quality of river Ganga with respect to land uses in Varanasi. *Environmental Science and Pollution Research*, *23*, pp.21872-21882.

Thakur, Y., Grover, A. and Sinha, R., 2023. Differential distribution of macroinvertebrate associated with water quality. *World Water Policy*, *9*(1), pp.84-112.

Ugwumba, A.A.A. and Esenowo, I.K., 2020. Anthropogenic impact on plankton and benthos assemblage in the Lagos Lagoon, Nigeria. *Croatian Journal of Fisheries: Ribarstvo*, *78*(4), pp.173-182.

Xu, M., Wang, Z., Duan, X. and Pan, B., 2014. Effects of pollution on macroinvertebrates and water quality bio-assessment. *Hydrobiologia*, *729*, pp.247-259.

Zhou, Z.Z., Huang, T.L., Ma, W.X., Li, Y. and Zeng, K., 2015. Impacts of water quality variation and rainfall runoff on Jinpen Reservoir, in Northwest China. *Water Science and Engineering*, *8*(4), pp.301-308.