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The bionomics and diversity of freshwater snails species in Yewa North, Ogun State, Southwestern Nigeria

O. T. SALAWU[1,2*], A. B. ODAIBO[2]

[1]Department of Biosciences and Biotechnology, Babcock University, Ilishan-Remo, Ogun State, Nigeria,
[*]E-mail: *zootund@yahoo.com*; [2]Parasitology Research Unit, Department of Zoology, University of Ibadan, Nigeria

Summary

Snail control as a form of integrated control for schistosomiasis has been strongly advocated but data on biocontrol using competitor snails are relatively lacking in most endemic areas. Monthly sampling of freshwater snails was conducted in four water bodies in Yewa North Local Government Area, Ogun State, Nigeria. Monthly *in situ* measurements of the physico-chemical characteristics of surface waters were carried out using field meters. A total number of 13 snail species were recovered from the water bodies. Of these, *Bulinus camerunensis* was reported for the first time in Nigeria. A significant positive relationship occurred between snail density and dissolved oxygen. Other important relationships were those between *Lanistes lybicus* and *Bulinus senegalensis*, *Bulinus globosus* and *Bulinus jousseaumei*, and *B. senegalensis* and *Segmentorbis augustus*. Snail control using competitor snails should be integrated into schistosomiasis management programmes in endemic areas in order to prevent residual schistosomiasis transmission after control intervention through mass drug treatment.

Keywords: schistosomiasis, freshwater snail diversity, physico-chemical parameters, biocontrol, Nigeria

Introduction

Schistosomiasis continues to be one of the most important and widespread neglected parasitic diseases in Nigeria especially in areas with poor water supply. The interplay between the infective stage of the causal organisms '*Schistosoma* spp.' which develop within specific snail and human definitive hosts when in contact with the transmission foci has been the incriminating factor.

Schistosoma haematobium is transmitted through snails primarily of the genus *Bulinus*, which contains around 37 species within 4 species groups. *Bulinus* spp. are extensively distributed throughout much of Africa, Madagascar, parts of the Middle East and Mediterranean (Brown, 1994). However, the intermediate host-parasite relationship is complex, in terms of specificity and compatibility, with both genetic and environmental factors playing a role in determining small-scale heterogeneities in schistosomiasis transmission (Rollinson *et al.*, 2001).

Environmental factors affect the distribution patterns, the life cycles and population dynamics of snails and hence patterns of transmission (Rollinson *et al.*, 2001). General studies on the ecology of freshwater snails in Nigeria have considered rainfall, pH, oxygen concentration, conductivity and presence or absence of macrophytes (Ndifon and Ukoli 1989; Olofintoye & Odaibo, 1996; Owojori *et al.*, 2006).

The majority of studies on schistosomiasis laid emphasis on disease prevalence andintensity of infection among human populations with little or no emphasis on the intermediate snail hosts.Some of such studies involving the local spatial and temporal transmission patterns for *S. haematobium* include those in Zanzibar (Rudge *et al.* 2008), in Tanzania (Hamburger *et al.*, 2004), in Niger (Labbo *et al.*, 2008), in Kenya (Clennon *et al.*, 2006), in Nigeria (Oladejo & Ofoezie, 2006), and in the Senegal River Basin (Opara *et al.*, 2007).

This study aims to assess the freshwater snails' distributions and the interactions between them in order to device a possible *Schistosoma* biological control measure in the study areas. In addition, we also assessed the physico-chemical factors that may influence snail distribution.

Materials and methods

Study area

The study was conducted in four river bodies in Yewa North Local Government, Ogun state, Nigeria. These river bodies are major water bodies with very high degree of human-water contact. The Local Government Area (LGA)

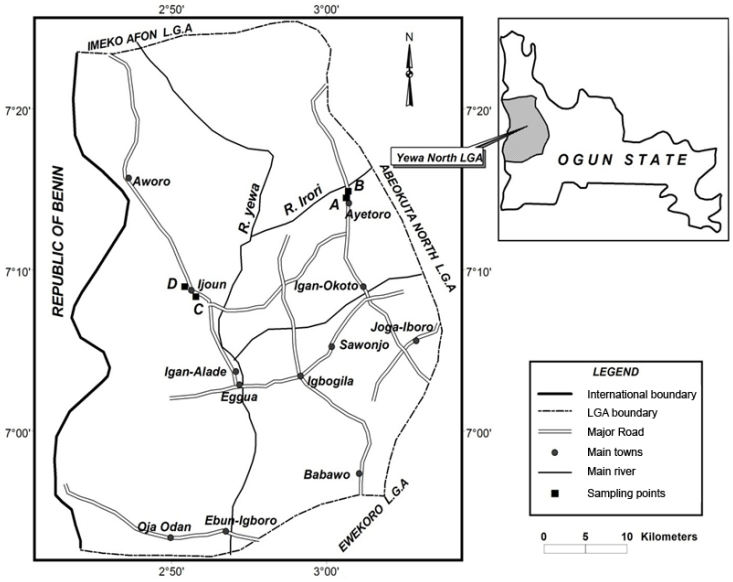

Fig. 1. The Map of Yewa North LGA, Ogun State, Nigeria
A – river Bareke, B – Irori, C – Idi, D – Isopa

has the largest land area in the Ogun state and is located in latitude 7°15′N and longitude 3°3′E in a deciduous/derived savannah zone (Onakomaya *et al.*, 1992). The LGA is one of the most endemic communities for *S. haematobium* in Ogun State, Nigeria (Mafiana *et al.*, 2003; Ekpo *et al.*, 2008). A preliminary study conducted by our group in the area revealed a prevalence of 54.8 % in school children (Hassan *et al.*, 2012), 9.8 % in preschool children (Salawu & Odaibo, 2014) and 21.5 % in pregnant women (Salawu & Odaibo, 2013). The endemicity of the disease is due to lack of good water sources thereby compelling the community dwellers to depend on water from river bodies for their domestic uses (Salawu & Odaibo, 2013).

Snail sampling

Snail samplings were carried out in four water bodies including Bareke (depth 88.9 ± 8.5 cm), Orori (93.8 ± 11.1 cm), Idi (132.5 ± 17.1 cm) and Isopa rivers (195.5 ± 204 cm) located in Ayetoro and Ijoun communities (Fig. 1). The predominant aquatic macrophytes in all the water bodies include *Nymphaea lotus*, *Polygonum senegalense*, *Echinochloa pyramidal* and *Vossia cuspidate*. The selection of the four water bodies was based on the degree of human-water contact activities. All sites of sampling are representative of the water bodies. Only one site in each water body was sampled with the same visited each month. Two river bodies (Bareke and Orori) were selected in Ayetoro town (a peri-urban settlement). The other two water bodies (Idi and Isopa) were located in Ijoun (a typical rural settlement). Snails were randomly sampled for 20 minutes along the littoral zones where human-water contact activities occurred using a long handled scoop (0.2 mm mesh) net once every month from February, 2010 to January, 2012 (Olofintoye & Odaibo, 1996). Each scoop

Table 1. Abundance of freshwater snails species in selected rivers in Yewa North LGA, Ogun State

	River bodies					
Snail species	**Bareke**	**Orori**	**Idi**	**Isopa**	**Total**	**% Abundance**
Melanoides tuberculata	63	0	19	27	109	12.9
Potadoma moerchi	2	0	26	17	45	5.3
Lanistes lybicus	27	91	36	122	276	32.6
Bulinus globosus	0	0	2	6	8	0.9
B. senegalensis	28	2	2	8	40	4.7
B. camerunensis	25	0	0	5	30	3.5
B. jousseaumei	0	0	0	9	9	1.1
Segmentorbis augustus	9	0	0	2	11	1.3
Ferrissia sp	37	13	60	29	139	16.4
Biomphalaria pfeifferi	0	0	0	1	1	0.1
Gyraulus costulatus	1	1	56	115	173	20.4
Lymnaea natalensis	0	0	0	5	5	0.6
Number of species	10	5	8	13	13	
Total	192	107	201	346	846	100

was thoroughly searched and all snails collected were kept in pre-labeled plastic containers containing wet cotton wool. The container was then covered with perforated lids and was taken to the laboratory where they were washed, identified and counted (to determine the number of each snail species collected per month). *Bulinus camerunensis* was identified based on the presence of aperture more than the half of the body and somewhat broad shell. The snails were identified using reference specimens from the Danish Bilharziasis Laboratory Charlothenlund, Denmark. The vouchered collection of the specimens was housed in the Department of Zoology, University of Ibadan, Nigeria.

Measurement of physico-chemical parameters

Monthly *in situ* determinations of water temperature, pH, total dissolved solid (TDS) and conductivity were carried out using the electronic combined meter (model M1806). Dissolved oxygen (DO) was determined using DO meter (model MW600). The rainfall data was obtained from the Meteorological Station in Abeokuta, Ogun State Nigeria. Sampling was done usually between 9 a.m. and 12 p.m.

Data analyses

Data were entered into an Excel spreadsheet, checked for entry errors and transferred into SPSS for Windows (version 17.0, SPSS Inc, Chicago, USA) for analysis. A One-way Analysis of Variance (ANOVA) was used to compare the difference in snail abundance between water bodies. Post-hoc Bonferroni adjustment (where appropriate) was used to account for multiple comparisons. Karl Pearson's equation of coefficient of correlation was used to assess the relationships between snail abundance and the physico-chemical parameters, and biological interactions between different snail species. Snail diversity index for species richness was determined using Margalef's diversity index (Margalef 1951). Shannon Wiener index (H) was used for the general diversity and evenness (E) of distribution (Ajao, 1990). The P-values < 0.05 were considered statistically significant.

Results

Diversity and distribution of snails

Thirteen species of snails belonging to six orders and eight families were recovered from the water bodies. A total number of 846 snails were recovered from the rivers. Of these, *B. camerunensis* (Mandahl-Barth, 1957) was reported for the first time in Nigeria (Fig. 2). Isopa River was richest water course in snail species (Table 1). Irori River had the least, with only four species. The total number of snails sampled throughout the sampling period also followed a similar pattern with Isopa (338) and Irori (107) having the highest and least number respectively. *Lanistes lybicus* (Morelet, 1848) (276) was the most abundant while *Biomphalaria pfeifferi* (Krauss, 1848) (1) constituted the least number (Table 1). *Lanistes lybicus*, *Bulinus senegalensis* (Müller, 1781), *Gyraulus costulatus* (Krauss, 1848) and *Ferrissia* sp. (Walker, 1903) were present in all the four rivers. Two snail species *B. pfeifferi* and *L. natalensis* were found only in Isopa River. Bareke, Isopa and Idi rivers had the highest relative abundance of *Melanoides tuberculata* (Müller, 1774) (57.8 %), *L. lybicus* (33.3 %) and *Ferrissia* sp. (43.2 %) respectively.

Generally snail abundance varied significantly across the river bodies ($P<0.05$). However, results from multiple comparisons showed no significant difference in the snail abundance of Idi and Isopa rivers. The diversity of snails in Bareke river was significantly higher than those of other rivers ($P<0.05$). However, there was no significant difference in snail diversity of Isopa and Idi rivers (Table 2).

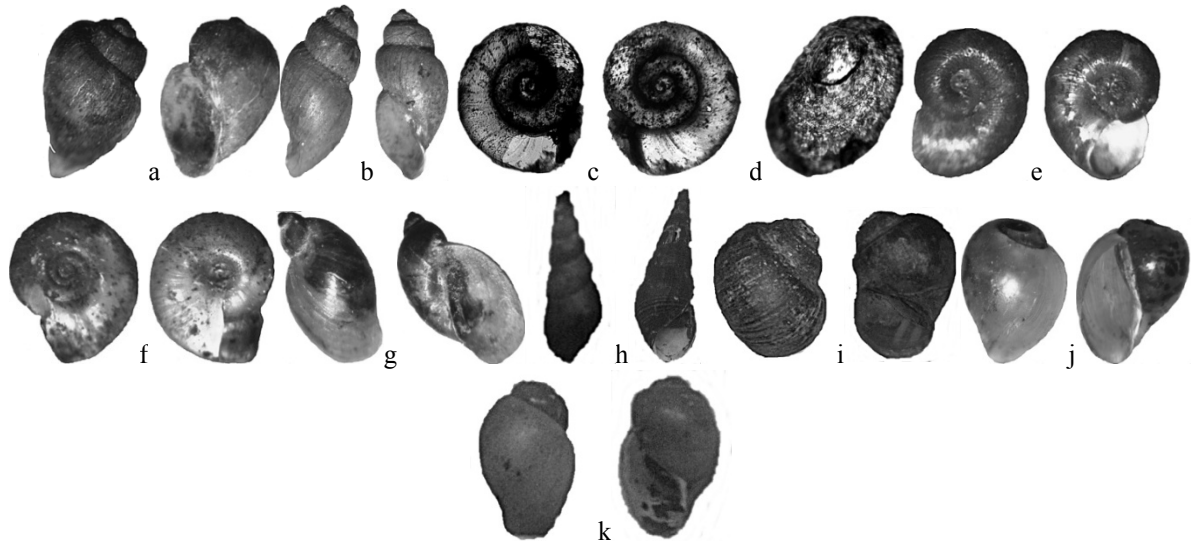

Fig. 2. Snail species recovered from the selected river bodies
a. *Bulinus camerunensis* (3.0 mm); b. *B. senegalensis* (5.0 mm); c. *Biomphalaria pfeifferi* (3.0 mm); d. *Ferrissia* sp (3.0 mm); e. *Gyraulus costulatus* (3.0 mm); f. *Segmentorbis augustus* (3.0 mm); g. *Lymnaea natalensis* (9.0 mm); h. *Potadoma moerchi* (21.0 mm); i. *Lanistes lybicus* (29.0 mm); j. *B. jousseaumei* (6.0 mm); k. *B. globosus* (8.0 mm);

Table 2. Biodiversity indices of snails in selected rivers in Yewa North LGA, Ogun State

Indices	Bareke	Irori	Idi	Isopa
Species Richness Index (d)	1.676[a]	0.841[b]	1.301[c]	2.053[d]
Shanon-Weiner Index (H)	0.822[a]	0.324[b]	0.760[c]	0.741[c]
Shanon Index (H′)	1.893[a]	0.746[b]	1.750[c]	1.706[c]
Evenness Index (E′)	0.762[a]	0.300[b]	0.811[c]	0.687[d]

Note: similar alphabets denote no significance difference while different alphabets denote there were significant differences

Snail densities were generally higher in the dry season with a total of 460 and 379 snails recovered during the dry and wet seasons respectively. The early rainy period of the second wet season (May, 2011) recorded the highest snail abundance (78) while the late rainy period of the first wet season (October, 2010) had least snail density (12) (Fig. 3). An inverse relationship existed between snail density and rainfall pattern of the area.

Seasonal variations in physico-chemical parameters and relationships with snail density

Generally, temperature varied significantly in the different water bodies (P<0.05). However, the results of the multiple comparisons of temperature in different locations showed no significant variation in temperature values in Bareke and Irori Rivers. The mean temperature values in the dry and wet seasons were 25.4 ± 2.1°C and 25.7 ± 1.1°C respectively. The relationships between temperature and snail abundance varied with different species of snails. Increasing in temperature showed significant positive correlations with *G. costulatus* (r=0.336; P<0.01) and *B. globosus* (Morelet 1866) (r=0.272; P<0.05). Although not significant, negative correlations were observed between temperature and abundance of *M. tuberculata*, *B. camerunensis*, *B. senegalensis* and *L. natalensis*.

There were similarities in the pH variations in the river bodies. Bareke River had the least mean pH value (6.7 ± 0.9) while others had 6.9 each (Table 3). The overall mean pH value was 6.9 ± 0.8 with values ranging from the minimum value 5.3 recorded in Idi River (December, 2010) to 8.6 recorded in Irori River (June, 2010). There was no significant variation in pH values of the river bodies. The pH also showed no significant variations with seasons but higher in the dry season (6.9 ± 0.9) than the wet season (6.8 ± 0.8). The pH of the water bodies showed significant positive correlation with the abundance of *G. costulatus* (r=0.292; P<0.05), however, the positive relationship was not significant with the abundance of *B. globosus* and *B. senegalensis*. Negative relationships were observed between pH of the rivers and the following aquatic snails; *L. lybicus*, *P. moerchi* and *L. natalensis*.

There was a wide variation in dissolved oxygen values across sampling sites. The overall mean value of dissolved oxygen was 6.1 ± 4.6 mg/L with values ranging from 1.02mg/L in Bareke River (June, 2010) and Irori (March-June, 2010) to 17.2 mg/L in Isopa River (May, 2011). Bareke River had the smallest mean dissolved oxygen value (3.4 ± 2.0 mg/L) while Isopa River recorded the highest mean dissolved oxygen value (8.1 ± 4.9 mg/L). Generally dissolved oxygen varied significantly with the river bodies and seasons (P<0.05) with dry seasons recording higher mean value (6.3 ± 3.9mg/L) compared with the wet seasons (6.0 ± 5.1mg/L). Dissolved oxygen showed significant positive correlations with *L. lybicus* (r=0.387; P<0.01), *Ferrissia* sp. (r=0.356; P<0.01) and *L. natalensis* (r=0.324; P<0.01).

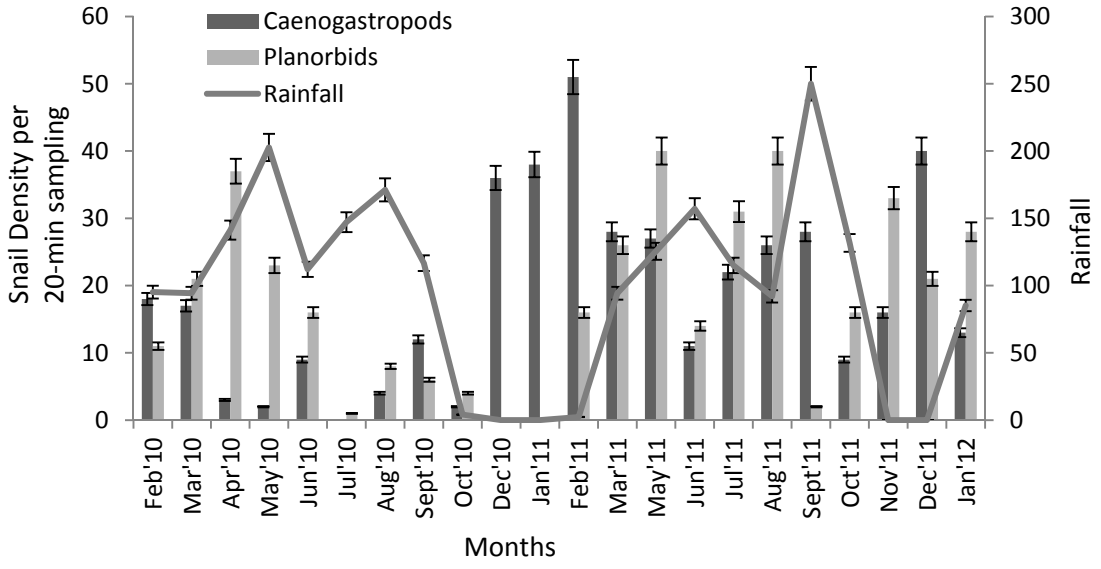

Fig. 3. Monthly variation in snail density in relation to rainfall pattern in selected river bodies in Yewa North LGA, Ogun State

Table 3. Variations in physicochemical parameters of selected water bodies

River bodies	Physicochemical parameters Mean ± SD (Range)				
	Temp (°C)	DO (mg/L)	pH	Cond (µS/cm)	TDS (mg/L)
Bareke	25.2 ± 1.5 (21.8 – 28.0)	3.4 ± 2.0 (1.0 – 6.8)	6.7 ± 0.9 (5.5 – 8.5)	77.5 ± 56.0 (26.7 – 258.0)	39.3 ± 30.3 (20.0 – 151.0)
Irori	25.0 ± 1.5 (21.7 – 27.5)	4.9 ± 4.4 (1.0 – 15.2)	6.9 ± 0.9 (5.8 – 8.6)	75.9 ± 18.0 (41.4 – 120.0)	41.7 ± 10.8 (23.3 – 67.5)
Idi	25.9 ± 1.7 (22.3 – 29.0)	7.9 ± 4.8 (3.0 – 17.1)	6.9 ± 0.8 (5.3 – 8.5)	46.7 ± 16.6 (22.8 – 70.7)	24.7 ± 11.2 (10.0 – 49.8)
Isopa	26.3 ± 1.5 (23.7 – 28.5)	8.1 ± 4.9 (1.5 – 17.2)	6.9 ± 0.8 (6.0 – 8.5)	47.9 ± 19.8 (23.3 – 106.9)	24.7 ± 12.2 (10.0 – 63.9)

DO – Dissolved Oxygen, TDS – Total Dissolved Solids, Cond – Conductivity

Electrical conductivity varied widely in the different water bodies. The overall mean conductivity value of the rivers was 63.0 ± 34.5 µS/cm. Bareke River had the highest mean conductivity value (77.5 ± 56.0 µS/cm) while Idi River had the least value (46.7 ± 16.6 µS/cm) (Table 3). The minimum value (22.8 µS/cm) was recorded in Idi River in January, 2012 while the maximum value (258.0 µS/cm) was recorded in Bareke River in October, 2011. Conductivity varied significantly with river bodies ($P<0.05$) but variation was not significant with seasons. Conductivity showed negative correlations with most of the snail species. More importantly was the significant negative correlation between conductivity and abundance of *L. lybicus* ($r=-0.262$; $P<0.05$). A significant positive relationship was however observed between conductivity and abundance of *B. senegalensis* ($r=0.269$; $P<0.05$).

The overall mean value for total dissolved solids in all the water bodies was 32.5 ± 19.4 mg/L. Irori River had the highest mean total dissolved solids value (41.7 ± 10.8 mg/L) while Idi and Isopa Rivers had the least mean value (each 24.7 mg/L). The total dissolved solids like conductivity varied significantly with river bodies ($P<0.05$) but was not significant with seasons.

Relationships between snails

Melanoides tuberculata correlated negatively with *G. costulatus*, *L. lybicus*, *P. moerchi* and *S. augustus*. However, *M. tuberculata* showed a significant positive correlation with the abundance of *Ferrissia* sp. ($r=0.462$; $P<0.05$) and *L. natalensis* ($r=0.308$; $P<0.05$). *L. lybicus* showed negative relationships with *B. senegalensis* ($r=-0.240$; $P<0.05$), *S. augustus*, *B. camerunensis*, *Ferrissia* sp and *L. natalensis*. However, *L. lybicus* correlated positively with *B. globosus*. Other important relationships include the significant positive relationship between *B. senegalensis* and *S. augustus* ($r=0.657$; $P<0.01$), *B. globosus* and *B. jousseaumei* ($r=0.30$; $P<0.05$), *B. camerunensis* and *B. senegalensis* ($r=0.841$; $P<0.01$) (Table 4).

Discussion

Although shell characteristics suggest an identification of *Bulinus camerunensis*, a first report of such in Nigeria freshwater habitats, this needs to be confirmed by mo-

Table 4. Relationships between physico-chemical parameters and snail density

	Temp	pH	DO	TDS	Cond	Mel	Gyr	Lan	B.g	B.s	Pot	Seg	B.c	Fer	L.n	B.j
Temp	1	.07	-.16	-.13	-.14	-.17	.34*	-.14	.27*	-.03	.10	-.11	-.03	-.06	-.03	.09
pH		1	.03	.16	-.08	.00	.29*	-.21	.15	.10	-.03	.07	-.00	.04	-.04	.04
DO			1	-.25*	-.26*	.17	.11	.39*	.18	-.07	.15	-.08	-.06	.36*	.32*	.31*
TDS				1	.97*	-.02	-.17	-.27*	-.22	.29*	-.14	.10	.24*	-.16	-.09	-.14
Cond					1	-.04	-.22	-.26*	-.22	.27*	-.13	.11	.22	-.17	-.10	-.14
Mel						1	-.02	-.05	.00	.13	-.06	-.03	.06	.46*	.31*	-.05
Gyr							1	.03	.23*	.02	.18	.00	-.08	-.04	-.06	-.06
Lan								1	.12	-.24*	.01	-.17	-.17	-.06	-.02	.02
B.g									1	.03	.08	.09	-.07	.06	.08	.30*
B.s										1	-.00	.66*	.84	.08	.03	-.04
Pot											1	-.02	-.02	.13	-.05	-.03
Seg												1	.61*	.01	-.05	-.03
Hom													.00	-.08	-.07	-.04
B.c													1	.01	-.02	-.03
Fer														1	.09	-.04
L.n															1	-.02
																1

*Correlation is significant at 0.05 level (2-tailed)

Temp – Temperature, DO – Dissolved Oxygen, TDS – Total Dissolved Solids, Cond – Conductivity, Mel – *M. tuberculata,* Gyr – *G. costulatus,* Lan – *L. lybicus,* B.g – *B. globosus,* B.j – *B. jousseaumei,* B.s – *B. senegalensis,* Pot – *P. moerchi,* Seg – *S. augustus,* B.c – *B. camerunensis,* Fer – *Ferrisia* sp, L.n – *L. natalensis*

lecular analysis of the samples. An earlier report on the snail intermediate hosts of *Schistosoma* has revealed the occurrence of *B. jousseaumei* in Isopa River (Salawu & Odaibo, 2012). The ecology of the snail as influenced by the physicochemical parameters of the river and its role in *Schistosoma* transmission has also been reported (Salawu & Odaibo, 2012). *Bulinus camerunensis* has only been reported in Cameroon and its characteristic shell and exceedingly small radula teeth separate it from all other *Bulinus* (Mandahl-Barth, 1965). Although it is a known intermediate host of *Schistosoma haematobium in* Cameroon (Brown, 1994), its status as intermediate host of *Schistosoma* in Nigeria is not known as no infected individuals were discovered in the present study.

The probable influence of water flowing from bordering countries in the introduction of alien snail species into these river bodies has been reported earlier (Salawu & Odaibo, 2012). Certain long distance migratory birds employed by aquatic snails for their dispersion have also been incriminated (Wesselingh *et al.*, 1999).

Of the thirteen species of snail encountered, *B. pfeifferi* and *B. globosus* are established intermediate hosts of schistosomiasis in Nigeria (Olofintoye & Odaibo, 1999; Oladejo & Ofoezie, 2006). However, the lack of infected *B. pfeifferi* and *B. globosus* is surprising in such highly endemic community with over 50 and 20 % prevalence of urogenital schistosomiasis in school children and pregnant women respectively (Salawu & Odaibo, 2013, 2014). Although, our earlier study (Salawu & Odaibo, 2013) reported the occurrence of infected *B. jousseaumei* using the classical method of cercariae shedding (Salawu & Odaibo, 2012), their absence in other potential intermediate hosts cannot be proven, hence a more reliable method of infection detection in snails is advocated.

The higher density of snails recorded in the dry season could have been due to the indirect impacts of flourishing microflora (food supply) and aquatic macrophytes during the season. The macrophytes supply the water with dissolved oxygen and also provide suitable surface on which the snails can crawl and deposit their egg masses. The low water current in the dry season could also offer a stable environment for snails to lodge onto surfaces and not being washed away (WHO, 1965). During the wet season, rainfall affects water movement and temperature, thereby, affecting the distribution and density of the aquatic snails (Appleton, 1978; Sturrock, 1993). Snail intermediate hosts of *Schistosoma* are intolerant of strong currents, and breeding colonies are not found in swift flowing streams or water bodies; they are usually found in areas where the velocity off low is below 40 cm/s (Jones, 1993). This probably accounts for most of the snails in our study being recovered along the littoral zone; where the water current velocity is very low.

Temperature has been recognized as an important factor on any biotope especially freshwater (Hira, 1970). Several studies have reported the influence of temperature on certain stages of aquatic snails. The optimum temperatures for hatching *B. globosus* eggs is 25 – 28 °C while at higher temperatures, hatching rate and survival decreases (Madsen, 1985). Egg production in *Biomphalaria* spp. has been shown to reduce at temperatures above 30°C due to pathological changes in the reproductive system of the snails (Madsen, 1985).High temperature causes thermal stress in snail vectors and shows an inverse relationship with dissolved oxygen (Hofkins *et al.*, 1991).The temperature range of 21.7 – 29 °C recorded in all river bodies during the study appears therefore to be favourable to the aquatic snails, as there were no significant changes in temperature throughout the sampling seasons.

The mean pH value in all the water bodies in the present study was within favourable limits for aquatic snail development (Boelee & Laamrani, 2004). The higher mean pH value recorded during the dry season could be due to higher transparency of the water bodies resulting in active removal of carbon (iv) oxide and consequently production of oxygen through photosynthesis. The concentration of hydrogen ions is rarely a factor conditioning the presence and distribution of the snails (Madsen, 1985). This probably explains the insignificant relationships between abundance of snails and pH values in our study.

The mean dissolved oxygen (6.1 ± 4.6 mg/L) recorded in this study falls within the desired range (0.4 and 16.0 mg/L) for snail intermediate hosts (Harman & Berg, 1971). The high dissolved oxygen content is a result of fast flowing river types washing away most of the polluting materials (Salawu & Odaibo, 2012) and greater mixing due to the current. During one of the sampling months in Bareke River, a low dissolved oxygen (1.02 mg/L) recorded in June, 2010 could have resulted to the limited number of snails (only 2) sampled during this period. In addition, Bareke River with the least overall mean dissolved oxygen content recorded lower number of snails compared to Isopa River with higher dissolved oxygen content. A low concentration of oxygen, even if not immediately fatal to the snail, reduces its movements and thus impairs feeding and reproduction (Malek, 1958). An increase in snail abundance influenced by an increase in dissolved oxygen observed in this study has also been reported elsewhere (Boelee & Laamrani, 2004).

The higher conductivity values reported in the wet season is unusual as other reports have indicated higher levels in the dry season (Tubonimi *et al.*, 2010). The deposition of solute materials by run-off from surrounding environments followed by reduction in ion uptake due to instability of macrobenthos population in the microhabitat had been suggested to be the reasons for such variation (Salawu & Odaibo, 2012). Seasonal variation in total dissolved solids and its relationship with snail abundance is similar to that of conductivity.

The relationships between aquatic snails differ from one species to the other. The negative correlations observed between *M. tuberculata* and some bulinids and planorbids are similar to other reports (Madsen, 1992; Giovanelli *et al.*, 2005). The diet of *M. tuberculata* is similar to that of planorbids (Giovanelli *et al.*, 2005), hence competition for food is possible. *M. tuberculata* has been reported to elimi-

nate *B. glabrata* (Giovanelli *et al.*, 2005). Part of this reduction could be attributed to the phenomenon of "one way competition" in which one species releases substances harmful to another into the water, as pointed out by Gomez *et al.*(1989) who reported that *Thiara granifera* probably produces one or more chemical factors that reduce the fecundity of *B. glabrata*. Another important factor is habitat type, which affects whether or not thiarids and planorbids are able to co-exist (Gumarães *et al.*, 2001). The role of *M. tuberculata* as a biological control agent of molluscs has been questioned, concluding that it was able to co-exist with *B. pfeifferi* and other pulmonate snails in Kenya without displacing them completely (Mkoji *et al.*, 1992). Similar mechanisms can be used to explain the interactions between *L. lybicus* and many of the planorbids especially *B. senegalensis* which showed a significant negative correlation with *M. tuberculata*. Since our result showed significant positive co-existence in the population of the planorbids (e.g. *B. globosus* and *B. jousseaumei*), it can be suggested that *L. lybicus* can serve as biocontrol for other planorbids other than *B. senegalensis*. Biological invasion of some caenogastropods especially *M. tuberculata* has also been reported to cause decline in the population of *Biomphalaria glabrata* in Martinique and Guadeloupe islands (Pointier *et al.*, 2011). One potential limitation in this study was the identification of snails based on morphological characteristics alone. The use of more sensitive molecular tools for future studies to verify the identified species would be of importance especially in the separation of ambiguous *Bulinus africanus* groups. Also, the 20 minutes sampling duration may not have been sufficient owning to relatively small number of snails recovered.

Conclusion

Our findings showed that the survival of freshwater snails in the habitat is to a large extent dependent on the physicochemical properties of the water of which dissolved oxygen is the most important. Interactions between snails also gave some insights to the biocontrol potentials of *Melanoides tuberculata* and *Lanistes lybicus* against potential intermediate hosts of schistosomes. Therefore, for all encompassing *Schistosoma* control strategies in the study area, the use of competitor snails will play a major role in reducing transmission.

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