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DISTRIBUTION OF SNAIL INTERMEDIATE HOST OF SCHISTOSOMIASIS IN RIVER NIGER WATERS, LOKOJA

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Abstract
This study aimed to investigate the distribution, abundance, and infection status of these snail intermediate hosts in Lokoja, Kogi State, Nigeria. Lokoja is of particular interest due to its unique location at the confluence of the Niger and Benue rivers, which creates ideal habitats for these snail vectors. A six-month longitudinal survey (May to Oct. 2022) was conducted across three identified hotspots in Lokoja: Kpata, Adankolo, and Ganaja settlements. A total of 1500 snail specimens were sampled using an improvised scoop net, identified based on Danish Bilharzia Laboratory, and examined for cercariae emergence using artificial illumination (60 watts bulb) for 4 to 6 hours. The results revealed the consistent presence of *Bulinus globosus* (36%) and *Biomphalaria pfeifferi* (30%) across all study locations, Snails belonging to the genera *Bulinus* and *Biomphalaria* were identified across the various study sites. These snails were confirmed to be active intermediate hosts for *Schistosoma haematobium* and *Schistosoma mansoni*, respectively. This identification was established following the emergence and identification of patent schistosome cercariae during shedding assays. Significant spatial heterogeneity was observed, with Ganaja presenting a distinct ecological profile characterized by a higher prevalence of *Melanoides tuberculata* (37%). The result revealed significant differences ($p<0.05$). Snail abundance also demonstrated clear seasonal variations: *Biomphalaria pfeifferi* was most abundant during the dry season (35.0%), while *Bulinus globosus* dominated in the rainy season (41.0%). Overall, snail populations peaked in June–July before sharply declining toward October. Importantly, cercariae emergence was confirmed; *Bulinus globosus* showed the highest infestation rate (9.91%), followed by *Biomphalaria pfeifferi* (5.17%), with *Melanoides tuberculata* exhibiting no infestation. These findings are critical for understanding the epidemiology and transmission dynamics of schistosomiasis in this endemic area, providing essential baseline data for developing targeted and effective control strategies.

Keywords: Distribution, Abundance, *Bulinus globosus*, *Biomphalaria pfeifferi* and Schistosomiasis

Introduction

Schistosomiasis, commonly known as bilharzia, is a significant parasitic disease caused by trematode worms of the genus *Schistosoma* (Umar *et al*., 2023). It remains a major neglected tropical disease (NTD), globally affecting over 120 million people, primarily in sub-Saharan Africa. Nigeria, as Africa's most populous country, carries a substantial burden, with an estimated report that at least 253.7 million people required preventive treatment in 2024 due to close contact with contaminated water bodies (Kokaliaris *et al*., 2022; WHO, 2022; Ekpo *et al*., 2012; Barkia *et al*., 2014).

The transmission of schistosomiasis critically depends on the distribution of freshwater snails serving as intermediate hosts. Specifically, *Bulinus globosus* which is the primary intermediate host for *Schistosoma haematobium*, responsible for urogenital schistosomiasis, while *Biomphalaria pfeifferi* transmits *Schistosoma mansoni*, causing intestinal schistosomiasis (Manyangadze *et al*., 2021). These snails release cercariae into water, which then infect humans upon contact. The spread of infection is driven primarily by human contact with cercariae-infested water bodies, due to inadequate sanitation, urbanization, and agricultural/fishing activities near water bodies, creating conducive habitats for snail proliferation (Oladejo *et al*., 2021; Akinwale *et al*., 2018; Stothard *et al*., 2013).

Lokoja, the capital of Kogi State, Nigeria, is of particular interest due to its unique geographical position at the confluence of the Niger and Benue rivers. This location provides ideal habitats for these essential snail intermediate hosts (Umar *et al*., 2023). Despite their critical role in disease transmission, there is often limited information regarding the epidemiology, biology, and ecology of these snail hosts and their parasite interactions in many endemic areas (Sow *et al*., 2021).

Therefore, this study investigated the distribution, abundance, and infection status of snail intermediate hosts of schistosomes in Lokoja, Nigeria, focusing on the ecological factors influencing their presence and density. Understanding these dynamics is essential for elucidating the local epidemiology of schistosomiasis and designing targeted intervention strategies to interrupt disease transmission.

Materials and Methods

Study Area

Lokoja, the capital of Kogi State in Nigeria, is uniquely positioned at the confluence of the Niger and Benue rivers, earning it the nickname “Confluence City.” having Latitude: 7° 48'

8.352" N and Longitude: 6° 44' 0.0348" E (Figure 1) (Patrick and Umar, 2019). While fishing and farming are primary occupations, particularly along the Niger River Basin, increasing human settlement has led to significant environmental health challenges. Many residents now inhabit slum areas lacking basic sanitary facilities, with open defecation being a common practice. These conditions create predisposing factors for parasitic infections and the distribution of snail intermediate host, highlighting a critical public health concern in the study area (Umar *et al*., 2023).

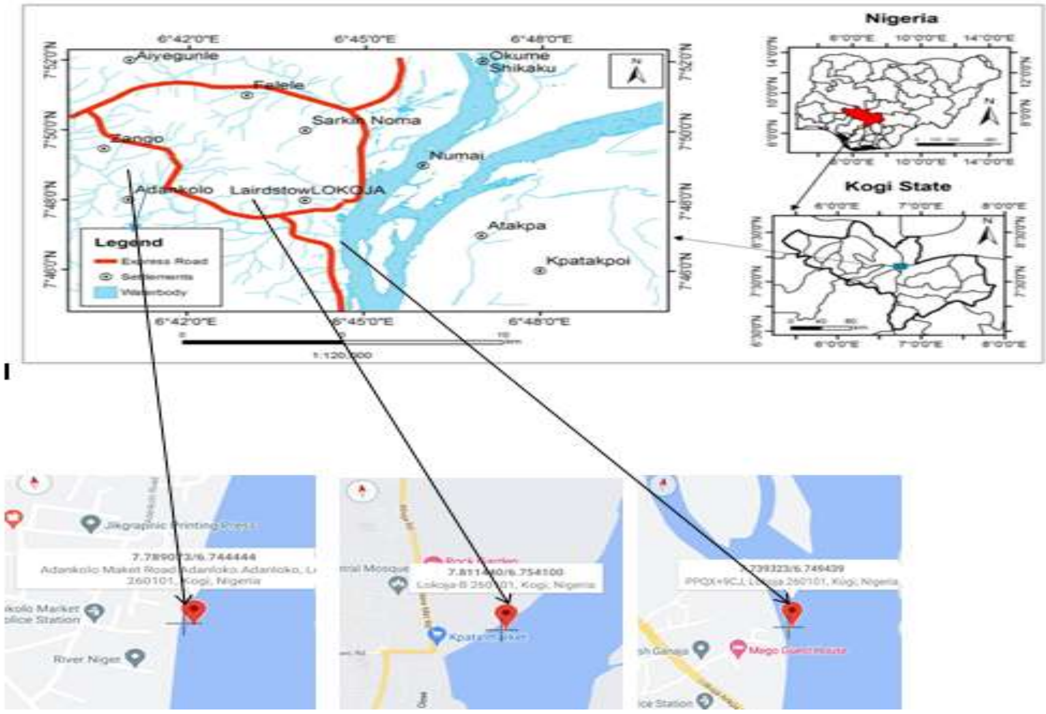

Figure 1: Map of Study Area

Source: Adapted from Umar *et al.* (2023)

Study design

The study employed a longitudinal survey for six months to investigate snail populations, specifically focusing on hotspots like Ganaja, Adankolo, and Kpata, which were identified in a pilot study. The study specifically aimed to examine the presence of cercariae within these snail intermediate hosts across rainy season (May, June and July) and early dry season (August, September and October) in 2023. Freshwater snail vectors were collected and examined throughout these varying climatic conditions, the study sought to explore potential seasonal differences in the prevalence of these parasitic larval forms.

Sample Size Determination

Sample size was determined using Cochran's formula:

$$\frac{Z^{2} \times p \times (1-p)}{d^{2}}$$

Where:

n = the target sample size.

Z = the standard normal deviate corresponding to a 95% confidence interval (typically 1.96).

p = Estimated proportion of snail infection/infestation in the study area (P = 0.50 for maximum sample size estimation).

d = When requiring a narrow margin of error of d = 0.0253 (2.53%) to detect low-density cercariae shedding

n= $\frac{(1.96)^{2} \times 0.50 \times (1-0.50)}{(0.0253)^{2}}$

n= 3.8416 X0.025/0.00064009

n= 1,500.41 ≈ 1,500

Snail Collection and Identification

A total of 1,500 snail vectors were collected using an improvised scoop net at three distinct points, spaced 100 meters apart, during each field survey. The collected snails were placed into plastic containers containing freshwater, sticks, and water hyacinth. It was transported to the Biology laboratory. All collections were conducted early in the morning between 7 am and 9 am, and the snails were cleaned within two to three hours; first, the collected snails were introduced into a plastic container, gently rinsed with tap water, and all the mud in the plastic container was poured through a plastic mesh scoop strainer sieve. The procedure was repeated three to four times. Finally, grasses, plant leaves, algae, and debris were removed with fine-tipped forceps. The snails were then identified and classified by species based on the criteria of the Field Guide to African Freshwater Snails of the Danish Bilharziasis Laboratory as described by Ismail *et al*. (2022) and the identification keys by WHO (1980).

Cercariae shedding

Infections in the snails were examined from the day of collection for a 1-month period using the artificial emergence technique. Clean snails were separated in groups. Each group of 20 snails was transferred to a small beaker containing 200 ml of dechlorinated tap water. They were placed under artificial illumination of 60 watts bulb for an interval of 4 to 6 hours starting at 9:00 am for stimulation. The emergence of cercariae was checked at regular short intervals of one hour since emerged cercariae might encyst onto external substrates or sometimes re-enter the snails quickly. Any beaker confirmed to contain emerged cercariae; the snails in that beaker were subsequently transferred into small glass bottles for individual screening. This procedure was repeated by placing each snail into separate bottles individually to check their infection status. The number of snails shedding cercariae was recorded, and those shedding no cercariae were re-examined on a weekly basis using the same procedure for a 1-month period. Snails observed to shed any other trematodes cercariae were placed in separate plastic bowls containing 5 litres of dechlorinated water and kept in the dark at room temperature. Immediately after cercariae shedding the snails that shed the same type of cercariae were transferred into a petri dish containing 10 ml of dechlorinated water, live cercariae shed by each snail species in a petri dish were characterized by a distinct split or forked tail and swimming behaviour, often alternating between active swimming using the forked tail and resting positions suspended in the water column (Usman *et al*., 2023). This was transferred in water solution onto a microscopic slide using a Pasteur's pipette, covered with a cover slip and viewed directly under the microscope using X10 and X40 objective lenses as described by Anorue *et al*. (2021).

Statistical Analysis

Collected raw data were entered into Excel 2010 spread sheet and descriptive statistics were used to summarize the data. One-way ANOVA was used to compare cercariae emergence and the distribution of snail intermediate host across the three study sites. Post- hoc test was used to determine the least significant differences.

Results

The Distribution and Abundance of Freshwater Snails in Relation to Locations

The result of Table 1 revealed that *Bulinus globosus* recorded a higher relative abundance (36%) and *Biomphalaria pfeifferi* (30%), this was followed by *Melanoides tuberculata* which exhibited variable dominance (29-37%), notably, Kpata and Adankolo showed similar species composition patterns, whereas Ganaja presented a distinct ecological profile with higher *M. tuberculata* prevalence. The least relative abundance of intermediate hosts was *Galba truncatula* which recorded 4-5%. The result revealed significant differences (P<0.05).

Table 1: Distribution and Abundance of Freshwater Snails in Relation to Locations

Location	Snail species	Total number	Relative Abundance (%)
Kpata	*Bulinus globosus*	180	36.0
	Biomphalaria pfeifferi	150	30.0
	Melanoides tuberculata	150	30.0
	Galba truncatula	20	4.0
	Total	500	100
Adankolo	*Bulinus globosus*	180	36.0
	Biomphalaria pfeifferi	150	30.0
	Melanoides tuberculata	145	29.0
	Galba truncatula	25	5.0
	Total	500	100
Ganaja	*Bulinus globosus*	145	29.0
	Biomphalaria pfeifferi	150	30.0
	Melanoides tuberculata	185	37.0
	Galba truncatula	20	4.0
	Total	500	100

*P< 0.05(0.0009), F. Cal = 13.514, F. Crit= 4.196

Distribution and Abundance of Freshwater Snails in Seasons

Table 2 shows the result during the dry season survey, a total of 1,000 freshwater snails were collected and classified into four species. The most abundant species was *Biomphalaria pfeifferi*, accounting for 35.0% (350) of the total snail population. *Bulinus globosus* and *Melanoides tuberculata* were equally prevalent, each representing 30.0% (300) of the population. In contrast, *Galba truncatula* was the least abundant species, making up only 5.0% (50) of the total snails recorded. The results showed significant differences(P<0.05).

During the rainy season, a total of 500 freshwater snails comprising four distinct species were collected (Table 3). Among the identified species, *Bulinus globosus* was the most dominant, constituting 41.0% of the total population. This was followed by *Biomphalaria pfeifferi*, which accounted for 36.0%, and *Melanoides tuberculata*, which represented 16.6%. *Galba truncatula* was the least abundant species, accounting for 6.4%. Furthermore, comparative seasonal analysis indicated that the variation in total snail abundance between the rainy season and the dry season was statistically significant ($p < 0.05$).

Table 2: Distribution and Abundance of Freshwater Snails in Dry Season

Snail Species	Total Number	Relative Abundance (%)
Biomphalaria pfeifferi	350	35.0
Bulinus globosus	300	30.0
Galba truncatula	50	5.0
Melanoides tuberculata	300	30.0
Total	**1,000**	**100**

* P<0.05(0.001), F. Cal: 64.62, F. Crit: 4.07

Table 3: Distribution and Abundance of Freshwater Snails in Rainy Season

Snail Species	Total Number	Relative Abundance (%)
Bulinus globosus	205	41.0
Biomphalaria pfeifferi	180	36.0
Melanoides tuberculate	83	16.6
Galba truncatula	32	6.4
Total	**500**	**100**

*P<0.05(0.001), F. Cal: 7.815, F. Crit: 1.587

Monthly Abundance of Freshwater Snails

Table 4 shows the monthly abundance of four freshwater snail species *Bulinus globosus*, *Biomphalaria pfeifferi*, *Melanoides tuberculata*, and *Galba truncatula* across three ecological sites (Kpata, Adankolo, and Ganaja) from May to October, 2023. The results revealed distinct patterns in species dominance; *Bulinus globosus* and *Biomphalaria pfeifferi* were the most prevalent species, which recorded 36% and 30% of the population in Kpata and Adankolo, respectively. In Ganaja, however, *Melanoides tuberculata* was the dominant species (37%), followed closely by *Biomphalaria pfeifferi* (30%). *Galba truncatula* was the least abundant across all sites (4–5%), suggesting limited ecological suitability or competitive exclusion by other species. A clear seasonal trend emerged, with snail populations peaking in June–July before declining sharply toward October**.** In Kpata, *Bulinus globosus* numbers rose from 25 (May) to 50 (July), then fell to 5 in the month of October. In Adankolo, the total snail counts were highest in July (124), and then the least was 26 by October. In Ganaja, *Melanoides tuberculata* peaked in June (45), while other species declined steadily in July and August. According to study sites; Kpata and Adankolo exhibited similar dominance by *Bulinus globosus* (36%), but Adankolo had slightly higher counts of *Galba truncatula* (5% and 4%). Ganaja recorded the dominance of *Melanoides tuberculata* (37%) and lower abundance of *Bulinus globosus* with significant differences (P<0.05).

Table 4: Monthly Distribution of Freshwater Snails in the Study Area

Location	Snail Species	May	June	July	August	Sept	Oct	Total	R. A (%)
Kpata	*Bulinus globosus*	25	35	50	45	20	5	180	36.0
	Biomphalaria pferifferi	20	30	40	35	15	10	150	30.0
	Melanoides tuberculate	35	40	25	25	20	5	150	30.0
	Galba truncatula	3	5	6	3	2	1	20	4.0
	Monthly Total	**83**	**110**	**121**	**108**	**57**	**21**	**500**	**100**
Adankolo	*Bulinus globosus*	30	40	50	35	15	10	180	36.0
	Biomphalaria pferifferi	25	35	40	30	10	10	150	30.0
	Melanoides tuberculate	30	35	30	25	20	5	145	29.0
	Galba truncatula	4	7	4	6	3	1	25	5.0
	Monthly Total	**89**	**117**	**124**	**96**	**48**	**26**	**500**	**100**
Ganaja	*Bulinus globosus*	20	30	45	35	10	5	145	29.0
	Biomphalaria pferifferi	25	35	40	30	15	5	150	30.0
	Melanoides tuberculate	40	45	30	35	25	10	185	37.0
	Galba truncatula	3	5	6	3	2	1	20	4.0
	Monthly Total	**88**	**115**	**121**	**103**	**52**	**21**	**500**	**100**

*P<0.05(0.0059), F.crit: 2.092, F.cal: 12.778, R.A=Relative Abundance.

Cercariae Emergence in Freshwater Snail Species

The results presented in Table 5 revealed the prevalence of cercariae emergence across four freshwater snail species. Out of 454 *Bulinus globosus* snails examined, 45 (9.91%) were infected. *Biomphalaria pfeifferi* had 22 infected snails out of 425 (5.17%), while *Melanoides tuberculata* showed no infections (0.0%) out of 375 examined. *Galba truncatula* had 15 infections (6.0%) out of 247 snails. The results showed significant differences ($P < 0.05$) across the infected snail species. The freshwater snails *Bulinus globosus* and *Biomphalaria pfeifferi* were observed to harbor the infective stages (cercariae) of the parasite; schistosoma under artificial stimulation using 60 watts bulb (Plate i).

Table 5: Prevalence of Cercariae Emergence in Freshwater Snail Species

Snail Species	No Examined	No Infected	Percentage Infected (%)
Bulinus globossus	454	45	9.91
Biomphalaria pfeifferi	425	22	5.17
Melanoides tuberculata	375	0	0.0
Galba truncatula	247	15	6.0
Total	**1500**	**82**	**5.47**

*P<0.05(0.012), F. Cal: 6.459, F. Crit: 3.885

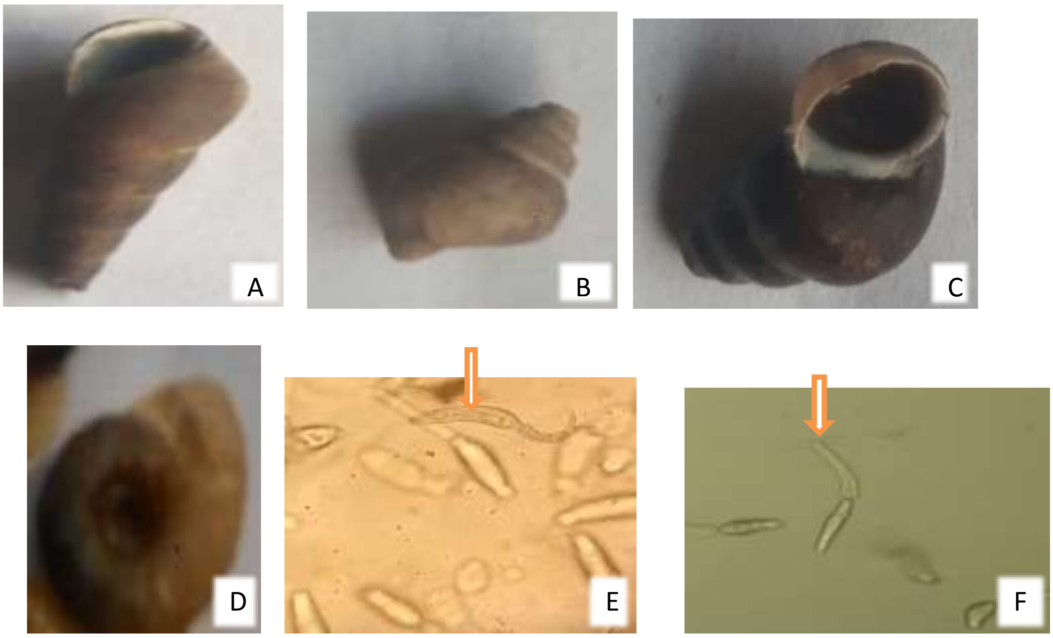

Plate i: Photomicrograph of Snail Intermediate Host and Cercariae Encountered
A=*Melanoides tuberculata*. B= *Galba truncatula*. C=*Bulinus globossus.*
D=*Biomphalaria pferifferi.* E=*S.haematobium* cercariae. F= *S. mansoni* cercariae.

Discussions

Freshwater snails are extremely important in spreading a disease called schistosomiasis, which affects millions of people around the world. To effectively control and prevent this disease, it's critical to understand where these snails are found (distribution) and how many of them exist (abundance), particularly the specific types of snails that act as intermediate hosts for the parasite. The result of this study revealed that *Bulinus globosus* (36%) and *Biomphalaria pfeifferi* (30%) were consistently present across all study locations, which was in-line with the reports of. These species are known intermediate hosts for *Schistosoma haematobium* and *S. mansoni*, respectively, and are responsible for urinary and intestinal schistosomiasis (Kuo *et al*. 2023; Sibula *et al*., 2024; Moser *et al*., 2014; Barkia *et al*. 2014). The consistent presence and confirmed infection of these snail vectors suggest that conditions in the study area are favourable for supporting active schistosomiasis transmission. This finding aligns with other research demonstrating the importance of *Bulinus* and *Biomphalaria* snails in schistosomiasis transmission in Africa (Mudavanhu *et al*., 2024; Sacolo-Gwebu *et al*., 2019). *Melanoides tuberculata* exhibited variable dominance (29-37%) across the study locations. Although, *M. tuberculata* is not a known vector for schistosomiasis, its high prevalence can still impact the local ecology and potentially influence the transmission dynamics of the disease this is in-line with the reports of Krishnan *et al*. (2024). The ability of *Melanoides tuberculata* to compete with *Bulinus globosus*, *Biomphalaria pfeifferi*, and *Lymnaea natalensis* carries significant ecological and public health implications. Because *M. tuberculata* does not serve as a host for human schistosomes or *Fasciola* species, its competitive dominance over these vector species can lead to population suppression (competitive exclusion). In the context of this study, the presence and expansion of *M. tuberculata* may act as a natural biological control mechanism, thereby reducing the local density of intermediate hosts and lowering the risk of schistosomiasis and fascioliasis transmission in the study area. The study also found that Kpata and Adankolo showed similar species composition patterns, whereas Ganaja presented a distinct ecological profile with higher *M. tuberculata* prevalence. This spatial heterogeneity in snail species composition underscores the importance of considering local environmental factors in schistosomiasis control efforts. *Galba truncatula* recorded the least relative abundance of snail vectors at 4-5%, which is in line with the findings of Mereta *et al*. (2019) whose reports showed that this may reflect the limited suitability of the study area for this particular snail species. The compact shell and amphibious nature of *Galba truncatula* restrict its primary habitat to mud margins, temporary wetlands, and damp soil edges rather than open, deeper water bodies. This microhabitat specificity likely explains its low relative abundance in this study, as the sampling sites were primarily characterized by the nature of the aquatic environments, which favour's fully aquatic vectors such as *Bulinus globosus* and *Biomphalaria pfeifferi*.

The presence and abundance of specific snail species can also vary based on the type of water body and seasons. Thus, the study recorded that during the dry season, *Biomphalaria pfeifferi* was the most abundant snail species (35.0%), followed by *Bulinus globosus* and *Melanoides tuberculata* (30.0% each), and *Galba truncatula* (5.0%). In contrast, during the rainy season, *Bulinus globosus* became the most dominant species (41.0%), followed by *Biomphalaria pfeifferi* (36.0%), *Melanoides tuberculata* (16.6%), and *Galba truncatula* (6.4%). These findings align with other research, which indicates seasonal variations in freshwater snail populations and their role in schistosomiasis transmission (Li *et al*., 2021; Ahmad *et al*., 2021; Ntonifor & Ajayi, 2007). Several studies highlighted the importance of seasonal variations in assessment of snail distribution for effective disease control (Ahmad *et al*., 2021; Ntonifor & Ajayi, 2007; Nwoko *et al*., 2023). *Biomphalaria pfeifferi* and *Bulinus globosus* are intermediate hosts for *Schistosoma* species (Li *et al*., 2021) (Ntonifor & Ajayi, 2007). The observed shift in dominance from *Biomphalaria pfeifferi* in the dry season to *Bulinus globosus* in the rainy season could be attributed to differences in their ecological adaptations, habitat preferences, or breeding cycles (Li *et al*., 2021; Ntonifor & Ajayi, 2007). Other studies in KwaZulu-Natal, South Africa, have also explored the spatial and seasonal distribution of these snail vectors, emphasizing the need for micro-geographical scale investigations (Ntonifor & Ajayi, 2007; Nwoko *et al*., 2023).

The seasonal trends and statistical variations in snail populations in this study reveal fluctuations driven primarily by seasonal changes in rainfall, water temperature, flow velocity, and the availability of aquatic vegetation. The study found significant differences ($P<0.05$) between the sites. Previous studies have highlighted the influence of various ecological and environmental factors on freshwater snail distribution and abundance (Mereta *et al*., 2019). Several studies have shown that freshwater snail species exhibit distinct distribution patterns influenced by environmental factors and interspecies competition (Mudavanhu *et al*., 2024; Barkia *et al*., 2014). Species distribution and the dominance of specific snail species in different locations, as observed in the study, aligns with findings from another research (Hussein *et al*., 2011). A similar study in Nigeria reported that *Bulinus globosus* and *Biomphalaria pfeifferi* were dominant, consistent with the findings from Kpata and Adankolo (Oladejo *et al*., 2021). In contrast, the dominance of *Melanoides tuberculata* in Ganaja could be attributed to specific local conditions favoring this species, such as nutrient levels or substrate type (McGarrigle & Hunt, 2023; Wickramasingha & Weerasinghe, 2024). The low abundance of *Galba truncatula* across all sites may indicate that the ecological conditions are not optimal for this species compared to others, possibly due to competition or habitat suitability (Ardalan *et al*., 2023; Sibula *et al*., 2024). The observed peak in snail populations during June–July and the subsequent decline towards October correspond with the findings from previous studies that linked snail abundance to seasonal variations in temperature, rainfall, and vegetation cover (Meleko *et al*., 2025). Increased rainfall and temperature during the summer months often lead to increased breeding and survival rates, resulting in population peaks (Lourenço *et al*., 2019). Conversely, as conditions become drier and temperatures drop, snail populations may decline due to reduced breeding activity and increased mortality (Feng *et al*., 2024).

Environmental factors significantly influence snail distribution and infection rates. A recent study has shown that land use patterns, water quality, and the presence of other snail species can affect trematode transmission (Mereta *et al*., 2023). In this study, the higher infestation rate in *B. globosus* (9.91%) compared to *B. pfeifferi* (5.17%) is consistent with studies identifying *B. globosus* as a primary intermediate host for *Schistosoma haematobium* in many regions of Africa (Manyangadze *et al*., 2021). Similarly, *Biomphalaria pfeifferi* is a well-established intermediate host for *Schistosoma mansoni* (Plate i), but infection rates can vary based on local environmental conditions and parasite strains (Spaan *et al*., 2023; Ismail *et al*., 2022). The absence of infection in *Melanoides tuberculata* (0.0%) is notable (Plate i). *Melanoides tuberculata* is often considered a competitor to other snail species and may exhibit resistance to trematode infections (Phiri *et al*., 2007). The 6.0% infection rate in *Galba truncatula* suggests its role as an intermediate host for certain trematodes, although it is generally less studied in the context of schistosomiasis compared to *Bulinus* and *Biomphalaria* species (Barkia *et al*., 2014).

Conclusion

The study identifies that the freshwater snails *Bulinus globosus* and *Biomphalaria pfeifferi* are consistently present across all studied locations in Lokoja (Kpata, Adankolo, and Ganaja). These species are the known intermediate hosts for *Schistosoma haematobium* (causing urogenital schistosomiasis) and *Schistosoma mansoni* (causing intestinal schistosomiasis). Their consistent presence signifies a persistent risk of schistosomiasis transmission in the region. Also, overall cercariae emergence was 5.47% from *Bulinus globosus* and *Biomphalaria pfeifferi*. Although *Melanoides tuberculata* is not a vector for human schistosomiasis, it exhibited variable dominance across the sampling stations, highlighting its competitive presence in the ecosystem. *Galba truncatula* was found to have the least relative abundance across all sites. Significant spatial heterogeneity was observed in snail species composition, with Kpata and Adankolo sharing similar patterns, but Ganaja showing a distinct ecological profile with a higher prevalence of *Melanoides tuberculata*. This highlights the importance of considering local environmental factors in control efforts. In essence, the study successfully mapped the distribution and abundance of schistosomiasis intermediate hosts in parts of Lokoja, confirming the widespread presence of snail vectors and their seasonal dynamics, which are essential for evaluating the epidemiology and transmission dynamics of schistosomiasis in this endemic area.

Authors Contribution

Victor Umar: designed the study, original draft, data curation, laboratory analysis. Jacob Sule Ngwamah: conceptualize the study, review and edited. Sanni Anataku Muhammed, Emmanuel Joseph and Okpanachi M. Grace: participated in the field work, data collection, validation and laboratory analysis. Obaze Felix Oluwasinnaayomi, Muhammed Ibrahim Ozovehe, Victor Odesanmi and Olawale Covenant Ayomide: assisted with snail identification, verification data analysis and interpretation.

Conflict of Interest

There is no competing interest.

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