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Distribution, Seasonal Fluctuation and Infectivity of Schistosome Snail Hosts at Kiri Reservoir, Nigeria

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Abstract

Kiri Lake, now over four decades old, has received limited scientific attention regarding its role in the transmission of water-related diseases. Recent reports, however, have linked schistosomiasis transmission in seven nearby communities to the lake, as its waters serve as the primary source for domestic use. In light of these concerns, this study investigated the distribution, seasonal population dynamics, and infection rates of freshwater snails, which act as intermediate hosts of schistosomes. Snails were sampled over a 20-month period using long-handled scoop nets at five strategically selected water contact sites. The study focused on species identification, seasonal population density, and infection prevalence. In addition, physicochemical parameters of lake water were analyzed, aquatic vegetation types were recorded, and human water contact activities were monitored throughout the study period. Three schistosome intermediate host snails were identified: *Bulinus globosus*, *Bulinus truncatus*, and *Biomphalaria pfeifferi*. The densities of *B. globosus* and *B. pfeifferi* peaked during the hot dry season but declined markedly during the rainy season. These seasonal variations were statistically significant within sites ($p < 0.001$), but not between sites ($p > 0.001$). In contrast, *B. truncatus* populations showed little seasonal fluctuation. All three species were naturally infected with schistosomes. The seasonal infection trend mirrored that of uninfected snails, though differences in infection prevalence were not statistically significant ($p > 0.001$). The findings confirm that schistosomiasis is endemic in the Kiri Lake area and underscore the lake's role as a persistent transmission focus. Control strategies should therefore adopt an integrated approach, combining snail population management, health education to reduce risky water contact behaviors, and provision of alternative potable water sources. Such interventions will be crucial to reducing disease burden and improving public health outcomes for the surrounding communities.

Keywords
Kiri,
Nigeria,
Schistosome hosts,
Seasonal variation.

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Introduction

Kiri lake was created in 1982 by constructing a dam on River Gongola. The lake has a 20m high embankment with a maximum depth of 10m with a storage capacity of 615 million liters. It was created primarily for irrigating the Savannah Sugar Plantation, hydroelectric power generation and water supply to the sugar company. It also serves as the main source of drinking water to several communities around the sugar plantation and factory. A recent report associated the lake with enhancing the transmission of schistosomiasis to the surrounding communities (Kaleson *et al*., 2022). This is because the natural ecology of the area had been altered which provided suitable breeding sites for freshwater snail hosts of trematode parasites especially schistosomes. In spite of the over four decades of existence of the lake, no deliberate attempt had been made to unravel its role in disease transmission. Therefore, we report here, the distribution, seasonal population fluctuation and infection rates of schistosome intermediate host snails in Kiri lake, Adamawa State, Nigeria with the hope that it will give sufficient insight into the role of the lake in disease transmission.

Materials and Methods

Description of study area

The study was conducted in Kiri Lake which is located in Shelleng Local Government Area of Adamawa State, Nigeria (Fig.1). The lake is located at coordinates $9^{0}40'47''$N and $12^{0}00'51''$E. The area has sedimentary rocks, limestone and ignite. The landforms of the area are characterized by extensive flood plains and swamps liable to waterlogging during the rainy season spanning from April/May to September/October with a mean annual rainfall of 759-1011mm. The dry season last from November to March/April. The average minimum and maximum temperature is 25^{0}C and 40^{0}C respectively.

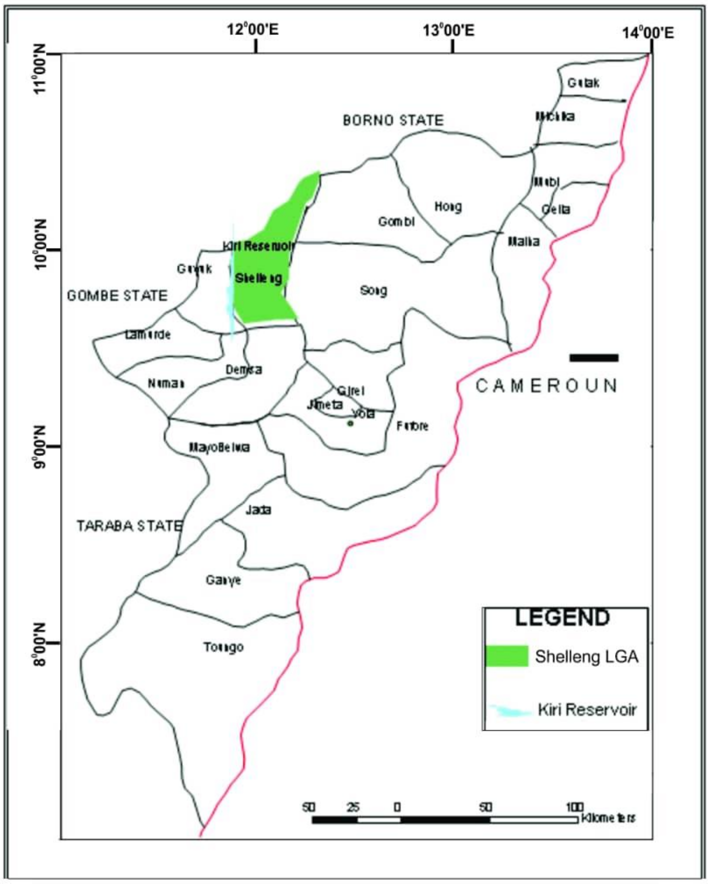

Fig. 1: Map of Adamawa State Showing Location of Shelleng LGA and Kiri Reservoir

Selection of snail sampling sites

Prior to the commencement of detailed snail study, a visit was made to the lake in order to identify water contact sites through observations of presence of foot prints, disturbed vegetation growth, presence of stones placed for washing of feet or stepping on during contact activity along the lake shore line. Thus, on the basis of evidence of water contact, five sites A-E (Table 1) were selected for detailed snail studies.

Table 1: Description of the five study sites

Site/location	Substratum	Aquatic vegetation	Maximum distance (m) surveyed
A/Lawubuk	Clay/mud	*Cyrodonlemfucusis*	
		Eichemiacrassipers	20
		Commenlinadiffusa	
B/Bopalda	Clay/mud	*Cynodonlemfuensis*	
		Polygonumsaliefolium	15
		Eichorniacrassipers	
		Conmelinadiffusa	
C/Boberi	Loamy	*Cynodonlemfuensis*	
		Polygonumsaliefolium	
		Eichorniacrassipers	35
		Commelinadiffusa	
		Nymphaea lotus	
		filamentous algae	
D/Talum	Loamy	*Cynodonlemfuensis*	
		Commelinadiffusa	20
		filamentous algae	
E/Bonto	Clay/mud	*Cynodonlemfuensis*	
		Polygonunsaliefoliun	50
		Eichorniacrassipes	
		Commelinadiffusa	
		Nymphaea lotus	
		filamentous algae	

Snail sampling

Longitudinal surveys on spatial and temporal distribution of snails at the selected human water contact sites were conducted where snails were carefully searched for, along the lake shore as well as in patches of vegetation off-shore using a long handle metal scoop net for 30 minutes, twice a month, for a period of 20 months in all the five sites spanning from December 2016 to July, 2018.

Snails collected were kept in plastic containers in lake water and brought to the laboratory for further examination, after which they were returned to the sites where they had been collected. Distance from lake shore line and depth where snails were found were recorded.

In the laboratory, snails were sorted into species with reference to the keys of Brown (1994) based on morphological characteristics. Natural schistosome infection were assessed by inducing cercarial emission by exposing snails individually in petridishes in 2-5 m/lsof lake water to artificial light for a maximum period of one hour. Emission of cercariae was then recorded and the type of cercariae shed was identified with reference to Fatima, Maikaje and Umar (2018). At each sampling site and on each sampling occasion, water samples were collected in 750mls plastic bottles and brought to the laboratory where dissolved oxygen (DO), calcium and magnesium contents were determined using a SIGMA spectrophotometer Model Do 700. Conductivity, turbidity, environmental and water temperature and pH were determined in the field using their respective instruments. In addition, the different types of aquatic vegetation at each site were collected and identified at the herbarium.

Water contact activities

Human water contact activities in the reservoir were observed monthly at each study site for the entire study period. Visual observation using a pair of binoculars from a hideout were made. The type of contact, duration, gender and approximate age of person(s) making contacts were recorded.

Statistical analysis

Snail population fluctuation data and the average monthly data on physicochemical parameters were subjected to Friedman two-way Analysis of Variance (2- way ANOVA) at 1% confidence limit (p=0.001) using SPSS computer software version 21 of 2012.

Result

Snail occurrence

All the five study sites harboured schistosome intermediate host snails. These were *Bulinus globosus, Bulinus truncatus* and *Biomphalaria pfeifferi*. The density of *B. globosus* and *B. Pfeifferi* was relatively high in all sites while that of *B. truncatus* was very low. Snails were not restricted to the shoreline but were also found in patches where there were aquatic macrophytes off-shore. In such cases, snails were found at a maximum distance of 50m off-shore from the shoreline and a maximum depth of 1m below the water surface. A total of 4,067 snails occurred at all the sites combined. Site E (Bondo) had the highest number of snails while site C (Boberi) had the least number. Also *B. pfeifferi* had the highest density followed by *B. globosus* and *B. truncatus* in that descending order (Table 2). Other freshwater snails found in the lake were *Lymnaea natalensis, Lanistes ovum, L. varicus, Melanoides tuberculata, M. maculata, Bellamya unicolor, Gabiella tchadiensis* and *Pila ovata*.

Table 2: Average sum of density scores of 20 months sampling of schistosome intermediate host snails encountered at the five sampling sites during the study.

Site/location	Snails species			Total
	B. globosus	*B. truncatus*	*B. pfeifferi*	
A/ Lawubuk	274	95	531	900
B/ Bopalda	310	76	403	789
C/ Boberi	208	63	281	552
D/ Talum	360	68	400	828
E/ Bondo	441	156	401	998
Total	**1,593**	**458**	**2,016**	**4,067**

Distribution and seasonal fluctuation in uninfected intermediate host snail populations

Intermediate host snails encountered were present at all the study sites but with some variation in their densities (Fig. 2) *B. pfeifferi* occurred more densely in four of the five sites followed by *B. globosus* at these same sites but had higher density at one of the five sites. *B.truncatus* had the least density at all the study sites. The population densities of uninfected *B. globosus* and *B. pfeifferi* snails showed considerable fluctuation within site over the study period at all the sites while the density of *B. truncatus* showed only slight variation within the same period (Fig. 2). For *B. globosus* and *B. pfeifferi,* the overall pattern that emerged was that populations built up slowly during the last part of the rainy season into the beginning of the dry season of one year and peak density was observed in March/April of the succeeding year. This peak was followed by a decline in both cases as the high temperatures persisted but density rose again after the rains and similarly peaked during the dry hot season. However, there was no marked fluctuation in density of *B. truncatus* over the study period (Fig. 2). The observed density fluctuation was statistically significant within sites ($p<0.001$) but was however not significantly different between sites ($p>0.001$) for all species.

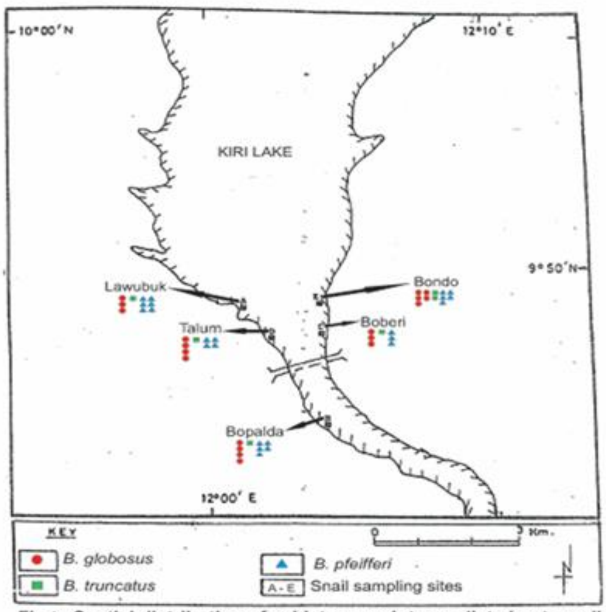

Fig 2: Spatial distribution of schistosome intermediate host snails in Kiri Lake during the study.

Distribution and seasonal fluctuation in infected intermediate host snail population
All the three intermediate host snails identified in this study had natural infections (Table 3). The cercarial type that emerged was the furcocercous/brevifurcate cercariae typical of schistosomes. Infected snails were found in all the five study sites.

The seasonal fluctuation in infected snail population was remarkably similar to patterns described for uninfected snails but the differences observed within sites and between sites were statistically insignificant (p>0.001)

Table 3: Infection rates observed among schistosome intermediate host snails during the study

Sampling sites	Snail species					
	B. globosus		*B. truncatus*		*B. pfeifferi*	
	No. collected	No. infected (%)	No. collected	No. infected (%)	No. collected	No. infected (%)
A	274	53 (19.3)	95	12 (12.6)	531	51 (15.4)
B	310	72 (23.2)	76	13 (17.1)	403	74 (18.4)
C	208	48 (23.1)	63	7 (11.1)	281	60 (21.4)
D	360	88 (24.4)	68	5 (7.4)	400	82 (20.5)
E	441	133 (25.6)	156	19(12.2)	401	91 (22.7)
Total	**1,593**	**394 (29.7)**	**458**	**56 (11.5)**	**2,016**	**358 (17.8)**

Water physicochemical parameters
The values of physicochemical parameters monitored in the lake over the study period are shown in Table 3. There was generally an insignificant variation in values of parameters both within and between sites (P>0.001). The average values for all parameters fell within the normal optimum values required for survival. Thus, all values of physicochemical parameters monitored did not appear inimical to the snails.

Table 3: Physicochemical parameters of the lake monitored during the study

Water parameters	Optimum range	Sampling sites					Mean value
		A	B	C	D	E	
Calcium (mg/l)	4.5- 5.8	5.1	5.1	4.7	4.9	5.1	4.9
Magnesium (Mg/L)	11.0 - 23.0	13.8	14.9	14.9	15.3	16.9	15.1
Dissolved oxygen	6.0 - 8.5	7.0	7.2	7.4	7.6	7.9	7.4
Turbidity (m)	8.0 - 12.0	8.5	9.1	9.2	9.2	9.2	9.1
Env. Temp (^0C)	29.0 - 33.0	29	31	31	32	32	31
Water Temp (^0C)	19.0 - 23.0	21	20	22	20	22	21
pH	6.3 - 7.1	6.8	6.8	7.0	6.9	7.0	6.9

Aquatic Vegetation

Six (6) different aquatic macrophytes were found in the lake, the most common of which was *Eichornia crassipers*. However, *Cynodon lemfuensis* and *Commelina diffusa* were fairly common as well. The rarest aquatic macrophyte was *Nymphaea lotus*. These are set out in Table 4. Although the association between intermediate host snails and these macrophytes was not rigorously determined, cursory observation revealed that all macrophytes sampled had many snails attached to them indicating a close association.

Table 4: Aquatic macrophytes encountered at the five sampling sites during the study

Type/species	**Sampling sites**				
	A	B	C	D	E
Cynodon lemfuensis	++	++	+	+	+
Polygonum saliefolium	-	+	+	-	+
Eichornia crassipers	+++	+++	+	-	+
Commelina diffusa	++	+	+	+	+
Nymphaea lotus	-	-	+++	-	++
Filamentous algae	-	-	++	++	+

Key: - = Absent += present ++ = averagely abundant +++ = very abundant

Observations on water contact activities

The record of water contact activities observed during the study is in Table 5. Men were predominantly engaged in fishing and swimming while women were preoccupied with washing of clothes and domestic utensils. The boys and girls were more involved in playing and fetching water for domestic use. Altogether, 1,030 contact activities were recorded. While bathing was the shortest activity made which took only 10 minutes, activity like fishing took the longest time of 6 hours.

Table 5: Record of water contact activity observed during the study

Contact activity	**Nos. contacts/day**					**Duration of contact (min)**		**Total**
	Men	**Women**	**Boys**	**Girls**	**Total**	**Min.**	**Max.**	
Bathing	48	0	30	0	78	10	10	20
Swimming	90	1	65	0	156	20	40	60
Fetching water	6	0	106	44	156	30	60	90
Fishing	110	17	60	0	187	60	240	300
Playing	18	8	152	106	284	60	180	240
Washing	34	133	58	59	284	30	180	210
Irrigation	27	0	1	0	28	20	60	80
Ablution	16	0	1	0	17	10	20	30
Total	**349**	**159**	**473**	**209**	**1190**			**1030**

Discussion

Snail occurrence

The occurrence of the three schistosome intermediate host snails in this study is noteworthy and is in agreement with an earlier report on the diversity of fresh water snail fauna in Kiri dam (Sanu, Istifanus and Panda, 2020). It is also in consonance with reports from neighbouring Gombe, Bauchi and Taraba States respectively where they were reported as the schistosome intermediate host snails encountered (Agere, Istifanus and Kela, 2009; Istifanus, Panda and Sunday, 2018, Sunday, Istifanus and Adamu, 2019). It would therefore appear that *B. globosus, B. truncatus* and *B. pfeifferi* are major schistosome intermediate hosts in north eastern Nigeria. Snail occurrence in this study appeared to have been influenced by a combined effect of microhabitat nutrients, aquatic vegetation, distance from the shore and depth of water.

In lake Kariba Zambia, Mungomba *et al*., 1995) found that at gently sloping sites, snail densities remained high up to distances of 100m offshore while at steep slopes, snail densities were low from 10m distance offshore. Our finding agrees with this general trend although we did not sample as far as 100m offshore. However, snails were found at distances of 50m which was the maximum distance sampled offshore showing that snails were not restricted to only the shoreline.

Similarly, at sites that had steep slopes, snail occurrence was much closer to the shoreline. The colonizable depth range for snails and vegetation was given as 0-12m and in their study in Lake Kariba, 12m was the maximum depth at which intermediate host snails were collected (Mungomba *et al.,* 1995). In this study, snails were encountered at an average maximum depth of 1m which appear much shallower than in Lake Kariba. The reason for this disparity is not clear and it requires further clarification.

The intermediate hosts for *S. haematobium* in northern Nigeria include *B. globosus, B. truncatus* and to a lesser extent *B. senegalensis* while the only snail host for *S. mansoni* in the region is *B. pfeifferi.* Thus, the occurrence of the three schistosome snail hosts in the Kiri Lake further supports the view expressed that *B. globosus* and *B. truncatus* are the major *S. haematobium* snail hosts in northern Nigeria for now. The presence of these snails in the Kiri Lake should be a cause for great concern as some reports from the sub-region indicted dams in Kaduna and Katsina States with enhancing the transmission of schistosomiasis (Abdulkadir, Maikaje and Umar, 2017; Timothy, Emmanuel and Elaigu, 2018). Recently, Kaleson *et al.,* (2022) reported a prevalence of 43% for urogenital schistosomiasis among seven communities residing around the Kiri Lake. This strongly suggests that the infected *B. globosus* and *B.truncatus* found during this study are actively involved in disease transmission in the area and therefore merits control.

Apparently, the presence of vegetation was favourable to the snails because they were more abundant in areas with vegetation than barren ones. Vegetation have been reported to be important to snail occurrence for the provision of shade in shallow habitats (Imevbore, 1975) for oviposition, food and/or food support (Marti *et al*., 1985). Thus, in the current study, many snails were found underneath aquatic macroplytes with large numbers of egg masses glued to them. Although snails do not consume live macrophytes, there is an apparent existence of a symbiotic relationship (Thomas, 1982) and this positively influenced snail occurrence in this study.

Distribution and infection rates

The observed distribution of infected snails in all the five study sites which are actually water contact sites indicate that these sites are contributing immensely to transmission of infection. This agrees closely with a report from the Bauchi Area (Istifanus, Panda and Sunday, 2018). Also, since infected snails occurred at all sites throughout the year albeit in low densities during some months, means that transmission of infection may similarly occur throughout the year. This finding is very important in the epidemiology of schistosome infection in the Kiri Lake area. With the variety of water contact activities observed in the lake during the study communities surrounding the reservoir are at great risk of contracting infection. The most intense transmission period would appear to be February/April when peak infected snail population was observed. This period of the year coincides with the very hot weather condition in the area which heightened recreational activities especially among young people so as to cool the body. By so doing, they are actually exposing the entire body surface to penetration by cercariae shed by the infected snails.

Seasonal fluctuation in snail density

The density in population of *B. globosus* and *B. pfeifferi* in this study underwent great seasonal variation with a single annual peak. Although water temperature favoured the reproduction of these two species throughout the year as adjudged by continuous presence of hatchlings, the actual increase in density occurred with increase in environmental temperature. However, Lake water level reduced during the same period and this would have probably enable stable conditions to establish which may have caused some aggregation of snails. This situation is similar to one earlier observed in the Zobe Dam, Katsina State, Nigeria (Timothy, Emmanuel and Elaigu,2018). Towards the end of the hot dry season, the constraint of high temperature above the optimum range may have resulted in the decline in snail populations. A situation similarly observed for snail habitats in the Bauchi Area (Istifanus, Panda and Sunday, 2018).

The influence of rainfall on lake level fluctuation affected the spatial distribution of snails in their habitats. Snail densities were low close to the shore during the rising phase and density in this zone increased during the period of water recession. This observation is similar to that at the Zobe Dam in Katsina State (Timothy, Emmanuel and Elaigu, 2018). Water quality parameters monitored during the study were all within the tolerable ranges for intermediate host snails in Nigeria (Istifanus,2023). Therefore, they could not account for the observed fluctuation. Consequently, the major factors responsible for decimation in snail density at the Kiri Lake would appear to be rainfall and high environmental temperature.

Conclusion

The present findings have demonstrated without doubt that the Kiri reservoir plays a major role in schistosomiasis transmission and this has considerable significance for schistosomiasis control in the area since the surrounding communities rely heavily on it for water for domestic use. First, there is need for creating awareness among the populace on how the disease is acquired and on water contact activities that are serious risk factors. Informal interaction with the people showed that such awareness is currently lacking. Secondly, there is also a need for snail control operations to be initiated. Molluscicide application should be targeted at the beginning of the dry season so as to crash the population before the main transmission period. Thirdly, mass chemotherapy using praziquantel, the drug of choice, should be done in affected communities for infection control and finally provision of portable water should be intensified through the provision of at least hand operated boreholes so as to reduce dependence on lake water for domestic use.

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