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Bionomics and diversity of bulinid species in Patigi, North-Central, Nigeria

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Ability of the snail species to repopulate an aquatic environment is a risk factor to be considered by an epidemiologist in an area where schistosomiasis is endemic. A survey was conducted on the distribution of aquatic snail species in schistosome endemic areas, Kwara State, North-Central Nigeria. Physicochemical factors (water temperature, velocity, depth of water, atmospheric temperature, transparency, pH, electrical conductivity, and dissolved oxygen) were measured for twelve months with a field meter while other parameters were done in the laboratory. Aquatic flora influencing the abundance of the potential snail intermediate hosts in the selected water bodies was also observed. Spearman's rank correlation coefficient was used to test the relationship between physicochemical parameters and snail species. Overall, 5,246 aquatic snails comprising five species of Planorbidae and a species each of Thiaridae, Lymnaeidae, Ampullariidae, Bithyniidae, and Bivalviae were identified in three sampled stations. In this study, *Bulinus truncatus* correlated positively with air temperature (r=0.401; p<0.05), water temperature (r=0.324; p<0.01), calcium (r=0.465; p<0.01), and magnesium (r=0.428; p<0.01); however, a negative significant relationship occurred between *B. truncatus* and water depth (r=-533; p<0.01), nitrate (r=-0.433; p<0.01). The occurrence of *B. jousseaumei* was strongly associated with dissolved oxygen (r=0.260; p<0.05). Since the presence of snail intermediate host of schistosome is confirmed in the study area and the effect of different physicochemical parameters on the survival of the snail species is demonstrated, environmental modification and the introduction of control measures should be done to eliminate schistosomiasis in the study area.

Key words: Bionomics, bulinid species, Nigeria, physicochemical parameters, schistosomiasis.

INTRODUCTION

The snail intermediate host for schistosome infection is found in aquatic environments, both in rural and urban centers across every endemic area. This disease is common in Nigeria, as well as other countries in Africa where there is poor sanitation and inadequate water supply (King et al., 2015; Rabone et al., 2019). Under the influence of light, the free-swimming miracidium hatched from egg passed in urine into freshwater bodies by

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infected individual, actively locate and penetrate suitable snail intermediate host. The other active stage (cercariae) emerged from bulinids through the presence of light and other suitable conditions (Théron, 2015), which coincide with the period when humans are in contact with water bodies (for domestic, recreational, or other activities), hence, humans are infected when the cercariae locate human host and secrets an enzyme that breaks down the skin protein to enable penetration (Gryseels et al., 2006; Lund et al., 2019; Nwele et al., 2017; Oso and Odaibo, 2020).

Over 37 bulinid species are involved in the transmission of schistosomiasis in Africa, the Middle East, and other regions where the disease is endemic (Akinwale et al., 2015; Chibwana et al., 2020; Tumwebaze et al., 2019). While in freshwater bodies, the snail species feed on both fresh and dead decaying plants, and to avoid being washed off by water current, the snails are attached to a suitable substratum (Yigezu et al., 2018). More so, series of environmental factors influence the development of snail species, hence, the seasonal variation in the occurrence and abundance of the snail species throughout the year (Chibwana et al., 2020; Olkeba et al., 2020). Among some of the environmental characteristics which influence the seasonal mobility of snail species are rainfall, conductivity, dissolved oxygen, calcium, magnesium, pH, water flow, temperature, and macrophytes (Afiukwa et al., 2019; Ajakaye et al., 2017; Akindel et al., 2020; Ntonifor and Ajayi, 2007; Oladejo et al., 2021; Owojori et al., 2006; Salawu and Odaibo, 2014). Although the importance of the presence of a suitable intermediate host cannot be overemphasized, few studies have been conducted to know the interplay between the snail species and many physicochemical factors which influence the development and abundance of the species in the aquatic environment. Meanwhile, most research focused on the diagnosis, prevalence, and intensity of the diseases in Nigeria (Abdulkareem et al., 2018; Ojo et al., 2021; Otuneme et al., 2019; Ugbomoiko et al., 2010) and other parts of the world (Exum et al., 2019; Hajissa et al., 2018; Joof et al., 2021; Léger et al., 2020).

The authors therefore, design this research to know the physicochemical characteristics of the river Niger, access the distribution of freshwater snails, and understand the influence of the physicochemical factors on the occurrence and abundance of snail intermediate host of schistosomiasis in North-Central, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in river Niger, Patigi Local Government Area (LGA), Kwara State, North-Central Nigeria. The inhabitants of the Patigi LGA are predominantly Nupes; they practice subsistence crop farming, fishing and petty trade. Potable water supply and waste disposal are inadequate in the study area.

Snail sampling

Snails were collected fortnightly from the three sample stations in Patigi LGA from April 2016 to May 2017. The three stations consist of active human-water contact points along the river and sampling was done during rainy season (April to November) and dry season (December to March). Snail sampling was done in areas where human-water activities occurred by the same collector for uniformity with aid of a snail scoop net. The duration for sample collection was 20 minutes (Olofintoye and Odaibo, 1996). Snails recovered were washed and gently placed in a plastic container with a perforated lid for aeration.

Identification of the snails/Infection in snail species

The snails collected were taken to the laboratory where they were sorted into taxonomic groups using taxonomic keys (Brown, 1994). Morphological identification was confirmed by Prof. Alex Odaibo of the Department of Zoology, University of Ibadan, Nigeria. All bulinid species were exposed to direct sunlight for cercaria shedding. None of the bulinid species shed cercaria.

Physicochemical analysis

Snail occurrence was studied in the selected locations fortnightly in relation to physicochemical factors of the water bodies. These include water temperature, dissolved oxygen, water pH, water velocity, depth of water, transparency, calcium, magnesium, nitrate, and phosphate. The physical parameters - water temperature, water velocity, depth of water, atmospheric temperature and transparency, and some chemical factors such as pH, electrical conductivity, and dissolved oxygen were determined in the field. Other parameters were determined in the laboratory from the water samples collected from the site. Analyses of the chemical parameters were done at the Environmental and Water Quality Laboratory of Mainstream Energy Nigeria Limited and the Department of Industrial Chemistry, Kwara State University, Malete.

Statistical analysis

The data collected were statistically analyzed using IBM.SPSS 22.0 (International Business Machine-Statistical analysed for Social Science Inc, Chicago, USA). Spearman's correlation was used to test the relationship between the physicochemical parameters and snail species abundance. Comparisons across groups were done using Fisher's exact test and a p-value <0.05 was considered significant (Ajao, 1990).

RESULTS

A total of 5,246 snails belonging to 6 families (Planorbidae, Thiaridae, Lymnaeidae, Ampullariidae, Bithyniidae, and Bivalviae) were collected from three stations in the study areas (Table 1). Only one species was recorded belonging to the family Thiaridae (*Melanoides tuberculata*), Lymnaeidae (*Lymnaea natalensis*), Ampullariidae (*Gabbiela tchadiensis*), Bithyniidae (*Lanistes carinatus*), and Bivalviae (*Anodonta* spp.) *Melanoides tuberculata* and *L. natalensis* were the most common species encountered with an abundance of 38.81% and 21.4% respectively. This was closely

Table 1. Mean seasonal variation in snail species collected from Patiji. North Central Nigeria.

Spp/ Month	*A* n(%)	*B* n(%)	*C* n (%)	*D* n(%)	*E* n(%)	*F* n(%)	*G* n(%)	*H* n(%)	*I* n(%)	*J* n(%)	Total
May	268(13.1)	70(7.1)	127(12.1)	0(0)	2(4.7)	12(8.8)	23(5.9)	16(6.1)	39(14.6)	3(5.9)	560(10.7)
Jun	223(10.9)	111(11.2)	90(8.6)	0(0)	0(0)	12(8.8)	16(4.1)	25(9.5)	16(6.0)	7(13.7)	505(9.6)
Jul	177(8.7)	105(10.6)	86(8.2)	0(0)	1(2.3)	0(0)	36(9.3)	24(9.1)	29(10.9)	0(0.0)	458(8.7)
Aug	107(5.2)	57(5.7)	61(5.8)	1(9.1)	0(0)	4(2.9)	39(10.1)	13(4.9)	37(13.9)	7(13.7)	326(6.2)
Sept	98(4.8)	46(4.6)	32(3.1)	0(0)	0(0)	3(2.2)	23(5.9)	12(4.6)	6(2.2)	3(5.9)	223(4.3)
Oct	60(2.9)	30(3.0)	28(2.7)	0(0)	5(11.6)	5(3.7)	6(1.5)	5(1.9)	0(0)	5(9.8)	144(2.7)
Nov	119(5.8)	67(6.8)	124()11.8	0(0)	1(2.3)	27(19.9)	50(12.9)	31(11.8)	20(7.5)	1(2.0)	463(8.8)
Dec	160(7.8)	109(11.0)	60(5.7)	1(9.1)	3(7.0)	35(25.7)	29(7.5)	35(13.3)	40(15.0)	11(21.6)	483(9.2)
Jan	176(8.6)	74(7.5)	116()11.1	6(54.5)	12(27.9)	18(13.2)	78(20.1)	24(9.1)	16(6.0)	0(0.0)	525(10.0)
Feb	209(10.2)	68(6.9)	133(12.7)	0(0)	10(20.9)	13(9.6)	52(13.4)	32(12.2)	7(2.6)	4(7.8)	538(10.3)
Mar	225(11.0)	130(13.1)	101(9.6)	3(27.3)	3(7.0)	6(4.4)	32(8.2)	32(12.2)	52(19.5)	2(3.9)	586(11.2)
Apr	224(10.9)	125(12.6)	91(8.7)	0(0)	7(16.3)	1(0.7)	4(1.0)	14(5.3)	5(1.9)	8(15.7)	479(9.1)
Total	2046(39.0)	992(18.9)	1049(20.0)	11(0.2)	43(0.8)	136(2.6)	388(7.4)	263(5.0)	267(5.1)	51(10.0)	5246(100)

A=*M. tuberculata, B=G. tchadiensis, C=L. natalensis, D=B. jousseaumei, E=B. globosus, F=B. truncatus, G=L. carinatus, H=Bi. pfeifferi , I=I. exustus, J= Anodonta* spp.
Source: Author

followed by *G. tchadiensis* (16.7%). A low abundance of *B. jousseaumei* (0.3%), *B. globosus* (0.5%), and *Anodonta* spp. (1.0) were recorded. The seasonal variations of snail species in Patigi show that except for May (4.7%) and July (2.3%), *B. globosus* was not encountered in sampled stations at the onset of the rainy season (April to November).

The highest monthly occurrence (27.9%) of *B. globosus* was recorded at the peak of the dry season. This was followed by 20.9% in February and 16.6% in April. A similar trend was observed for *B. jousseaumei*. There was a steady increase in the occurrence of *B. jousseaumei* from 9.1% in December 2016 to a peak of 54.5% in January 2017. There was no *B. jousseaumei* encountered in Patigi in February and April. However, *B. truncatus* was recorded monthly in Patigi except in July. There was a steady increase in the occurrence of *B. truncatus* from 2.9% in August, to a peak of 25.7% in December before a steady decline from 13.2% in January to a low rate of 0.7% in April. Whereas, there was a decline in the occurrence of *Bi. pfeifferi* from 9.5% in June to the lowest occurrence of 1.9% at the peak of the rainy season, before a steady increase from 11.8% in November to 13.3% in December 2016. This was followed by a steady increase from 9.1% in January to 12.2% in February and March. A bimodal occurrence of *L. natalensis* was recorded in Patigi with 12.1% at the onset of the rainy season and 12.7% in the middle of the dry season. The seasonal occurrence of *M. tuberculata* in Patigi stations was unimodal, highest during the early rainy season with 13.1% and lowest (2.9%) during the peak of the rainy season (Table 1). Physical and chemical characterization of the river Niger in Patigi is shown in Table 2.

Table 3 shows the association between abundance of snail intermediate host and physicochemical properties of water body. In Patigi, *B. truncatus* correlated positively with air temperature (rho= 0.401; p<0.05), water temperature (rho=0.324; p<0.05), calcium (rho= 0.465; p<0.05), and magnesium (rho=0.428; p< 0.05); however, a negative significant relationship occurred between *B. truncatus* and water depth (rho=-533; p<0.05), nitrate (rho=-0.433; p<0.05). The relationship between *B. globosus* and most of the physicochemical parameters was negative; however, the association was not significant. *L. natalensis* had a negative significant relationship with water temperature (rho=-0.309; p<0.05) and water velocity (rho=-0.403; p<0.05), but a positive significant correlation occurred between *L. natalensis* and air temperature (rho=0.264; p<0.05). The occurrence of *B. jousseaumei* was strongly associated with dissolved oxygen (rho=0.260; p<0.05) (Table 3). Table 4 shows the

Table 2. Physical and chemical parameters of the river Niger, Patigi, North-Central Nigeria.

Parameters	Mean (x)	±SE	Minimum value	Maximum value
Physical properties				
Air temp(^{0}C)	25.60	0.39	20.40	32.10
Water temp(^{0}C)	25.90	0.38	20.10	31.90
Water depth (cm)	30.70	0.95	19.70	47.30
Transparency (cm)	23.30	0.46	2.02	33.20
Water velocity (m/sec)	0.31	0.02	0.13	0.67
Chemical Properties				
Dissolved Oxygen (mg^{-1})	4.93	0.10	3.60	7.00
pH	6.93	0.03	6.30	7.60
Free CO_2 (mg/l)	2.29	0.02	2.00	2.70
Calcium (mg/l)	22.80	0.46	22.90	38.40
Mg (mg/l)	12.90	0.21	9.00	16.10
NO_3 (mg/l	5.44	0.18	2.80	8.60
Phosphate (mg/l)	0.17	0.01	0.00	0.50
Conductivity (µmhoscm-1)	75.70	0.76	60.20	88.50
Alkalinity (Mg/LCaCO3)	27.80	0.58	10.00	38.20

Source: Author

correlation among snail species in the study areas. In Patigi, *B. jousseaumei* positively correlated with all the snail species encountered. Except for *Anodonta* spp., *M. tuberculata* also correlated with all the snail species. Similarly, *B. globosus* correlated with all the snail species except *B. truncatus*. *L. natalensis* had a significant ($p<0.05$) association with *B. jousseaumei, B. globosus*, and *Bi. pfeifferi* but negatively correlated with *B. truncatus* and *Anodonta* spp. (Table 4). A total of 29 aquatic plant species were recorded in the three study stations. They are separated into marginal, emergent, and floating plants. Ten marginal plants were recovered, 14 emergent plants and five floating plants were observed from the sampling stations (Table 5).

DISCUSSION

Ten different species of freshwater snails namely *M. tuberculata*, *L. natalensis*, *B. jousseaumei*, *B. globosus, B. truncatus, Bi. pfeifferi, I. exustus, Lanistes carinatus,* and *Anodonta* spp. were collected from water bodies in Patigi. The snails identified in these study areas have been reported by earlier investigators in Nigeria (Akinwale et al., 2015; Salawu and Odaibo, 2014). The variation in the snail species encountered in the study area could be an indication that the stations are habitats with suitable biotic and abiotic factors capable of supporting a mutually exclusive species population. Out of the ten snail species collected, five were known intermediate hosts of animal and human disease: *L. natalensis* of *Fasciola gigantica* in many parts of Africa; *B. jousseaumei, B. globosus,* and *B. truncates* of *Schistosoma haematobium* in Nigeria; *Bi. pfeifferi* of *S. mansoni* (Amarir et al., 2014; Stothard et al., 2002). Although the snail species were earlier identified by various authors, the relative abundance and distribution of various species varied due to different ecological factors. The extent which the environmental/ecological factors influence the abundance and distribution of schistosome snail intermediate hosts in the water bodies has not been adequately studied by many authors. In Patigi LGA, the recorded rainfall data varied from 0.0 mm to 246 mm during the sampling year. According to Abdulkadir et al (2017), rainfall produces a series of breeding habitats for the snail intermediate host; hence, a large number of juvenile freshwater snails emerged. However, this may be adversely affected by flooding owing to a change in water level. This study revealed different variations in the abundance of snail intermediate hosts with rainfall. Peak abundance of the snails recorded in the dry months for *B. globosus, Bi. pfeifferi, L. natalensis, M. tuberculata, B. truncatus,* and *B. jousseaumei* aligns with the work done by Owojori et al. (2006).

The seasonal variation and influence of various physicochemical factors on the abundance and distribution of schistosome snail intermediate hosts in various habitats have been investigated by several workers (Abdulkadir et al., 2017; Amarir et al., 2014; Owojori et al., 2006). The temperature of freshwater bodies influences the reproductive cycle of snail intermediate hosts (Knight et al., 2014). More so, the incubation period for snail intermediate hosts is 17 to 52 days. Also, highest hatching rate of 99% within a short incubation period of 10 to 13 days was observed when

Table 3. Correlation coefficient matrix, with rho values, between snail intermediate host and physicochemical properties of water bodies in Patiji, Kwara State.

	Air Temp.	Water Temp.	Water Dept.	Transparency	Water velocity	DO	pH	Conductivity	Alkalinity	Free CO_2	Ca++	Mg++	NO_3	PO_4
L. natalensis	0.264*	0.142	-309*	-0.005	-0.403*	0.162	0.121	0.083	-0.097	0.158	0.199	0.169	-0.058	0.096
B. jousseaumei	0.215	0.038	-119	0.214	-0.066	0.260*	0.043	-0.002	-0.078	-0.002	0.030	0.149	0.036	0.267
B. globosus	0.014	-210	-196	0.105	-183	-0.087	-081	-0.079	-0.113	-0.071	0.135	0.176	-0.080	0.346
B. truncatus	0.401*	0.324*	-533*	-0.200	-502*	0.118	-0.061	0.576*	0.039	-0.053	0.465*	0.428*	-0.433*	0.160
Bi. pfeifferi	0.176	0.080	-318*	0.187	-336*	-0.013	0.016	0.007	-0.157	0.021	0.257*	-0.174	0.021	0.146

a = not computable, DO=Dissolved Oxygen, *. Correlation is significant at the 0.05 level (2-tailed).
Source: Author

Table 4. Correlation coefficient matrix, with rho values, between snail species pairs in water bodies in Patigi, Kwara State.

	M. tuberculata	*G. tchadiensis*	*L. natalensis*	*B. jousseaumei*	*B. globosus*	*B. truncatus*	*I. exustus*	*Bi. pfeifferi*	*L. carinatus*	*Anodonta* spp.
M. tuberculata	1	0.433*	0.409*	0.008	0.019	0.135	0.115	0.283*	0.094	-0.008
G. tchadiensis		1	-0.097	-0.105	-0.106	0.176	-0.183	0.257*	0.145	0.239*
L. natalensis			1	0.321*	0.360*	-0.080	0.381**	0.336**	0.164	-0.175
B. jousseaumei				1	0.175	0.346*	0.525**	0.258*	0.122	0.003
B. globosus					1	0-.079	0.579**	0.544*	0.039	0.133
B. truncatus						1	0.232	0.556*	0.150	-0.153
I. exustus							1	372*	0.372*	0.090
Bi. pfeifferi								1.	0.222	0.119
L. carinatus									1	0.012
Anodonta spp.										1

*Correlation is significant at the 0.05 level (2-tailed).
Source: Author

the temperature is within an acceptable range (Knight et al., 2014). There was a variation in the water temperature throughout the sampling period in all the study stations and this could be a reflection of the influence of local climatic factors. The decrease in temperature values observed during the rainfall is in agreement with similar observations in Nigeria (Omonijo et al., 2016). Temperature affects the abundance of bulinid species by influencing the biological activities of snails like egg-laying, hatching, and rate of maturity (Sharma et al., 2013). It is probable, therefore, that the decrease in temperature range recorded during the period of rainfall favoured rapid egg-laying, incubation, and sporadic increase in snail abundance during this period. In most tropical areas, the temperature range is higher in the dry seasons than in rainy seasons (Stothard et al., 2013). In this study, water temperature correlated positively with the occurrence of *B. truncatus* in sampled stations which is in consonance with other reports in Lake Albert, Western Uganda (Kazibwe et al., 2006), and Niger River Valley (Rabone et al., 2019). Water current is a function of the amount of rainfall affecting the depth and width of the channel and the type of substratum (Omonijo et al., 2016; Stothard et al., 2013). Water velocity affects the potential of the snail as intermediate hosts of schistosomiasis. The ability of schistosome miracidia to locate the host snail is above this level (Strzelec and Królczyk, 2004). The maximum (0.67 m/sec) water velocity

Table 5. The occurrence of aquatic marcrophytes in Kwara State.

Checklist of aquatic macrophytes	Patigi		
	S1	S2	S3
Marginal			
Acronnae spp.		*	*
Agerantum conyzoides	*	*	
Commelina africana	*	*	*
Aspilia africana	*	*	*
Acroceras spp	*	*	*
Cynodon dactylon		*	*
Emilia coccinia	*	*	
Ludwigia decurrens	*	*	*
Ludwiga eracta	*	*	*
Paspalum polystachynum	*		*
Emergent			
Pycreus lanceolatus		*	*
Eclipta prostrate		*	*
Typa latifolia		*	
Ceratophyllum demersum		*	
Altermanitaera sessile		*	*
Polygonium lanigarum		*	
Commelina benshalensis		*	
Cyparus spp.		*	
Ipomoea aquatic		*	*
Leersia hexandra		*	
Ludwigia stonolifera		*	
Mimosa pigra		*	
Vossia nymphella		*	
Phragmite karka		*	
Floating			
Azolla africana		*	*
Pistia stratiotes		*	*
Eichhornia crassipes		*	*
Nymphea lotus	*	*	*
Heterantheria callifolia		*	*

S1,= Stations 1, S2=Station 2, S3=Station 3.
Source: Author

recorded in this study is not favourable for some snail species to thrive. The significant association between water flow and the occurrence of *L. natalensis*, *Bi. pfeifferi,* and *B. truncatus* in sampling stations align with other studies (Ikpeze et al., 2020). The combined effect of high water level and high velocity of water flow during heavy rainfall are probably among the major factors affecting the differences in snail abundance in the sample stations. High water flow would likely dislodge the snails attached to vegetation; however, in microhabitats, where the water flow is stagnant or slow, snail species prefer this condition for breeding. Such habitat encourages the growth of vegetation that serve as feed for snails. Water flow observed in our study areas shows a slight steepness of the area.

The pH value in the study stations ranges from 6.30 to 7.60. The irregular rise in pH between stations was due to the photosynthetic activities of the submerged macrophytes which could reduce their CO_2 content (Nwosu et al., 2015). It could also be affected by dissolved organic matter derived from allochthonous and autochthonous sources (Nwosu et al., 2015). The range of pH values reported in this study has earlier been recorded in Nigeria (Nwosu et al., 2015). The lack of a significant relationship between pH values and some bulinid (*B. truncatus* and *B. globosus*) is in agreement with another study (Nwosu et al., 2015). Meanwhile, acidic water is inimical to snail species while alkaline and calcium-rich water are highly suitable for some snail species. Similarly, slightly alkaline water could increase the rate of infections in snail species while infection in snail intermediate host reduces as water becomes acidic. More so, pH could affect the incubation, hatching, and growth of the snails (Strzelec and Królczyk, 2004). The recorded pH values from this study seem tolerable for most snail species.

There was a distinct variation in calcium content in the study areas. Our study stations had calcium ion concentration with a range of 22.90 mg/l to 38.40 mg/l. The high concentration of calcium in this station could be due to the high level of mineralization and concentration of salt through evaporation. The slight seasonal fluctuations observed throughout sampling periods may be attributable to the seasonal flora and fauna incorporating calcium ions into their tissues. A record of snail co-existence occurs where there are variations in the concentration of calcium ions (Agi and Okwuosa, 2001). In this study, the values of calcium ions do not align with similar reports (Ugbomoiko et al., 2007).

The significant monthly variation in magnesium ion content recorded in the study stations could be attributable to mineralization due to inflow from the magnesium-containing compound from adjoining rice farms and the concentration of salt through evaporation. Report showed that magnesium ions constitute about 0.6% of the chemical composition of snail shell (Jatto et al., 2010). In New Zealand, snail intermediate hosts were not recorded in the sampled water bodies due to the high concentration of magnesium content (Duggan et al., 2002). More so, reproductive inhibition was observed in *M. tuberculata* that are exposed to water with an increase in magnesium content in the laboratory. In the present study, the values of magnesium were much lower than the range (17.98 mg/l to 69.98 mg/l) recorded in India (Sharma et al., 2013). A significant relationship observed between *B. truncatus* and magnesium showed the tolerance of the snail species for moderate magnesium content.

The mean value of dissolved oxygen in all the sample stations in this study was approximately 4.93 mg/l. The solubility of oxygen is affected by temperature and it increases considerably in cold water (Zhang et al., 2010). Dissolved oxygen varied significantly across the stations. This could be attributable to poor aerating action due to intense biological or human activities occurring in the sampling sites. In contrast to the views that the dissolved oxygen of water bodies generally influence the distribution and abundance of freshwater snails (Mohamed et al., 2011), there was no significant relationship with snail abundance in this study which agrees with previous observations in Southwestern Nigeria (Oloyede et al., 2017; Owojori et al., 2006).

Overall, the mean alkalinity value of 27.80 Mg/L$CaCO_3$ was recorded; there was no distinct variation in the alkalinity in all the stations during this study. This is similar to the findings in Nigeria (Ugbomoiko et al., 2007) and Egypt (Mohamed et al., 2011). In this study, alkalinity positively correlated with all snail species recorded in all the stations which is in agreement with the previous findings (Dida et al., 2014) where a significant positive correlation occurred between alkalinity and the distribution of *Bi. pfeifferi* and *B. africanus* in Tanzania.

Various investigators have reported variations in the relationship between different freshwater snail species in different water bodies (Cañete et al., 2004; Kazibwe et al., 2006; Owojori et al., 2006). There was a variation in the relationship among snail species in the water body. For instance, *B. jousseaumei* positively correlated with all the snail species encountered. This could be an indication that there is no interspecific competition between *B. jousseaumei* and all the other snail species. Similarly, *B. globosus* correlated with all the snail species. This is in agreement with other findings where a positive correlation occurred between *Bi. pfeifferi* and *B. truncatus* in Eleyele river (Oloyede et al., 2017). The positive correlation between *M. tuberculata* and bulinids in this study is in deviance to other studies in Nigeria (Salawu and Odaibo, 2014). Although *M. tuberculata* could compete for the same food materials with different bulinid species (Giovanelli et al., 2005) and such competition could lead to the elimination of bulinid species (Salawu and Odaibo, 2014); however, such competition could be significant if the abundance of *M. tuberculata* is more than the bulinid species in their natural environment.

Conclusion

Our report showed a comprehensive report on the status of the water bodies in Patigi and the interplay between the snail species and physicochemical parameters. Since the presence of snail intermediate host of schistosome is confirmed in the study area and the effect of different physicochemical parameters on the survival of the snail species is demonstrated, environmental modification and the introduction of control measures should be done to eliminate schistosomiasis in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdulkadir A, Ahmed M, Abubakar BM, Suleiman IE, Yusuf I, Imam IM, Sule AA, Tela UM, Dogo HM, Yakasai AM, Musa BM (2017). Prevalence of urinary schistosomiasis in Nigeria, 1994-2015: Systematic review and meta-analysis. African Journal of Urology 23(3):228-239.

Abdulkareem BO, Habeeb KO, Kazeem A, Adam AO, Samuel UU (2018). Urogenital s chistosomiasis among School children and the associated risk factors in selected rural communities of Kwara State. Nigeria Journal of Tropical Medicine 2018:1-6.

Afiukwa FN, Nwele DE, Uguru OE, Ibiam GA, Onwe CS, Ikpo AU, Agumah NB, Odoemena OF (2019). Transmission dynamics of Urogenital Schistosomiasis in the rural community of Ebonyi State, South Eastern Nigeria. Journal of Parasitology Research 2019:1-8

Agi PI, Okwuosa VN (2001). Aspects of water quality of freshwater systems harbouring snail vectors of schistosome parasites in Jos. Nigeria Journal of Aquatic Sciences 16(1):13-17.

Ajakaye OG, Adedeji OI, Ajayi PO (2017). Modeling the risk of transmission of schistosomiasis in Akure North Local Government Area of Ondo State, Nigeria using satellite derived environmental data. PLoS Neglected Tropical Diseases 11(7):e0005733.

Ajao E (1990) The influence of domestic and industrial effluents on populations of sessile and benthic organisms in Lagos Lagoon Unpublished Doctoral Thesis), University of Ibadan.

Akindel AA, Adedeji OA, Amoo B, Adekunle AA, Adedokun SA, Bolaji OS, Olowe OA, Ojurongbe O (2020). Epidemiology and burden of *Schistosoma haematobium* infection among school children in Osun State, Nigeria. American Journal of Biomedical Sciences pp. 173-182.

Akinwale O, Oso O, Salawu O, Odaibo A, Tang P, Chen T, Gyang P (2015). Molecular characterisation of *Bulinus* snails – intermediate hosts of schistosomes in Ogun State, South-western Nigeria. Folia Malacologica 23(2):137-147.

Amarir F, Sebti F, Abbasi I, Sadak A, Fellah H, Nhammi H, Ameur B, El Idrissi AL, Rhajaoui M (2014). *Schistosoma haematobium* detection in snails by DraI PCR and Sh110/Sm-Sl PCR: Further evidence of the interruption of schistosomiasis transmission in Morocco. Parasites and Vectors 7(1):1-8.

Brown DS (1994). Freshwater snails of Africa and their medical importance in freshwater snails of Africa and their medical importance pp. 1-760.

Cañete R, Yong M, Sánchez J, Wong L, Gutiérrez A (2004). Population dynamics of intermediate snail hosts of *Fasciola hepatica* and some environmental factors in San Juany Martinez Municipality, Cuba Memorias Do Instituto. Oswaldo Cruz 99(3):257-262.

Chibwana FD, Tumwebaze I, Mahulu A, Sands AF, Albrecht C (2020). Assessing the diversity and distribution of potential intermediate hosts snails for urogenital schistosomiasis: *Bulinus* spp. (Gastropoda: Planorbidae) of Lake Victoria. Parasites and Vectors 13(1):1-18.

Dida GO, Gelder FB, Anyona DN, Matano AS, Abuom PO, Adoka SO, Ouma C, Kanangire CK, Owuor PO, Ofulla AVO (2014). Distribution and abundance of schistosomiasis and fascioliasis host snails along the Mara river in Kenya and Tanzania. Infection Ecology and Epidemiology 4(1):24281.

Duggan IC, Green JD, Shiel RJ (2002). Distribution of rotifer assemblages in North Island, New Zealand, lakes: Relationships to environmental and historical factors. Freshwater Biology 47(2):195-206.

Exum NG, Kibira SPS, Ssenyonga R, Nobili J, Shannon AK, Ssempebwa JC, Tukahebwa EM, Radloff S, Schwab KJ, Makumbi FE (2019). The prevalence of schistosomiasis in Uganda: A nationally representative population estimate to inform control programs and water and sanitation interventions. PLoS Neglected Tropical Diseases 13(8):e0007617.

Giovanelli A, Coelho Da Silva CLPA, Eccard Leal GB, Baptista DF (2005). Habitat preference of freshwater snails in relation to environmental factors and the presence of the competitor snail *Melanoides tuberculatus* (Müller, 1774) Memorias Do Instituto. Oswaldo Cruz 100(2):169-176.

Gryseels B, Polman K, Clerinx J, Kestens L (2006). Human schistosomiasis. The Lancet 368(9541):1106-1118.

Jatto OE, Asia IO, Medjor WE (2010). Proximate and mineral composition of different species of snail shell. The Pacific Journal of Science and Technology 11(1):416-419.

Joof E, Sanyang AM, Camara Y, Seyid AP, Baldeh I, Jah SL, Ceesay SJ, Sambou SM, Sanyang S, Wade CM, Sanneh B (2021). Prevalence and risk factors of schistosomiasis among primary school children in four selected regions of the Gambia. PLoS Neglected Tropical Diseases 15(5):e0009380.

Kazibwe F, Makanga B, Rubaire-Akiiki C, Ouma J, Kariuki C, Kabatereine NB, Booth M, Vennervald BJ, Sturrock RF, Stothard JR (2006). Ecology of *Biomphalaria* (Gastropoda: Planorbidae) in Lake Albert, Western Uganda: snail distributions, infection with schistosomes and temporal associations with environmental dynamics. Hydrobiologia 568(1):433-444.

King CH, Sutherland LJ, Bertsch D (2015). Systematic review and meta-analysis of the impact of chemical-based mollusciciding for control of *Schistosoma mansoni* and *S. haematobium* Transmission. PLoS Neglected Tropical Diseases 9(12):e0004290

Knight M, Arican-Goktas HD, Ittiprasert W, Odoemelam EC, Miller AN, Bridger JM (2014). Schistosomes and snails: a molecular encounter. Frontiers in Genetics 5(July):230.

Léger E, Borlase A, Fall CB, Diouf ND, Diop SD, Yasenev L, Catalano S, Thiam CT, Ndiaye A, Emery A, Morrell A, Rabone M, Ndao M, Faye B, Rollinson D, Rudge JW, Sène M, Webster JP (2020). Prevalence and distribution of schistosomiasis in human, livestock, and snail populations in Northern Senegal: a One Health epidemiological study of a multi-host system. The Lancet Planetary Health 4(8):e330-e342.

Lund AJ, Sam MM, Sy AB, Sow OW, Ali S, Sokolow SH, Merrell SB, Bruce J, Jouanard N, Senghor S, Riveau G, Lopez-Carr D, De Leo GA (2019). Unavoidable risks: Local perspectives on water contact behavior and implications for schistosomiasis control in an agricultural region of Northern Senegal. American Journal of Tropical Medicine and Hygiene 101(4):837-847.

Mohamed AH, Ahmed HO-A, Amal AM, Heba MF (2011). Population dynamics of freshwater snails (Mollusca: Gastropoda) at Qena Governorate, Upper Egypt. Egyptian Academic Journal of Biological Sciences, B. Zoology 3(1):11-22.

Ntonifor HN, Ajayi JA (2007). Studies on the ecology and distribution of some medically important freshwater snail species in Bauchi State, Nigeria. International Journal of Biological and Chemical Sciences 1(2):121-127.

Nwele DE, Afiukwa FN, Uhuo CA, Ibiam GA, Agumah NB (2017). Human water contact activities and associated urogenital schistosomiasis in Nkalagu Community, Ebonyi State, Nigeria. Nigerian Journal of Parasitology 38(2):153-158.

Nwosu D, Nwachukwu P, Avoaja D, Ajero C, Nwanjo H, Obeagu EI, Nnorom R, Okpara K, Kanu SN (2015). Index of potential contamination for urinary schistosomiasis in Afikpo North LGA, Ebonyi State, Nigeria. Eur J Biomed Pharm Sci 2(1):439-450.

Ojo JA, Adedokun SA, Akindele AA, Olorunfemi AB, Otutu OA, Ojurongbe TA, Thomas BN, Velavan TP, Ojurongbe O (2021). Prevalence of urogenital and intestinal schistosomiasis among school children in south-west Nigeria. PLoS Neglected Tropical Diseases 15(7):e0009628.

Oladejo MK, Oloyede OO, Adesakin TA, Morenikeji OA (2021). The abundance, distribution and diversity of invasive and indigenous freshwater snails in a section of the Ogunpa River, southwest Nigeria. Molluscan Research 41(3):222-234.

Olkeba BK, Boets P, Mereta ST, Yeshigeta M, Akessa GM, Ambelu A, Goethals PLM (2020). Environmental and biotic factors affecting freshwater snail intermediate hosts in the Ethiopian rift valley region. Parasites and Vectors 13(1):1-13.

Olofintoye LK, Odaibo AB (1996). Influence of ecological factors in the population and infection dynamics of *Bulinus globosus* and *Biomphalaria pfeifferi* in the river Odo-Ona, Ibadan, Nigeria. Helminthologia 33(2):81-86.

Oloyede OO, Otarigho B, Morenikeji O (2017). Diversity, distribution and abundance of freshwater snails in Eleyele dam, Ibadan, south-west Nigeria. Zoology and Ecology 27(1):35-43.

Omonijo AO, Asaolu SO, Ofoezie IE (2016). Ecology of *Schistosoma* snail vectors in Ado-Ekiti local government area, Ekiti State, Nigeria. International Journal of Pure and Applied Zoology 14(1):77-84.

Oso OG, Odaibo AB (2020). Human water contact patterns in active schistosomiasis endemic areas. Journal of Water and Health 18(6):946-955.

Otuneme OG, Obebe OO, Sajobi TT, Akinleye WA, Faloye TG (2019). Prevalence of Schistosomiasis in a neglected community, South western Nigeria at two points in time, spaced three years apart. African Health Sciences 19(1):1338-1345.

Owojori OJ, Asaolu SO, Ofoezie IE (2006). Ecology of freshwater snails in Opa Reservoir and Research Farm Ponds at Obafemi Awolowo University Ile-Ife, Nigeria. Journal of Applied Sciences 6(15):3004-3015.

Rabone M, Wiethase JH, Allan F, Gouvras AN, Pennance T, Hamidou AA, Webster BL, Labbo R, Emery AM, Garba AD, Rollinson D (2019). Freshwater snails of biomedical importance in the Niger River Valley: Evidence of temporal and spatial patterns in abundance, distribution and infection with *Schistosoma* spp. Parasites and Vectors 12(1):1-20.

Salawu O, Odaibo A (2014). The bionomics and diversity of freshwater snails species in Yewa North, Ogun State, Southwestern Nigeria. Helminthologia 51(4):337-344.

Sharma KK, Bangotra K, Saini M (2013). Diversity and distribution of Mollusca in relation to the physico-chemical profile of Gho-Manhasan stream. Jammu (J and K) International Journal of Biodiversity and Conservation 5(4):240-249.

Hajissa K, Muhajir AE, Eshag HA, Alfadel A, Nahied E, Dahab R, Ali SM, Mohammed M, Gaafar M, Mohamed Z (2018). Prevalence of schistosomiasis and associated risk factors among school children in Um-Asher Area, Khartoum, Sudan. BMC research notes 11(1):1-5.

Stothard JR, Ameri H, Khamis IS, Blair L, Nyandindi US, Kane RA, Johnston DA, Webster BL, Rollinson D (2013). Parasitological and malacological surveys reveal urogenital schistosomiasis on Mafia Island, Tanzania to be an imported infection. Acta Tropica 128(2):326-333.

Stothard JR, Mgeni AF, Khamis S, Seto E, Ramsan M, Hubbard SJ, Kristensen TK, Rollinson D (2002). New insights into the transmission biology of urinary schistosomiasis in Zanzibar. Transactions of the Royal Society of Tropical Medicine and Hygiene 96(5):470-475.

Strzelec M, Królczyk A (2004). Factors affecting snail (Gastropoda) community structure in the upper course of the Warta river (Poland) Biologia – Section. Zoology 59(2):159-163.

Théron A (2015). Chronobiology of trematode cercarial emergence: From data recovery to epidemiological, ecological and evolutionary implications. Advances in Parasitology 88:123-164.

Tumwebaze I, Clewing C, Dusabe MC, Tumusiime J, Kagoro-Rugunda G, Hammoud C, Albrecht C (2019). Molecular identification of *Bulinus* spp. intermediate host snails of *Schistosoma* spp. In crater lakes of western Uganda with implications for the transmission of the *Schistosoma haematobium* group parasites. Parasites and Vectors 12(1):1-23.

Ugbomoiko US, Ofoezie IE, Okoye IC, Heukelbach J (2010). Factors associated with urinary schistosomiasis in two peri-urban communities in south-western Nigeria. Annals of Tropical Medicine and Parasitology 104(5):409-419.

Ugbomoiko US, Onajole AT, Edungbola LD (2007). Prevalence and intensity of geohelminths infection in Oba-Ile community of Osun State, Nigeria. Nigerian Journal of Parasitology 27(1):62-67.

Yigezu G, Mandefro B, Mengesha Y, Yewhalaw D, Beyene A, Ahmednur M, Abdie Y, Kloos H, Mereta ST (2018). Habitat suitability modelling for predicting potential habitats of freshwater snail intermediate hosts in Omo-Gibe river basin, Southwest Ethiopia. Ecological Informatics 45:70-80.

Zhang W, Cao ZD, Peng JL, Chen BJ, Fu SJ (2010). The effects of dissolved oxygen level on the metabolic interaction between digestion and locomotion in juvenile southern catfish (*Silurus meridionalis* Chen) Comparative Biochemistry and Physiology - A Molecular and Integrative. Physiology 157(3):212-219.