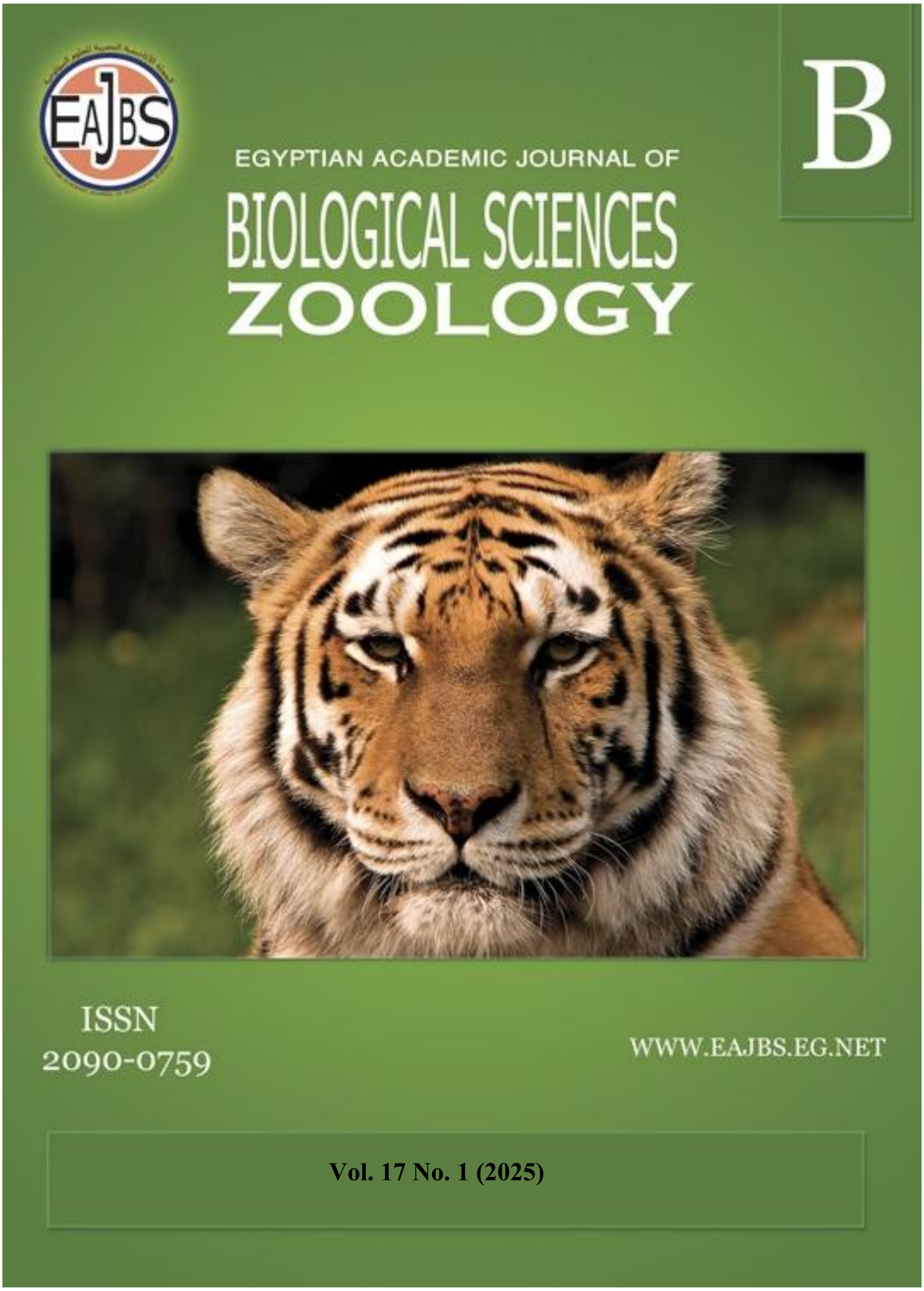

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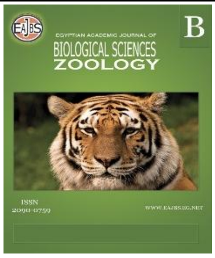

Bioaccumulation of Polycyclic Aromatic Hydrocarbons and Histopathological Alterations in African Knife Fish, *Gymnarchus niloticus* (Cuvier 1829) From Epe Lagoon, Lagos,Nigeria

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds that pose significant environmental and health concerns due to their toxicity, mutagenic properties, and potential carcinogenicity. These compounds are prevalent in various aquatic environments, including the Epe Lagoon, where their presence raises concerns about the safety and sustainability of local seafood resources. This study focuses on the bioaccumulation of PAHs in *Gymnarchus niloticus*, a commercially important fish species in the Epe Lagoon, which serves as a critical food source for the surrounding communities. The research involved the collection of *Gymnarchus niloticus* samples from multiple sites within the Epe Lagoon. These samples were subjected to rigorous analysis using chromatographic techniques and hispathological examination of fish tissues and multimeter horiba to quantify the concentration of both low and high molecular weight PAHs within the fish tissues and physiochemical parmeters. The findings revealed a higher propensity for bioaccumulation of high molecular weight PAHs, particularly Phenanthrene and Naphthalene, compared to their lower molecular weight counterparts. The results indicate that the levels of PAHs in *Gymnarchus niloticus* are significant, posing potential health risks to consumers who rely on this species as a staple in their diet. The study underscores the need for continuous monitoring of PAH levels in the Epe Lagoon and calls for the implementation of appropriate mitigation strategies to protect both the aquatic ecosystem and the health of the local population. This research contributes to the growing body of evidence on the environmental impact of PAHs and highlights the urgency of addressing contamination in vital water bodies like the Epe Lagoon.

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INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) represent a significant class of persistent organic pollutants with profound ecological implications. These hydrophobic organic compounds, primarily generated from incomplete combustion of organic matter, industrial discharges, and oil spills, are known to accumulate in aquatic sediments, posing substantial threats to benthic and pelagic organisms (Vijayanand *et al.*, 2023). *Gymnarchus niloticus*, a keystone species within the EPE Lagoon ecosystem, offers a valuable model for evaluating the ecological consequences of PAH contamination due to its trophic role and economic importance (Abdel-Shafy and Mansour, 2016). PAHs are characterized by their environmental persistence and bioaccumulative properties. Once introduced into aquatic systems, these compounds readily bind to organic matter in sediments, providing a long-term source of exposure for benthic and demersal organisms (Agbugui and Umaru, 2020).

Bioaccumulation in aquatic species, including G. niloticus, has been linked to carcinogenic, mutagenic, and teratogenic effects, with cascading impacts on population health and ecosystem dynamics (Akintola *et al.*, 2015; Eldos *et al.*, 2022). As PAHs bioaccumulate in tissues, they disrupt metabolic and biochemical processes, with histopathological manifestations such as liver lesions, reproductive dysfunctions, and immune system impairment commonly observed (Esmaeilbeigi *et al.*, 2021; Hasan *et al.*, 2022). These effects compromise individual fitness and reproductive success, reducing biodiversity and altering ecosystem stability. Because PAHs are lipophilic, they accumulate in biological adipose tissue. This process, known as bioconcentration, increases the concentration of PAHs in the organism compared to the environment (Akinyemi *et al.,* 2018). As PAHs move up the food chain through predators, they are not easily metabolized. Called bioaugmentation this process leads to a gradual increase in PAHs levels in higher predators such as Gymnarchus niloticus (Boonyathip *et al.,* 2008; Akinyemi *et al.,* 2018). Bioaugmentation of PAHs poses a particular threat to these higher predator's time collecting combined PAH concentrations from all predators from consumers over their lifetime.

The ecological significance of *G. niloticus* as both a top predator and a bioindicator species highlights its exceptional value in evaluating the impacts of polycyclic aromatic hydrocarbons (PAHs) on aquatic ecosystems. As a predatory species, *G. niloticus* occupies a high trophic level, integrating contaminant loads from its prey and reflecting the cumulative effects of pollutant bioaccumulation and biomagnification across the food web (Boonyathip *et al.,* 2008; Balmer *et al.,* 2019). Its role as a bioindicator is particularly noteworthy due to its sensitivity to environmental disturbances, making it an invaluable tool for monitoring the extent of anthropogenic stressors such as chemical pollution. The physiological and biochemical responses of *G. niloticus* to PAHs, including histopathological alterations and bioaccumulation metrics, can serve as early warning signals for ecosystem health, thereby informing conservation and remediation efforts (Eldos *et al.*, 2022).

Research on PAH bioaccumulation in *G. niloticus* offers an opportunity to elucidate critical ecological processes, such as trophic transfer mechanisms, wherein contaminants move through successive levels of the food web, and pollutant cycling, which governs the distribution and persistence of PAHs within aquatic systems (Esmaeilbeigi *et al.*, 2021). These studies not only provide insights into the direct impacts of PAHs on individual organisms but also reveal the indirect effects on ecosystem structure and function, including shifts in species composition, trophic dynamics, and habitat quality (Fisk *et al.,* 2000; Hasan *et al.,* 2022).

Identifying and quantifying the sources of PAHs, such as accidental oil spills, industrial effluents, and domestic discharges of petroleum by-products, is essential for designing targeted mitigation strategies (Ude *et al.,* 2021; Vijayanand *et al.,* 2023). These anthropogenic activities represent significant point and diffuse sources of PAHs, contributing to their pervasive presence in aquatic environments (Opadokun and Ajani, 2015). By linking pollution sources to observed ecological impacts in *G. niloticus*, researchers can establish causal relationships that drive effective policy development and pollution management (Honda and Suzuki, 2020). Furthermore, preserving the ecological integrity and functionality of aquatic ecosystems requires a comprehensive understanding of how pollutants like PAHs disrupt biogeochemical cycles and degrade ecosystem services. This underscores the importance of *G. niloticus* as a sentinel species in advancing both ecological research and practical conservation efforts aimed at mitigating the long-term consequences of environmental contamination.

The escalating levels of pollution in EPE Lagoon, driven by anthropogenic activities, have raised significant concerns regarding the health of aquatic organisms (Olanrewaju and Kareem, 2022). PAHs, as persistent and pervasive pollutants, accumulate in aquatic organisms, inducing metabolic, biochemical, and histopathological changes that impair population health (Jegede *et al.*, 2018). The extent of PAH bioaccumulation and its impacts on *G. niloticus* remain inadequately understood, hindering the formulation of effective environmental management strategies (Wola and Aboti, 2010; Wang *et al.*, 2021). This study is pivotal in advancing the understanding of PAH contamination within EPE Lagoon and its impacts on aquatic organisms. By elucidating bioaccumulation patterns and associated health risks, it will contribute to environmental monitoring efforts and inform policy decisions aimed at pollution mitigation (Jha *et al.,* 2009; Oladosu *et al.,* 2011). Furthermore, insights into the histopathological and biochemical responses of *G. niloticus* will enhance understanding of PAH toxicity mechanisms, providing a foundation for developing targeted management and conservation strategies. Ultimately, this research aims to safeguard the ecological integrity of EPE Lagoon and ensure the sustainable management of its aquatic biodiversity (Nwabueze and Nwabueze, 2021; Ogidi and Akpan, 2022).

This study aims to evaluate the levels and effects of PAHs in EPE Lagoon to determine PAH concentrations in water, sediments, and tissues of *G. niloticus*. It furher seeks to assess histopathological changes in the tissues of infected and uninfected *G. niloticus* to elucidate PAH-induced health effects. It is also aims to compare the PAH bioaccumulation and biochemical biomarkers in infected and uninfected *G. niloticus* to investigate the role of parasitism in pollutant dynamics and health outcomes.

MATERIALS AND METHODS

1-Study Area:

Epe Lagoon, situated between Lagos and Ogun States in Nigeria, spans between longitudes 4°00' and 4°15' E and latitudes 6°25' and 6°37' N (Fig. 1). The lagoon covers an area of approximately 247 square kilometres, with a predominantly shallow depth of less than 3.0 meters and a maximum depth of 6.4 meters (Kusemiju, 1973). This freshwater lagoon receives inflows from the Oni River in the northeast and the Oshun and Saga Rivers in the northwest. It connects to the sea through Lagos Lagoon and Lagos Harbour. Notably, EPE Lagoon serves as a transitional water body linking the southwesternstates of Ondo, Ogun, and Lagos. It is part of a complex network of waterways that includes various other lagoons and creeks extending along the southwestern Nigerian coast from the Dahomey border to the Niger Delta.

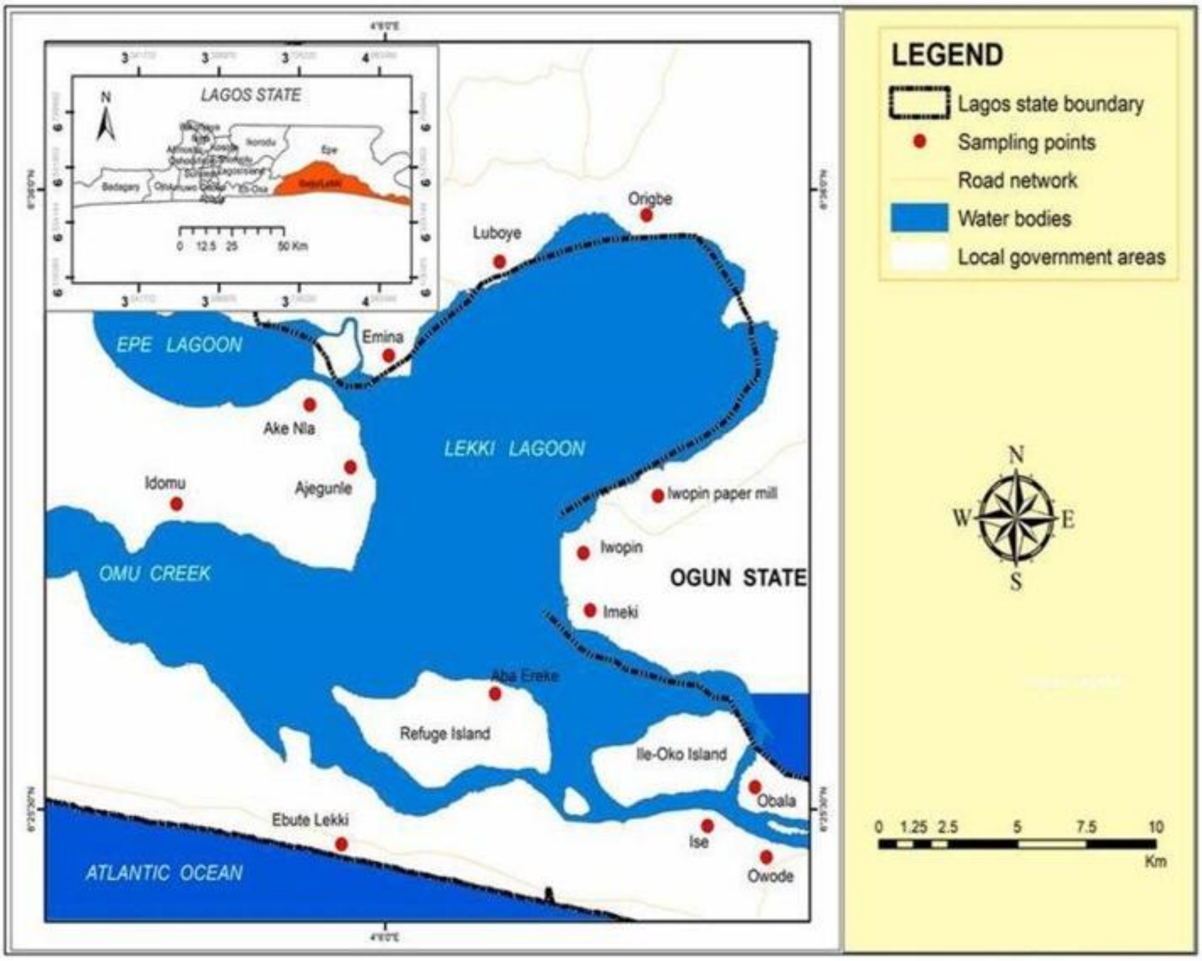

Fig. 1: Map of Epe Lagos showing the fishing villages

2-Sample Collection and Analysis:

A total of 21 randomly selected fresh specimen of Gymnacus niloticus were purchased at Oluwo market, Epe, Lagos, Nigeria over a period of 6 months. The weights,standard length and tonal lengths of the fishes were recorded.The Weight were taken with the aid of standard top, loading Denward balance while lengths of the fishes Were taken with the metre rule. The fishes were immediately subjected to Parasitological examinations. 'The collections were undertaken for a period of 6 months between November 2024 to April 2024. The abdominal cavity of each fish was then dissected using a dissecting set and the gastrointestinal part were removed and cut into parts. The gastrointestinal parts were separated from other visceral organs and placed in petri dishes containing physiological saline. The intestine was further carefully slit open to aid the emergence of the parasitic helminths and accumulation of heavy metals. The emergence of any worm was easily noticed by its wriggling movement in the saline solution. The emergence helminth parasites from different sites were fixed in 70% alcohol counted and recorded. the liver and the intestine were also kept in saline solution, and Fulton Condition Factor (kK) was estimated.

3-Examination of Intestines for Parasite Recovery:

The intestine of the fish hosts collected from the lagoons was examined for the presence of parasites. The fish were examined from orotozoan parasites using the technique suggested by Markevich (1951). The fraction of the tease's intestine wore collected in EDTA bottles and preserved in Blouin's fluid for histopathological analysis. The intestine was also examined for helminth parasites. The recovered parasite was preserved in 70% alcohol. The recovered helminths were soarted out into various groupd using standar parasistological guidelines. They were counted and labelled appropriately for detailed identification. Prevalence mean intensity and abundance was calculated using the formulae;

$$\text{Parasite prevalence (\%)} = \frac{\text{Number of infected fish x}100}{\text{Tolal number of fish examined}}$$

$$\text{Percentage load} = \frac{\text{Number of collected parsites x}100}{\text{Number of fish examined}}$$

The condition factor also known as the Ponderal index or the Fulton Coefficient of condition was computed using the formula described by Worthington and Ricardo (1936)

$$k=\frac{100W}{SL}$$

SL Standard length

W=Weight

Condition factor (k) was used as a base for grouping individuals into low condition status and high condition sttus (Cartander, 1969, Hfledmanet *et al.,* 2002). Median condition factor was calculated using linking values.

3.1-Morphological Parameters of the Fish:

The total length of each fish was taken on the spot from the tip of the snout (with the mouth closed) to the extended tip of the caudal fin while the standard length was obtained by constricting the length of the caudal fin from the length of the total length. This was done using a metre rule and recorded to the nearest centimetre (cm), After draining excess water the stomach and blot drying the weight(W) of the Same fish was obtained to the nearest 0.1 g using a standard loading Denward balance, sex determination of the fish species was done by Visual examination of the anal opening. The presence of an intromittent organ on the ventral side, just before the anal is indicative a female species. This was consequently confirmed by the presence or absence of testis or ovaries dissection.

3.2-Processing of Parasites Recovered:

The guts were removed, washed in saline and the parasites recovered were fixed and processed in 70% alcohol. They were counted, recorded and the identification of the parasites were carried out in the laboratory.

3.3-Processing of Intestine for Histopathology:

The tissue samples were first soaked in Bouin's solution for 6 hours and then transferred to 10% phosphate buffered formalin to preserve them. The tissue samples were cut into pieces and placed inside small embedding casettes. They were then processed automatically in a machine for 15-18 hours. The dehydration of the tissues was done step-by-step in increasing concentrations of alcohol (70%, 90% and then twice in 100%alcohol) for 30 minutes each. The dehydrated tissue samples were soaked three times in melted paraftin wax and then embedded in fresh paraffin wax to solidify. Each paraffin block was placed in a wooden holder, excess wax was trimmed off, and the tissue surface was exposed by slicing it thinly with a microtome into 4-5 micron sections.

The thin sections were gentlypicked up onto labeled glass slides. Using curved foreeps. The sections were floated in a 45°C water bath. A curved glass rod was used to collect the flattened, crease-free sections and position them in the center of the slide. The slides were then dried on a 60°C hot plate for the sections to stick properly.

The paraffin was removed from the sections by dipping in xylene, followed by dehydration again in decreasing alcohol concentrations (100%, 70%, water). The sections were then stained using two dyes-hematoxylin to stain the nuclei and cosin to stain the cytoplasm of cells. Excess stain was washed off with tap water and destained with 1%acid alcohol if needed. The stained sections were mounted on slides using DPX (di-n-butyl phthalate in xylene) as a clearing agent. The prepared slides were then examined under a FisherBraidTM Micromaster microscope at 40X and 100X magnification. The interpretation and analysis of any pathological lesions was done at the Pathology Laboratory in the Veterinary Pathology Department at the

University of Ibadan, Nigeria.

4-Statistical Analysis:

The examination utilized Microsoft Excel version (2021) and Statistical Package for Social Science (SPSS) version 20. The obtained results were presented as mean ± standard deviation and underwent analysis of variance (ANOVA) to ascertain significant differences. Subsequently, Bonferroni post-tests were applied to establish the relationships between various treatments. ANOVA results were deemed statistically significant when $p \leq 0.05$.

RESULTS

1-Physicochemical Parameters of Epe lagoon:

The pH at Station 3 was significantly higher ($p<0.05$) than the pH values at Stations 1 and 2 (Table 1). The turbidity and total dissolved solids at Station1 was significantly higher while the DO and salinity was significanlt lower than the values at Stations 2 and 3 ($p<0.05$).

Table 1: Physichochemical parameters of water samples at Epe lagoon

Parameters	STATION 1 Mean (Min- Max)	STATION 2 Mean (Min- Max)	STATION 3 Mean (Min- Max)	P value
Temp (oC)	30.34 (29.47- 30.55)	30.64 (30.02- 30.97)	29.62 (27.89- 30.95)	>0.05
pH	6.62 (5.61- 7.25)	6.50 (5.60- 7.30)	6.91 (6.61- 7.23)*	<0.05
Cond (ms/cm)	0.45 (0.27- 0.55)	0.45 (0.28- 0.55)	0.43 (0.27- 0.54)	>0.05
Turb (mg/L)	4.77 (1.00- 10.30)*	3.30 (1.30- 7.10)	3.33 (2.30- 7.00)	<0.05
DO (mg/L)	4.91 (3.89- 6.40)*	5.06 (5.03- 5.08)	5.10 (5.99- 5.50)	<0.05
TDS (mg/L)	0.32 (0.18- 0.44)*	0.29 (0.18- 0.34)	0.29 (0.18- 0.34)	<0.05
Sal (mg/L)	1.00 (0.10- 2.00)*	0.17 (0.10- 0.20)	0.70 (0.10- 1.80)	<0.05

2-Length-Weight Relationship of *G. niloticus:*

Based on the regression analysis, the relationship between the standard length and weight of *G. niloticus* can be described by the following equation:

$\text{Log } W = -1.085204745 + 2.182939339 * \text{Log } L$

This equation suggests that as the standard length (L) of the fish increases, the weight (W) increases exponentially. The high R-square value of 0.925 indicates that the model explains a substantial portion of the variability in the data, and the significant F-statistic (p-value < 0.00001) confirms the overall significance of the regression model (Fig. 2).

The residual analysis further supports the validity of the model. The residuals, which represent the difference between the observed and predicted log-transformed weights, are relatively small, with a mean close to zero and a standard deviation of 0.073. This indicates that the model provides a good fit to the observed data. Basically, the provided data and analysis suggest that the length-weight relationship of *Gymnarchus niloticus* can be well-described by the power function model, with the exponent (slope) of the relationship being approximately 2.18.

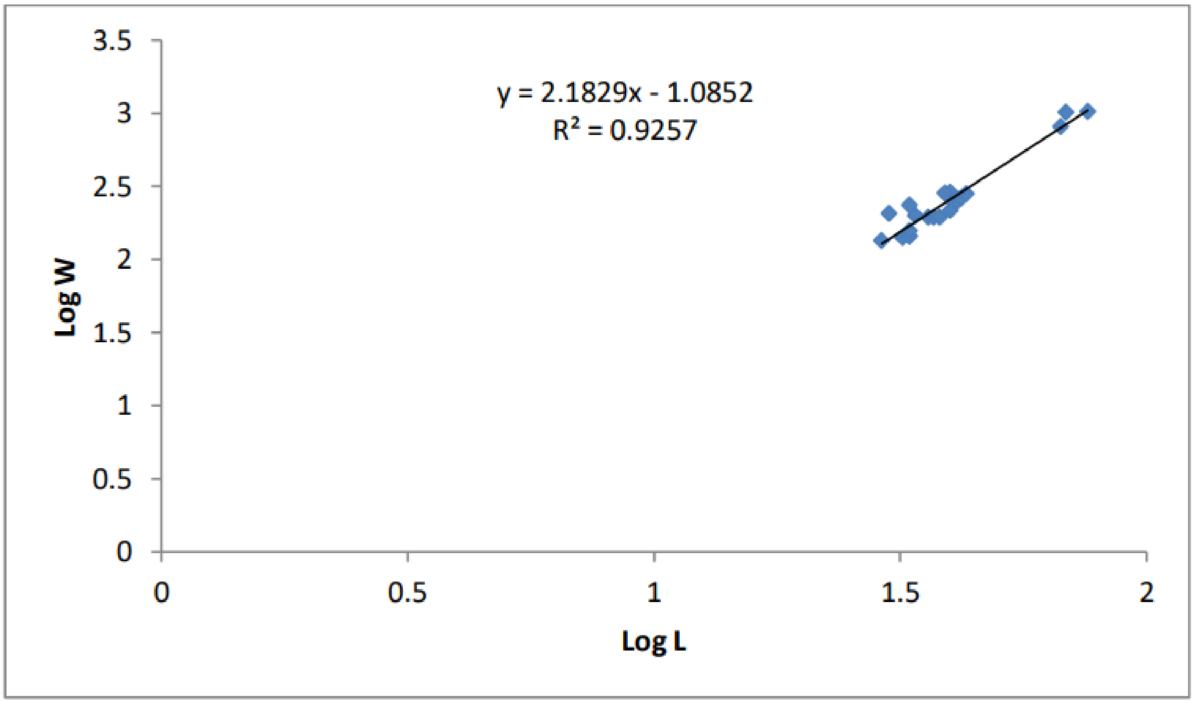

Fig. 2: Length weight relationship of *Gymnarchus niloticus*

The value of growth exponent (b)= 2.18 from the logarithmic equation Log W=b Log L + Log a indicates a negative allometry which implies slenderness among the fish population. The data presented is 93% reliable.

The regression analysis shows a significant relationship between parasite presence and the condition factor (k) of *Gymnarchus niloticus*. The multiple R value of 0.497 indicates a moderately strong correlation between the two variables. The R-Square value of 0.247 suggests that approximately 24.7% of the variation in the condition factor can be explained by the presence of parasites. The regression coefficient for the parasite variable is -0.0718, which suggests that the presence of parasites has a negative impact on the condition factor of *Gymnarchus niloticus*. In other words, as the number of parasites increases, the condition factor of the fish tends to decrease.

The 95% confidence interval for the parasite coefficient ranges from -0.132 to -0.0116, indicating that the true impact of parasites on the condition factor is likely to fall within this range. The residual analysis shows that the model fits the data reasonably well, with most of the residuals being within ±0.1 of the predicted values (Fig. 3). Basically, the data analysis suggests that the presence of parasites has a detrimental effect on the condition factor of *Gymnarchus niloticus*.

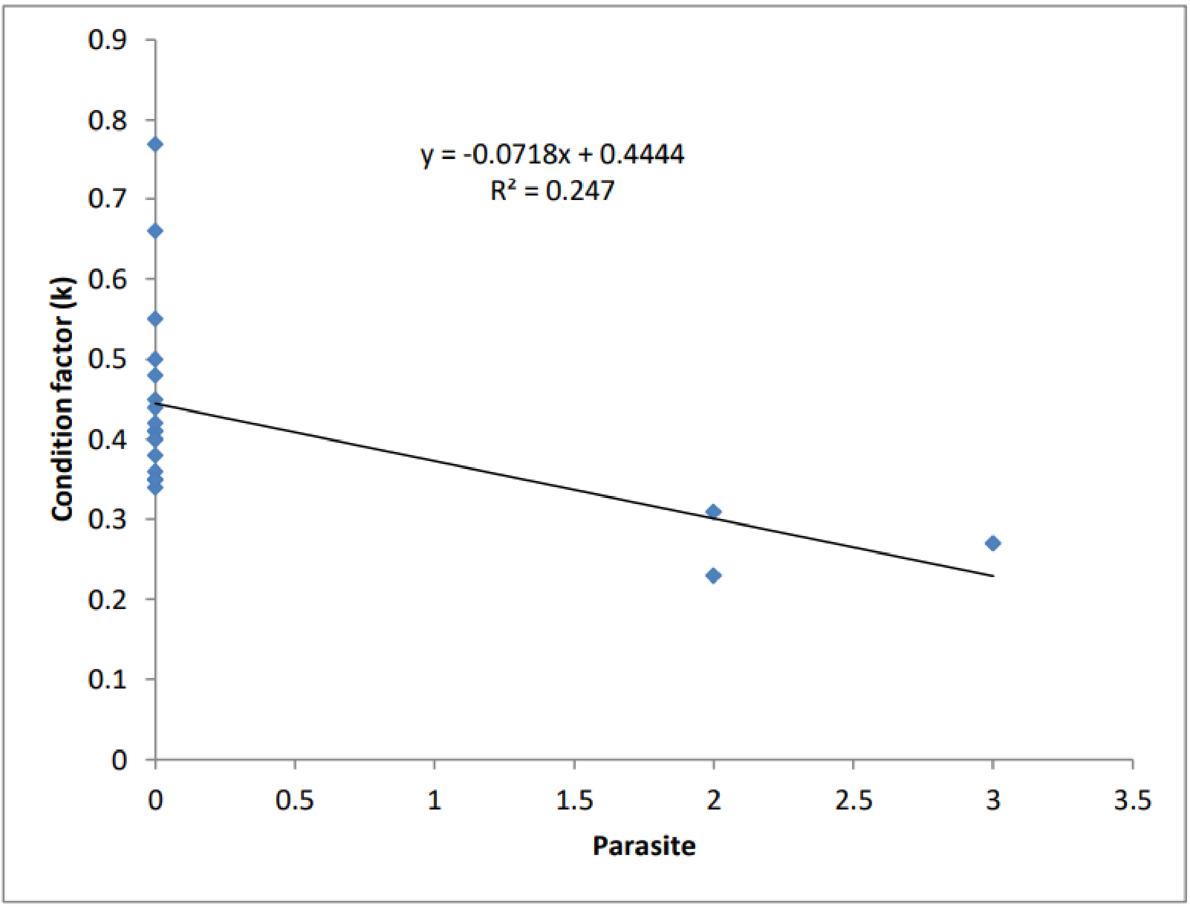

Fig. 3: Impact of Parasite Presence on the Condition Factor of *Gymnarchus niloticus*

3-Histopathological Alteration in the Intestine of *G. niloticus*:

The histologic sections of the intestinal tissue from all 7 samples (Figs. 4- 10) show consistent pathological changes. The primary findings showed a complete loss of the intestinal mucosa, including the mucosal glands. This condition is referred to as "mucosal erosion" or "complete mucosal erosion" in the summary of histologic findings.

Accompanying the loss of the mucosal layer, the underlying lamina propria appears distorted and contains intense infiltrates of inflammatory cells. This indicates a significant inflammatory response within the intestinal wall. In some cases, such as in sample F5, there is also evidence of vascular congestion, further highlighting the inflammatory nature of the pathological changes.

The loss of the superficial epithelium is another common feature observed across the samples. This epithelial layer normally serves as a protective barrier and its disruption can contribute to the mucosal erosion. These histopathological alterations suggest that the *Gymnarchus niloticus* from the EPE Lagoon are experiencing a significant inflammatory condition within their intestines. The complete loss of the mucosal layer and the presence of intense inflammatory cell infiltrates indicate a severe and potentially debilitating condition that could impact the overall health and well-being of these fish.

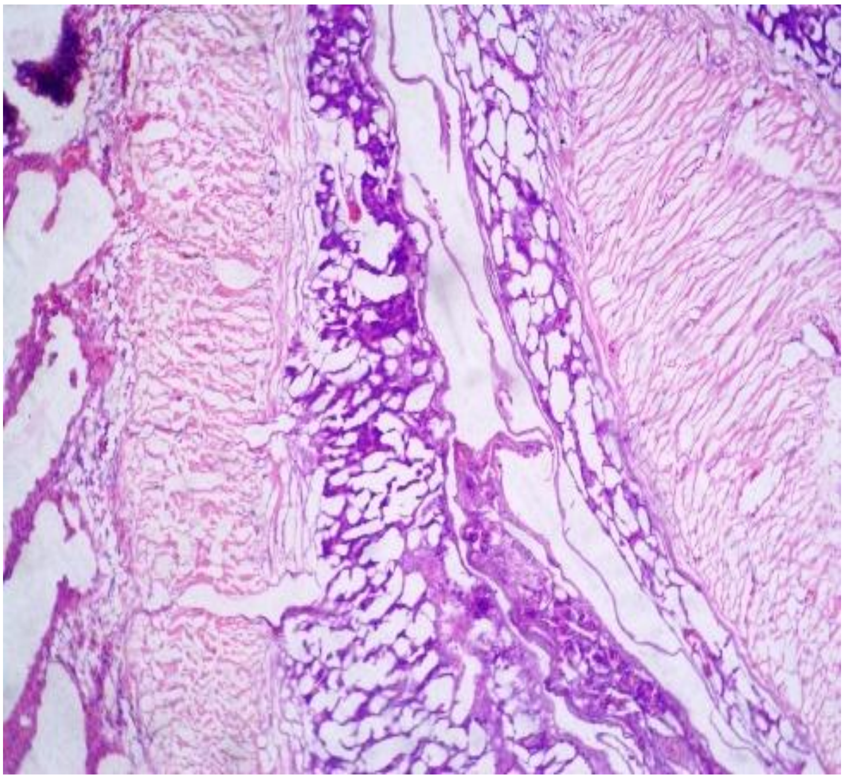

Fig. 4: Photomicrograph of the Intestine section of tissue shows complete loss of mucosa, mucosal glands displayed on a distorted lamina propria containing intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

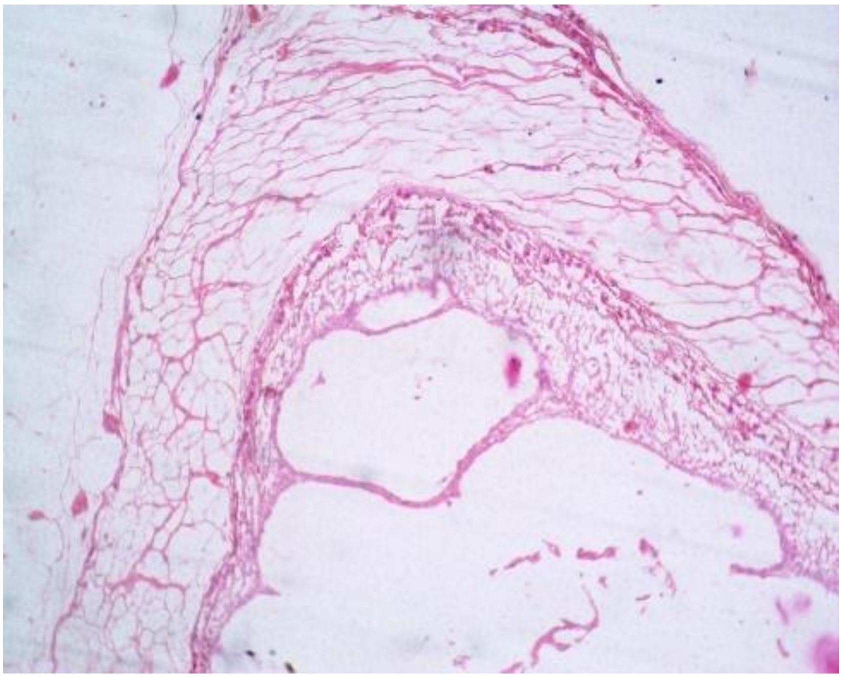

Fig. 5: Photomicrograph of the Intestine section of tissue shows complete loss of mucosa, mucosal glands and lamina propria displayed on intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

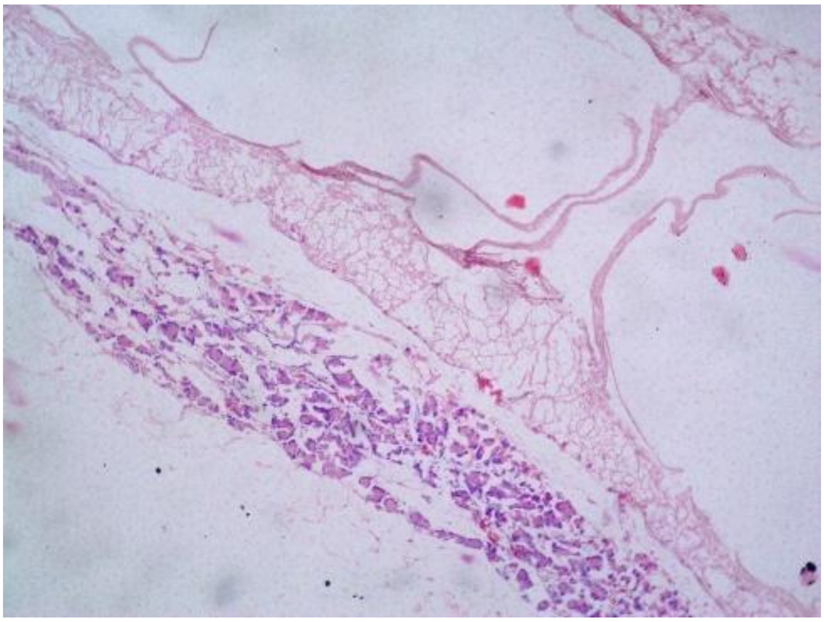

Fig. 6: Photomicrograph of the Intestine section tissue shows complete loss of mucosa, mucosal glands and lamina propria displayed on intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

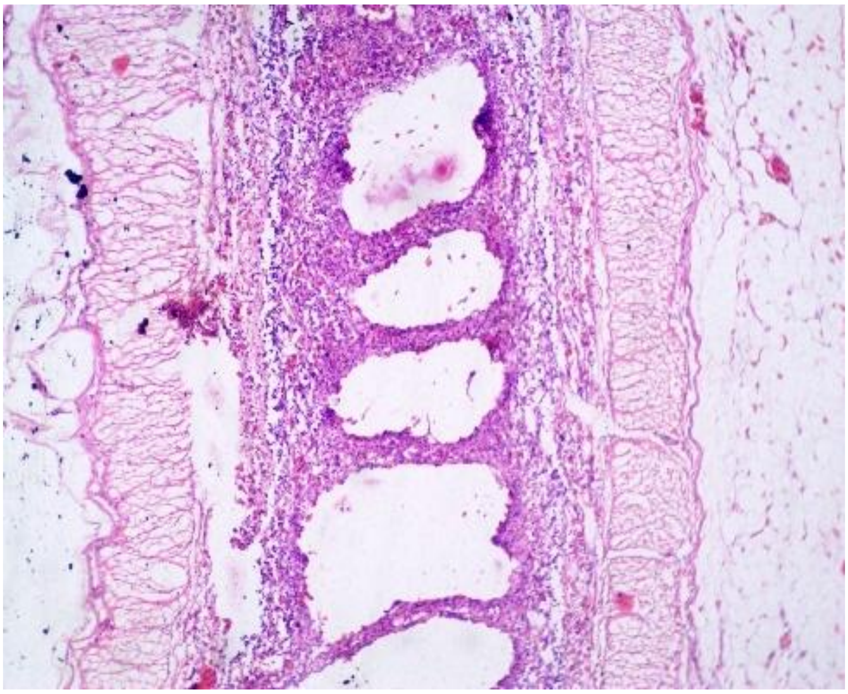

Fig. 7: Photomicrograph of the Intestine section of tissue shows complete loss of mucosa, mucosal glands displayed on a distorted lamina propria containing intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

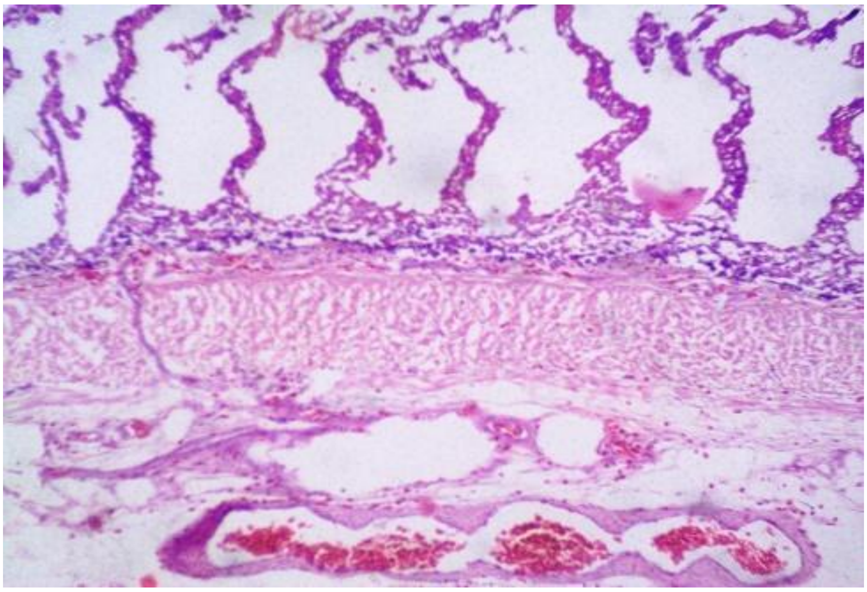

Fig. 8: Photomicrograph of the Intestine section of tissue shows complete loss of mucosa, mucosal glands and distorted lamina propria containing intense vascular congestion and infiltrates of inflammatory cells with loss of superficial epithelium mucosal erosion. H & E Stain X100

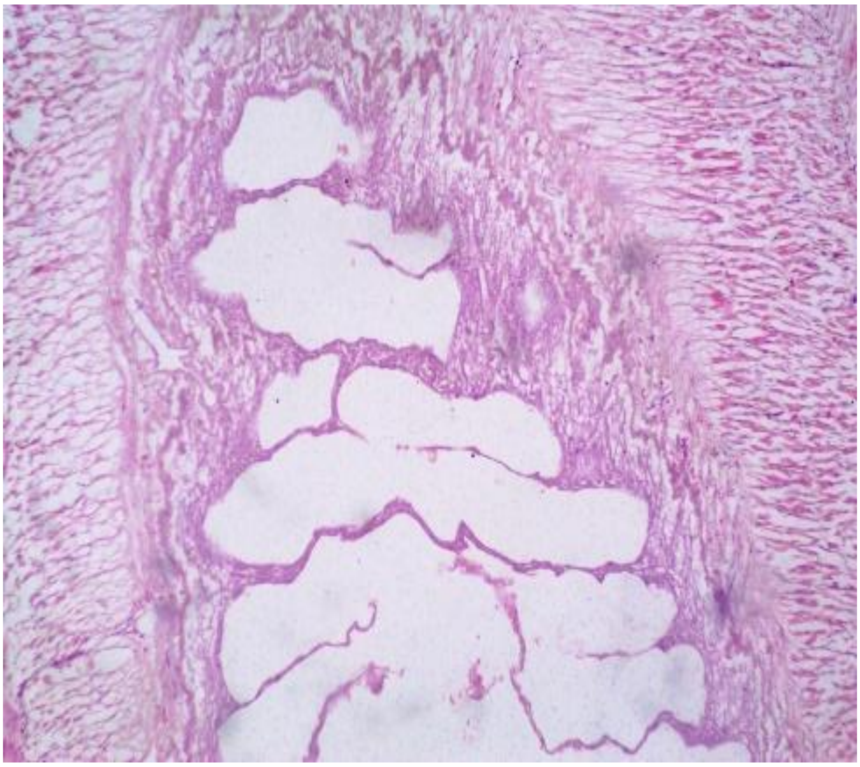

Fig. 9: Photomicrograph of the Intestine section of the Intestine section of tissue shows complete loss of mucosa, mucosal glands displayed on a distorted lamina propria containing intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

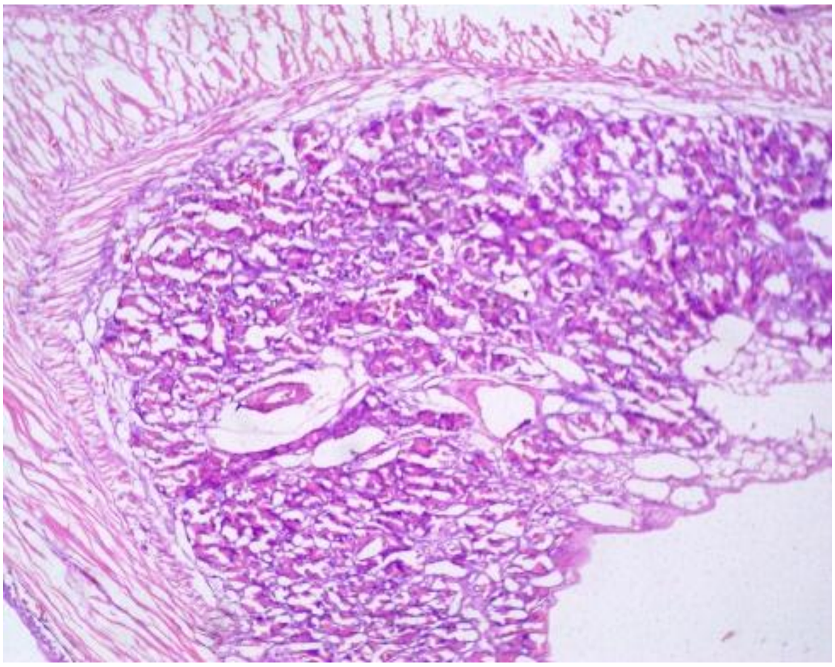

Fig. 10: Photomicrograph of the Intestine section of tissue shows complete loss of mucosa, mucosal glands displayed on a distorted lamina propria containing intense infiltrates of inflammatory cells and loss of superficial epithelium mucosal erosion. H & E Stain X100

DISCUSSION

The physicochemical parameters measured across the three stations in Epe Lagoon demonstrated minimal variation, suggesting a relatively stable aquatic environment conducive to aquatic life. The uniformity in temperature readings, which ranged from surface measurements of 28.6°C to 28.75°C at 3.2 m depth, reflects consistent solar radiation and the influence of the lagoon's shallow depth, promoting stable thermal conditions. The pH values, slightly acidic to neutral (6.60–6.74), indicate mild buffering capacity, with marginal fluctuations across stations. Similarly, dissolved oxygen (DO) levels, while decreasing with depth, remained within the range necessary to support aerobic aquatic life. Minor variations in turbidity (4.77 NTU at Station 1 versus 3.30 NTU at Station 2) and salinity were observed but were not statistically significant. These differences may result from localized disturbances such as sediment resuspension and freshwater influx, as corroborated by Wang *et al.* (2021). Overall, the water quality appears to support the ecological requirements of G. niloticus, the focal species of this study.

Analysis of polycyclic aromatic hydrocarbon (PAH) concentrations in G. niloticus revealed no significant influence of infection status on PAH levels. However, tissue type—specifically liver and intestine was a significant determinant of PAH accumulation, although the distribution of individual PAH compounds between these tissues was not significantly different. These findings indicate that while PAHs preferentially accumulate in specific tissues, parasitic infection does not markedly affect their distribution within G. niloticus. This observation suggests that PAH bioaccumulation is primarily driven by physiological factors such as tissue lipid content and metabolic activity rather than health status (Wang *et al.*, 2021). The length-weight relationship of G. niloticus followed a power function model, with a growth exponent indicating negative allometry. This suggests that as the fish grows, its weight increases at a slower rate relative to its length, indicative of a streamlined body morphology. Such negative allometric growth may represent an ecological adaptation to the species' specific habitat and feeding habits, enabling efficient navigation and energy utilization in its niche. Regression analysis of parasite presence and the condition factor revealed a moderate correlation ($R = 0.497$), with an R^2 value of 0.247, indicating that approximately 24.7% of the variation in the condition factor is attributable to parasite infestation. The ANOVA results ($p = 0.0219$) confirm the statistical significance of this relationship. These findings suggest that parasitism exerts a measurable influence on fish condition, with potential implications for fitness and population dynamics (Wola and Aboti, 2010; Wang *et al.,* 2021).

Histopathological examination of intestinal tissues from G. niloticus in Epe Lagoon revealed extensive pathological alterations. Consistent findings across all samples included complete loss of the intestinal mucosa and mucosal glands, a condition identified as mucosal erosion. This pathological state was accompanied by severe distortion of the underlying lamina propria, which was heavily infiltrated with inflammatory cells, indicative of a robust inflammatory response (Wola and Aboti, 2010). The erosion of the superficial epithelial layer further highlighted the severity of the condition, compromising the intestinal barrier and predisposing the fish to secondary infections and nutrient absorption deficiencies. The chronic nature of these findings underscores a significant health threat to G. niloticus, likely exacerbated by environmental stressors such as pollution and parasitic infections. The observed histopathological changes emphasize the critical need for continuous monitoring and targeted interventions to mitigate the underlying causes of these health issues and ensure the sustainability of G. niloticus populations in Epe Lagoon (Wang *et al.,* 2021).

The study underscores the intricate interactions between environmental parameters, pollutant bioaccumulation, parasitic infections, and fish health in Epe Lagoon. While physicochemical stability of the lagoon appears supportive of aquatic life, localized disturbances and pollutant exposure pose significant health risks to G. niloticus. The findings emphasize the importance of integrated management approaches, including pollutant source control, habitat conservation, and health monitoring, to sustain the ecological integrity of Epe Lagoon and the well-being of its aquatic inhabitants.

Conclusion

The study highlights the ecological complexity of Epe Lagoon, which supports diverse aquatic life, including Gymnarchus niloticus. Relatively stable physicochemical parameters, such as temperature, pH, and dissolved oxygen, indicate a conducive environment for aquatic organisms. However, minor variations in turbidity and salinity are likely attributable to localized disturbances rather than systemic environmental changes. The analysis of polycyclic aromatic hydrocarbon (PAH) concentrations reveals tissue-specific bioaccumulation patterns, with no significant differences in PAH levels under pathological conditions, suggesting that PAH distribution is primarily influenced by tissue physiology rather than health status. The observed negative allometric growth trend in G. niloticus suggests a slower increase in weight relative to length, indicative of ecological or trophic adaptations to environmental conditions. This growth pattern may reflect evolutionary strategies for optimizing energy use and survival within the lagoon's ecosystem.

Histopathological examinations reveal extensive intestinal damage in G. niloticus, including severe mucosal erosion and pronounced inflammatory responses, signaling critical health concerns. These pathological changes compromise the fish's well-being and highlight the impact of environmental and biological stressors. Additionally, the inverse relationship between parasite burden and condition factor underscores the need for effective parasite management strategies.

The findings emphasize the importance of continuous monitoring, pollution control, and targeted health interventions to safeguard the sustainability of G. niloticus populations and overall ecosystem integrity in Epe Lagoon.

Declarations:

Ethical Approval: The research was done after the purchase of the fish at Oluwo market, Epe, Lagos, Nigeria

Competing interests: The authors declare that there is no conflict of interest.

Author's Contributions: Akinsanya Bamidele conceptualized the research, went to the field with some students of Akeredolu excellence while Patrick Isibor wrote the manuscript and Akinsanya Bamidele also read and sent the manuscript for publication

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Availability of Data and Materials: All data sets are available in the manuscript and supplementary file.

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