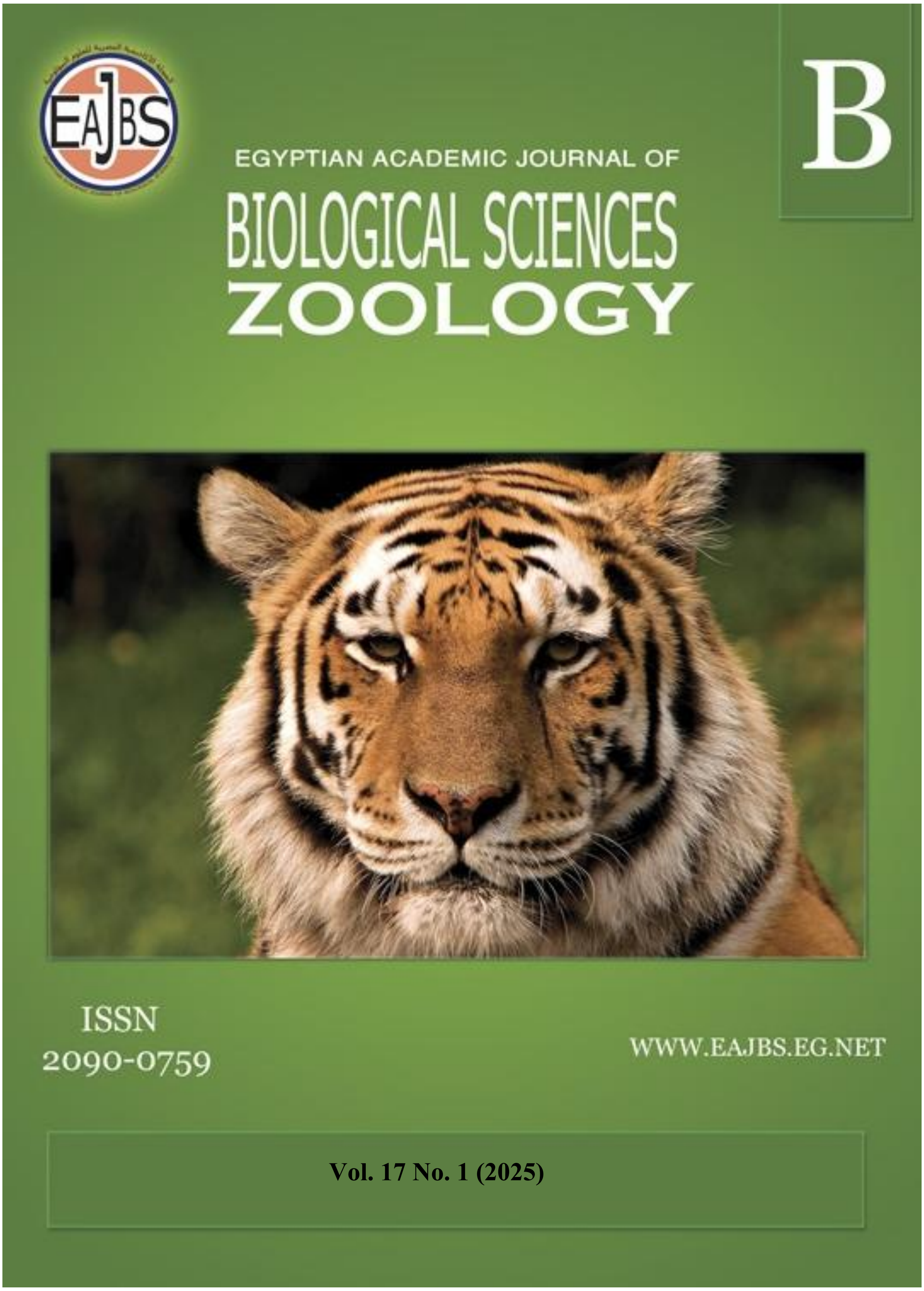

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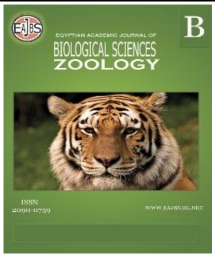

Comparative Parasitic Infections in *Gymnarchus niloticus* (Cuvier, 1829) and *Heterotis niloticus* (Cuvier, 1829) in Lekki Lagoon, Lagos State, Nigeria

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ABSTRACT

This study investigates the comparative parasitic infections in *Gymnarchus niloticus* (Cuvier, 1829) and *Heterotis niloticus* (Cuvier, 1829) within the ecological context of Lekki Lagoon, Lagos State, Nigeria. Both species, integral to the biodiversity and fisheries of the lagoon, exhibit ecological differences influencing their parasitic burdens. A total of 200 specimens (100 per species) were collected and examined for ecto- and endoparasites using standard parasitological techniques. Results revealed a higher prevalence and mean intensity of parasitic infections in *Heterotis niloticus* (*Tenuisentis niloticus*) (65%) compared to *Gymnarchus niloticus* (*Raphidascaroides sp*)(48%), with significant variation ($p < 0.05$) in parasitic taxa between the two hosts. Identified parasites included helminths (nematodes and trematodes), protozoans, and monogeneans, with *Heterotis niloticus* hosting a more diverse assemblage, likely attributable to its bentho-pelagic feeding strategy and omnivorous diet, which increase exposure to intermediate hosts. Conversely, *Gymnarchus niloticus*, as a piscivorous species, exhibited fewer parasite species, dominated by trophically transmitted helminths. Seasonal variations significantly influenced infection rates, with peaks during the wet season correlating with increased host density and ecological interactions. The findings underscore the ecological drivers of parasitism in Lekki Lagoon and their implications for fisheries management. Understanding host-parasite dynamics in these commercially and ecologically significant species is crucial for sustainable exploitation and conservation strategies in freshwater ecosystems.

INTRODUCTION

Gymnarchus niloticus, commonly known as the African knifefish or aba fish, is primarily a bentho-pelagic species. It inhabits freshwater systems such as rivers, lakes, and floodplains, often occupying zones near the bottom or midwater levels. While it can navigate near the surface when foraging, its behavior and ecological role generally associate it with the intermediate layers close to the substrate, making it characteristic of bentho-pelagic fish. *G. niloticus*, commonly referred to as the African knifefish, is a highly specialized, carnivorous

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species within the family Gymnarchidae. This nocturnal predator primarily preys upon small fish, crustaceans, and aquatic insects, employing its acute electrosensory system to detect prey in turbid or low-visibility waters (Akinsanya, 2007) . Its elongated body and reduced fin morphology, dominated by a dorsal fin used for propulsion, enhance its stealth and maneuverability, enabling precision strikes on prey. The diet of *G. niloticus* shows ontogenetic variation, with juveniles targeting smaller invertebrates, while adults focus on larger, energy-rich prey such as juvenile fishes. Ecologically, *Gymnarchus niloticus* occupies a top predator role within freshwater ecosystems, exerting significant influence on prey populations and trophic dynamics. Its predatory habits contribute to regulating fish community structures and maintaining ecological balance (Akinsanya, 2005). The species thrives in lentic and slow-flowing lotic environments, such as floodplains, lakes, and sluggish river channels, where dense vegetation provides optimal hunting grounds and protection from predators.

A key ecological adaptation of *G. niloticus* is its reliance on electrolocation for foraging, navigation, and communication. This adaptation is especially advantageous in hypoxic or heavily vegetated habitats where visual cues are limited. Additionally, its preference for floodplain habitats underscores its dependence on seasonal hydrological cycles, particularly during spawning and feeding migrations. *G. niloticus* exhibits a unique reproductive strategy, constructing floating nests within vegetated areas during the flooding season (Akinsanya, 2015). The species demonstrates parental care, with adults guarding and aerating the nests. This behavior ensures high offspring survival, reinforcing its position as a keystone species in its habitat. Behaviorally, *G. niloticus* is largely solitary, with territorial tendencies during the breeding season. Its electrogenic organ, capable of producing weak electrical signals, facilitates intraspecific communication and territorial defense, further enhancing its ecological role within complex freshwater ecosystems (Amundsen, 1996; Akinsanya *et al.,* 2015). The ecological niche of *Gymnarchus niloticus* is defined by its specialization as an electrolocating predator within low-oxygen, vegetated waters. Its habitat preferences overlap with other piscivorous species, yet its unique sensory adaptations enable niche differentiation. This reduces interspecific competition by allowing it to exploit prey undetectable to visually reliant predators (Andrew *et al.,* 1994; Amundsen *et al.,* 1996).

As an apex predator, *G. niloticus* is integral to the trophic stability and biodiversity of its habitats. However, anthropogenic pressures, including habitat degradation, pollution, and overfishing, pose significant threats to its populations. The construction of dams and water management schemes disrupt natural floodplain dynamics, adversely affecting its nesting and feeding habitats. Conservation efforts should prioritize the restoration of hydrological connectivity and the preservation of floodplain ecosystems to sustain populations of *G. niloticus*. *G. niloticus* represents a remarkable example of ecological specialization, with its electrosensory adaptations and trophic role underscoring its ecological significance (Ayoola and Abotti, 2010). Further research into its population dynamics, electrosensory mechanisms, and responses to environmental stressors is essential for developing effective conservation strategies for this.

Heterotis niloticus, commonly known as the African bony tongue, is primarily considered a bentho-pelagic fish. It inhabits freshwater systems such as rivers, floodplains, lakes, and swamps across tropical Africa. While it often forages near the bottom, particularly for detritus, small invertebrates, and organic matter, it also utilizes the water column for feeding and movement (Andrew *et al.,* 1994). The classification as bentho-pelagic reflects its ecological role and behavioral flexibility, occupying a niche that bridges benthic and pelagic zones depending on environmental conditions and life stages.

Heterotis niloticus, an obligate air-breathing teleost and a member of the family Arapaimidae, exhibits a trophic strategy characterized by opportunistic omnivory with a strong inclination towards detritivory. Its feeding behavior is primarily substrate-associated, utilizing specialized gill rakers to sieve fine organic particulates, detritus, and microfauna from sediments and water. Juvenile stages predominantly consume planktonic organisms, including microcrustaceans and phytoplankton, facilitating rapid growth. Adult individuals exhibit dietary plasticity, with a diet expanding to include insect larvae, mollusks, and plant material, reflecting their capacity to exploit diverse food resources. This adaptability is pivotal in environments with fluctuating resource availability, such as floodplain systems.

Ecologically, *H. niloticus* occupies a bentho-pelagic niche, integrating activities within both benthic and pelagic zones of aquatic systems. It is commonly associated with slow-moving or stagnant water bodies, such as rivers, floodplains, and lakes with dense macrophyte growth. The species plays a critical role in detrital food web dynamics, acting as a bioturbator by disturbing sediments during foraging, which enhances nutrient cycling and promotes microbial activity. Moreover, its trophic interactions contribute to the regulation of benthic invertebrate populations and the redistribution of organic matter across trophic levels. This species exhibits marked adaptability to seasonal hydrological changes, particularly in floodplain ecosystems. During inundation, individuals exploit expanded foraging grounds, capitalizing on increased resource availability. Conversely, during dry seasons, *H. niloticus* demonstrates resilience by retreating to permanent water bodies and relying on detrital reserves. The ecological niche of *Heterotis niloticus* is delineated by its dual reliance on benthic and pelagic resources, enabling coexistence with sympatric species through niche differentiation. Its preference for slow-moving, oxygen-deficient waters is supported by its capacity for obligate aerial respiration, conferring a competitive advantage in hypoxic environments (FAO/UN, 1970). This physiological adaptation further allows *H. niloticus* to thrive in anthropogenically impacted habitats, including those subject to eutrophication. As a species of significant ecological and economic value, *H. niloticus* is integral to artisanal fisheries and aquaculture systems across Africa. However, overfishing, habitat degradation, and hydrological modifications threaten its populations. Understanding its ecological role underscores the importance of sustainable management practices, particularly in maintaining floodplain connectivity and minimizing sediment pollution. Moreover, its detritivorous feeding strategy highlights its potential as an ecological engineer, fostering ecosystem resilience in degraded aquatic habitats.

H. niloticus exemplifies a species well-adapted to dynamic and challenging environments, with feeding and ecological strategies that underscore its pivotal role in freshwater ecosystem functioning. Further research into its trophic ecology, particularly in relation to ecosystem-level processes, will enhance conservation and management efforts (Bennett, 1971). Fish diseases are the major setbacks confronting the fish culturists. In Nigeria, the demands for fish exceed supply and the proportion of annual protein in the diet is generally low (Akinsanya *et al*., 2016). Parasitic diseases of fish are of particular importance in the tropics. Parasites usually exist in equilibrium with their hosts as a survival strategy (Dautremepuits *et al.,* 2002; Emmanuel, 2010). However, in instances where hosts are overpopulated such as in fish farms, parasitic diseases can increase very rapidly causing high mortality. Although this is usually not the case in the wild natural aquatic environments, it occurs when the environment is distorted by human activity and interference especially with populations that alter the natural distribution of their parasite communities (Imam *et al*., 2010).

The study was thusaimed at studying the facors that aid the susceptibility of two bentho-pelagic fishes (*G. niloticus* and *H. niloticus*). It seeks to delineate the relationship between the physicochemical properties of Lekki lagoon and the comparative susceptibilities of both fish species

MATERIALS AND METHODS

1-Study Area:

Lekki lagoon lies between longitude N 06° 33.710' E 004° 03 .710' and latitudes N 06°

31.893° E 003° 31.912° (Figure 1). The lagoon is sandwiched between two other lagoons, the Lekki Lagoon (freshwater) in the east and Lagos Lagoon (brackish water) in the west. It has a surface area of 243 km2 and a maximum depth of 6m (Oluwale, 2019). The lagoon is fairly shallow and is mainly plied by small barges and boats. It receives discharges from the Ogun and Osun rivers, located upstream of the lagoon, and empties into the Atlantic Ocean via Lagos Harbour, a main channel through the heart of the city, 0.5 km to 1 km wide and 10 km long (Akinsanya et al., 2019). The region consists of two major seasons, the rainy season between May and November, and the dry season occurring between December and April. The bank of the lagoon is made up of grasses and secondary rainforests, which are representative of riparian vegetation. The study area is a rural setting with most of the population concentrated along the bank of the lagoon and has extensive activities such as agriculture, sand mining, artisanal fisheries, and transportation of goods and people using Motorized boats, occurring there. A major attribute of the lagoon is the immense prevalence of floating vegetation of water hyacinth, an occurrence that has been connected to pollution (Nwankwo and Onitiri, 1992). Wastes from various sources are dumped into the lagoon, ranging from faecal waste, to contaminants from human activities and spent lubricant from motorized boats as a result of most of the population being situated along the lagoon's bank. Prominent makeup of the surrounding vegetation of the lagoon are shrubs and raphiapal. The most dominant are Raphiasudanica and oil palms, Elaeisguineensis. The lagoon boundaries are marked by floating grasses whereas the surrounding by coconut palm; Cocus nucifera vegetation. The species diversity of this lagoon, covers a broad range of fish species including the schilbe catfish (Schilbe mystus), the sole (Cynoglossus sengalensis), Tilapia zilli, Mormyrus rume, Clarias gariepinus, Synodontis clarias, Heterotis niloticus, Chrysichthys nigrodigitatus, Gymnarchus niloticus, Hemichromis fasciatus, Monodactylus sabae (elephant fish), Parachanna obscura, Tilapia galilae etc.

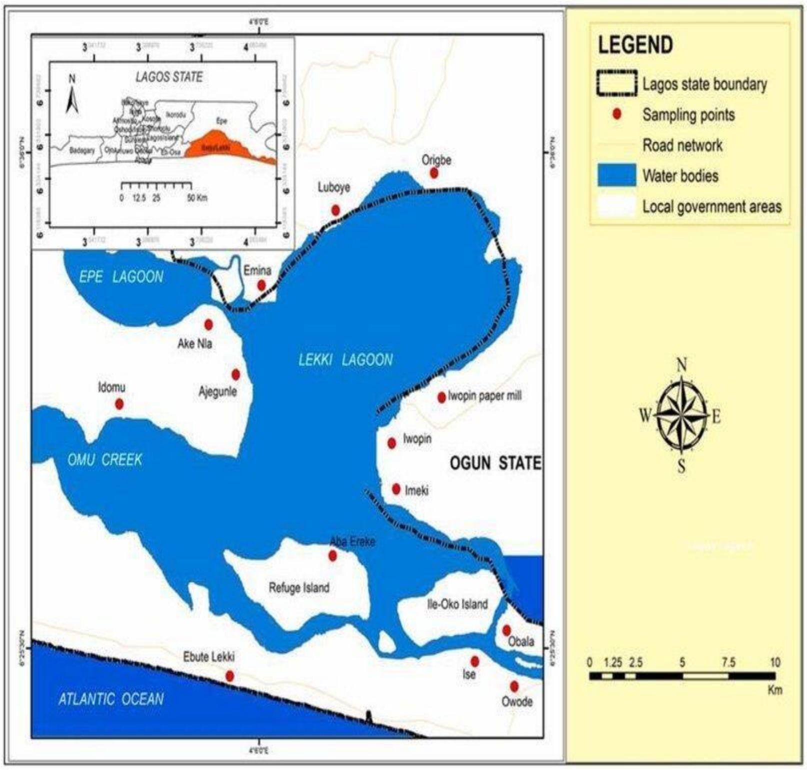

Fig. 1: Map of the Epe Lagoon, Lekki (Akinsanya *et al.,* 2021).

2-Sample Collection and Analysis:

The fish samples were identified applying FAO fish guide (Schneider, 1990). The collected Samples were labeled and carefully arranged on a table, body weight was measured with a digital electronic weighing balance (Camry EK5055) and recorded to the nearest gram. The standard length (SL) of the specimen was measured from the tip of the snout to the posterior caudal peduncle and total length was measured from the tip of snout to the end of the caudal fin making use of a measuring tape and recorded to the nearest centimeter. The sexes of the specimen were determined on the basis of the presence of milt for males and eggs in female species. Each labeled fish sample was slit open from the posterior end through the stomach. During this process, maximum precaution was taken to protect tissues or organs from possible damage during dissection. Subsequently, the liver and gastrointestinal tract were carefully removed and placed in Petri dishes filled with normal saline to provide a suitable condition for the organs.

The method described by Akinsanya et al. (2007) was adopted for the examination of gastrointestinal parasites in the fish sample. The intestines were carefully cut open lengthwise to aid the appearance of the parasite. The presence of the helminth parasite was indicated by the characteristic wriggling of the parasite as it emerged from the intestine in normal saline. The parasites were sized enough to be seen with the naked eye, so they could be easily seen during emergence. Parasites recovered were recorded and kept in a saline solution. Prevalence, mean intensity, and abundance were calculated using the formulae;

$$\text{Prevalence (\%)} = \frac{\text{Number of infected fish x 100}}{\text{Total number of fish examined}}$$

$$\text{Mean Intensity} = \frac{\text{Number of Parasites}}{\text{Number of infected parasites}}$$

3-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

The surface water temperatures at Stations 1 (28.60 ºC), 2 (28.51 ºC), and 3 (28.51 ºC) rose to 28.66 ºC, 28.74 ºC, and 28.75 ºC at 3.2m depth, and dropped to 27.36 ºC, 27.41 ºC, and 27.40 ºC respectively (Table 1). The surface pH increased from the 6.60, 6.69, and 6.71 at Stations 1, 2, and 3 respectively to 6.67, 6.74, and 6.71 at depth 3.2 m. It further increased to 6.67, 6.74, and 6.71at depth 6.4 m. The DO in the surface water decreased from 3.98 mg/L, 3.86 mg/L, 3.96 mg/L to 3.24 mg/L, 3.86 mg/L, and 3.09 mg/L at depth 3.2 m, while it dropped furher to 2.59 mg/L, 2.77 mg/L, and 2.39 mg/L at Stations 1, 2, and 3 respectively.

Among *G. niloticus* 3 males only were infected, amounting to a mean intensity of 2.33 while females were not captured hence no record was computed (Table 2). *H. niloticus* on the other hand exhibited a higher level of infection, 28 infected males and 12 females were infected, amounting to mean intensities of 16.9 and 18 respectively.

Among *G. niloticus* no member of length cohort 25-45 cm was infected while cohort 67-87 cm had 3 infetected fish with parasite mean intensity 2.33 (Table 3). *H. niloticus* on the other hand exhibited a higher level of infection in all length cohorts. Cohort 30-50 cm had 8 infected individuals with mean parasite intensity of 11. The highest infection occurred among length cohort 50-70 cm with mean parasite intensity of 20.2, followed by 70-90 cm which had 14 infected individuals, amounting to mean intensity of 14.4.

Table 1: Physicochemical Parameters of water at different depths

Depth (M)	Parameters	Station 1	Station 2	Station 3
SURFACE	Temp. (ºC)	28.60	28.51	28.51
	pH	6.60	6.69	6.71
	Cond. (ms/cm)	0.666	0.667	0.666
	Turb. (NTU)	12.2	11.6	11.6
	DO (mg/L)	3.98	3.86	3.96
	TDS (g/L)	0.427	0.427	0.426
	Salinity (ppt)	0.3	0.3	0.3
3.2	Temp. (ºC)	28.66	28.74	28.75
	pH	6.67	6.74	6.71
	Cond. (ms/cm)	0.666	0.665	0.667
	Turb. (NTU)	10.8	11.9	12.8
	DO (mg/L)	3.24	3.86	3.09
	TDS (g/L)	0.426	0.426	0.427
	Salinity (Ppt)	0.3	0.3	0.3
6.4	Temp. (ºC)	27.36	27.41	27.40
	pH	7.93	7.75	7.63
	Cond. (ms/cm)	0.153	0.153	0.153
	Turb. (NTU)	3.1	2.8	2.8
	DO (mg/L)	2.59	2.77	2.39
	TDS (g/L)	0.099	0.100	0.099
	Salinity (ppt)	0.1	0.1	0.1

Table 2: Comparative prevalence of Raphidascaroides infection in relation to sex of *G. niloticus* and *Tenuisentis niloticus* in *H. niloticus* relative to sex.

Sex	Fish Examined	Infected	Parasite Prevalence	Num of Parasites	Mean Intensity
G. niloticus					
Male	21	3	14.29	7	2.33
Female	0.0	0.0	0.0	0.0	0.0
H. niloticus					
Male	30	28	93.3	473	16.9
Female	15	12	80	216	18

Table 3: Comparative prevalence of *Raphidascaroides sp.* in relation to sex of *G. niloticus* and *Tenuisentis niloticus* in *H. niloticus* relative to standard length (SL).

SL (cm)	Fish Examined	Infected	Parasite Prevalence	Num of Parasites	Mean Intensity
G. niloticus					
25 - 45	18	0.0	0.0	0.0	
45 - 66	0.0	0.0	0.0	0.0	0.0
67 - 87	3	3	100	7	2.33
H. niloticus					
30-50	8	8	100	88	11
50-70	23	21	91.3	425	20.2
70-90	14	12	85.7	173	14.4

DISCUSSION

The observed surface water temperatures across Stations 1, 2, and 3 were relatively uniform, suggesting minimal spatial variation in thermal energy distribution at the surface. However, temperature gradients with depth, rising marginally at 3.2 m before dropping significantly at 6.4 m, indicate the onset of weak thermal stratification (Calamita *et al.,* 2021). Accirding to (Miller *et al.* (2020), this pattern is consistent with diurnal heating and subsequent cooling at deeper layers, driven by limited mixing in the water column. Such stratification likely affects dissolved oxygen (DO) dynamics by impeding vertical oxygen exchange.

The pH values, increasing slightly with depth, reflect a progressive shift from more acidic conditions at the surface to near-neutral conditions at depth. This trend may be attributed to reduced photosynthetic activity and diminished CO_2 uptake by phytoplankton in deeper waters, leading to less carbonic acid dissociation. Furthermore, the buffering capacity of the lagoon's sediments, potentially releasing base ions like bicarbonates, could contribute to the observed depth-dependent pH elevation (Chang *et al.,* 2022).

The significant decline in DO concentration with increasing depth highlights stratification-driven hypoxia, exacerbated by organic matter decomposition in benthic zones. Surface DO levels reflect oxygenation through atmospheric exchange and photosynthesis (Leach *et al.,* 2023). However, as depth increases, oxygen depletion becomes prominent due to limited diffusion and higher biological oxygen demand (BOD) from microbial decomposition processes. Notably, Station 3 exhibited the lowest DO values, possibly reflecting localized factors such as increased organic load or reduced mixing due to geomorphological features (Koparan *et al.,* 2020).

The parasitic infection profiles of *Gymnarchus niloticus* and *Heterotis niloticus* reveal stark contrasts in susceptibility and intensity. Among *G. niloticus*, only three infected individuals were recorded, all within the larger size cohort (67–87 cm). The absence of infection in smaller cohorts (25–45 cm) suggests size-selective predation or niche differences limiting exposure to parasitic intermediate hosts. Additionally, the low mean intensity (2.33) points to a generally low parasitic load, potentially reflecting the species' piscivorous diet, which limits ingestion of parasite-laden benthic invertebrates.

Conversely, *H. niloticus* exhibited widespread and higher levels of infection across all length cohorts, indicative of its bentho-pelagic feeding strategy and omnivorous diet that increases exposure to parasitic stages. Notably, the highest mean intensities were recorded in the 50–70 cm (20.2) and 70–90 cm (14.4) cohorts, suggesting a cumulative parasitic burden with age and size. This size-related parasitic intensity reflects prolonged exposure to infective stages and potentially reduced immunological efficiency in older individuals. The comparable mean intensities between infected males (16.9) and females (18) suggest no significant sex-based difference in parasitic susceptibility, aligning with their similar ecological behaviors (Wang *et al.,* 2023).

The differential parasitic infection patterns between *G. niloticus* and *H. niloticus* underscore the influence of feeding ecology and habitat use on parasite-host dynamics. The higher infection rates in *H. niloticus* highlight its ecological role as a key host in the transmission of trophically transmitted parasites (Lehun *et al.,* 2023). This burden may affect the species' growth, fecundity, and overall fitness, with potential implications for its population dynamics and fisheries yield.

The stratified DO levels, coupled with parasitic stress, further compound ecological risks for these species, particularly in deeper hypoxic zones. Effective management should prioritize mitigating organic pollution to reduce BOD and improve oxygen availability (Mrugała *et al.,* 2023). Furthermore, regular parasitological monitoring and studies on intermediate host distribution are essential for understanding transmission pathways and developing targeted control strategies.

In summary, the results elucidate complex interactions between abiotic factors, feeding ecology, and parasitism, emphasizing the need for integrated ecosystem management to sustain the health and productivity (Gobbin *et al.,* 2021) of Lekki Lagoon's aquatic biodiversity.

This study highlights significant interactions between abiotic factors and parasitic dynamics in *Gymnarchus niloticus* and *Heterotis niloticus* within Lekki Lagoon, providing critical insights into the ecological health and stressors affecting these species (El-Seify *et al.,* 2021). The observed thermal stratification and declining dissolved oxygen levels with depth underscore the importance of maintaining hydrological and ecological balance in the lagoon, as hypoxia can exacerbate biological stress, including parasitic infections.

The stark differences in parasitic burdens between the two species reflect their contrasting ecological niches, with *H. niloticus* experiencing higher infections due to its bentho-pelagic and omnivorous feeding habits. This highlights the ecological vulnerability of species occupying broader trophic niches (Venter *et al.,* 2022). In contrast, the piscivorous *G. niloticus* demonstrated lower parasitic prevalence, possibly due to reduced exposure to parasite-laden intermediate hosts. These findings underscore the complex interplay of diet, habitat use, and parasitism in shaping the health and fitness of aquatic organisms.

To ensure the sustainability of these species and the broader lagoon ecosystem, it is crucial to address key stressors, including organic pollution and habitat degradation (Jerônimo *et al.,* 2022). Conservation strategies should incorporate regular monitoring of water quality parameters and parasitic infections, as well as efforts to enhance oxygenation and reduce anthropogenic impacts. Understanding these dynamics not only informs species-specific management but also provides a framework for safeguarding the ecological integrity of Lekki 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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