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Research Article

Shell Morphology of Three Medical Important Tropical Freshwater Pulmonate Snails from Five Sites in South-Western Nigeria

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ABSTRACT

Biomphalaria pfeifferi, *Bulinus globosus* and *Lymnaea natalensis* act as obligatory vectors of schistosomiasis and fascioliasis in Sub-Saharan Africa. Although, they are known to be widely distributed throughout Nigeria, there is the need for precise species identification to help vector control initiatives. Snail shell morphometry has previously proved useful in taxonomic studies. We thus employed seven morphological parameters of snail shells in identifying three snail vectors from five water bodies in South-Western Nigeria. Snails were sampled for 14 months and total of 718 snails were collected, which include 204 *B. pfeifferi*, 316 *B. globosus* and 198 *L. natalensis*. Eleyele Lake had 278 snails which was the highest number followed by Osun River with 64 snails. Our finding revealed *B. globosus* as the dominant snail in all the five sites, while *B. pfeifferi* and *L. natalensis* were present in only three sites. The presence of the snails in otherwise uninfected water bodies may have implications for transmission and disease control in these areas. Our findings should prove useful for improved snail identification, information, which will be invaluable for vector control in affected communities.

How to cite this article:

Mofolusho O. Falade and Benson Otarigho, 2015. Shell Morphology of Three Medical Important Tropical Freshwater Pulmonate Snails from Five Sites in South-Western Nigeria. *International Journal of Zoological Research, 11: 140-150.*

DOI: 10.3923/ijzr.2015.140.150

URL: http://scialert.net/abstract/?doi=ijzr.2015.140.150

Received: June 22, 2015; **Accepted:** August 19, 2015; **Published:** September 01, 2015

INTRODUCTION

Freshwater snails belonging to the genus *Biomphalaria*, *Bulinus* and *Lymnaea* are common species of the subfamily Planorbidae and Lymnaeidae, respectively and are widely distributed throughout much of Sub-Sahara Africa (Mandahl-Barth, 1962; Brown, 1980; Gryseels, 1989; Jordan *et al*., 1993; WHO., 1995). Species in these genera inhabit various natural and artificial freshwater environments including shallow lakes, streams, rivers, wetlands, seasonal pools, rice paddies, irrigation canals and ponds (Brown, 1980; Gryseels, 1989; Utzinger and Tanner, 2000). Members of these families of snails are necessary intermediate hosts of blood-dwelling trematode parasites, which cause serious public health problems to man and animals in tropical and subtropical regions of the world (Brown, 1980; Gryseels, 1989; Jordan *et al*., 1993). Global losses in agriculture attributed to fascioliasis due to increase in animal mortality and reduced production is estimated in the billions. With an estimated 17 million infected and 180 million at risk of infection in endemic areas. Schistosomiasis has global prevalence of 207 million people mostly from Sub-Saharan Africa (Hotez *et al*., 2008), where the disease burden is the highest.

Some of the snails transmitting the above infections like *B. pfeifferi* and *B. globosus* transmit *Schistosoma* parasites to man causing human Schistosomiasis (Brown, 1980; Gryseels, 1989; Jordan *et al*., 1993; Opisa *et al*., 2011; Dida *et al*., 2014) while, *L. natalensis* transmits *Fasciola*

parasites to animals and man causing fascioliasis (Utzinger and Tanner, 2000; Dida *et al*., 2014). *Biomphalaria pfeifferi* is mainly found in tropical regions of Africa and Southwest Arabia. It is widespread throughout Eastern, Western and Southern Africa while Northern Africa has few isolated populations in Southeast Algeria and Southern Libya (Woolhouse, 1992). *Biomphalaria pfeifferi* populations have also become established in Southern Madagascar. It is found in number of freshwater habitats including man-made water channels (Woolhouse and Chandiwana, 1989; Bandoni *et al*., 1990; Akufongwe *et al*., 1995; Sturrock, 2001). *Biomphalaria globosus* belonging to the *Bulinus africanus* group are distributed throughout Africa, with the species further extending its distribution to Madagascar (Stothard *et al*., 2001) and the Middle East (Jorgensen *et al*., 2007). *Lymnaea natalensis* is widespread in tropical Africa, but it is rare in the Northeast coastal area (Appleton *et al*., 2009).

These three snails of immense medical importance are found in Nigeria (Thomas and Tait, 1984; Betterton, 1984; Betterton *et al*., 1988) especially in the Southwest region (Ndifon and Ukoli, 1989), with habitat fragmentation that has resulted in their patchy distribution in lakes, dams, canals, ponds and rivers. Despite the fact that these snails are well distributed in Nigeria with wide geographical range, the morphological variations of these species are poorly known making precise identification problematic and information of snail distribution in local water bodies difficult to verify. This consequently impedes control efforts to limit disease transmission via vector control herculean task.

Shell morphometric is useful tool and first step in identification in mollusc taxonomy and ecological studies (Mandahl-Barth, 1962; Abdel-Malek, 1958). In malacology, shell morphology has been useful in describing, identifying, characterizing (Wullschleger and Jokela, 2002) and recognizing intraspecific morphological variations (Schniebs *et al*., 2013). It has also assisted in deducing shell structures and properties affected by environmental variations to determine (Bertin *et al*., 2012; Mahilum and Demayo, 2014) snail geographical distribution (Goodfriend, 1986).

In this study, we conducted long time sampling of *Biomphalaria pfeifferi*, *Bulinus globosus* and *Lymnaea natalensis* from five water bodies, which include rivers and lakes in South-Western, Nigeria. Morphometric analyses were carried out on the collected snails, to better determine the range of variation in bid to improving species delineation.

MATERIALS AND METHODS

Study sites: Five water bodies which include three rivers and two lakes were selected for this study. The different water bodies are (1) Orori River, Ogun state (Latitude: 7°14’00’’ N, longitude: 3°02’00’’ E),(2) Bareke River, Ogun State (Latitude: 7^{O}14’02’’ N, longitude: 3°02’ 01’’ E), (3), Eleyele Lake, Oyo State (Latitude: 7°25'36" N, longitude: 3°51'58" E)(4) Eko-Ende Lake, Osun State (Latitude: 7°55'60" N, longitude: 4°34'60" E) and (5) Osun River, Osun State (Latitude: 7°46 N, longitude: 4°34 E). Thereis recent report of urinary schistosomiasis in communities around; Orori and Bareke rivers, Ogun State (Morenikeji and Idowu, 2011; Salawu and Odaibo, 2013, 2014) and Eko-Ende Lake and Osun River, Osun State (Hassan *et al*., 2012; Babatunde *et al*., 2013). There are also reports of animal fascioliasis around some of these water bodies (Adedipe *et al*., 2014).

Survey design: The study was conducted from October, 2012 to December, 2013. The snail collection was done early in the morning between 8.00 am and 12.00 pm using flat dip-net scooping as described by Ritchie *et al*. (1962) and Demian and Kamel (1972), however hand picking was employed in areas that were woody or rocky in nature.

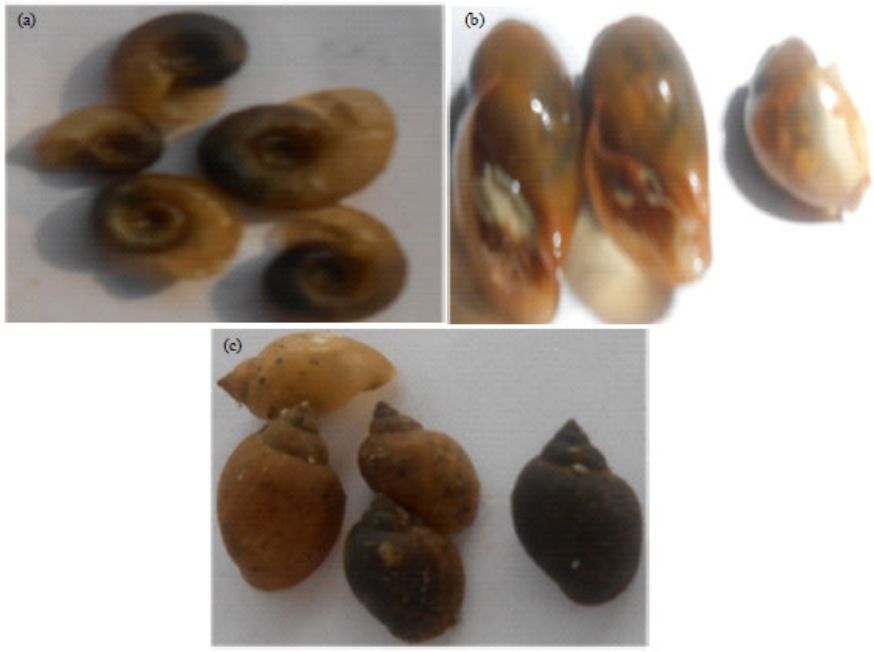

Fig. 1(a-c): Shells of (a) *Biomphalaria pfeifferi*, (b) *Biomphalaria globosus* and (c) *Lymnaea natalensis*

The collected snails were gathered in sterile plastic container and *in situ* identification was done using an identification key was employed in areas that were woody or rocky in nature. The collected snails were gathered in sterile plastic container and *in situ* identification was done using an identification key (Mandahl-Barth, 1962). A total of 718 snails were collected across the five sampling sites at the end of the sampling period, 204 *B. pfeifferi*, 316 *B. globosus* and 198 *L. natalensis*. Morphological parameters were measured using vernier caliper. The selected measurable parameters were Shell Height (SH), Shell Width (SW), Aperture Height (AH), Aperture Width (AW), Spiral Length (SL) and Aperture Circumference (AC) (Fig. 1). The measurable and non-measurable morphological parameters were selected after properly reviewing the available taxonomic shell descriptions from literature that were practical for use in snail identification (Pace, 1973; Brandt, 1974). A total of 6 continuous shell parameters were measured along imaginary straight lines as shown in Fig. 2. The raw data was entered into Excel and saved for analysis.

Data analysis: Data analysis was done on Excel 2013, using the scatter plot for shell height against shell width and aperture height against aperture width. The linear regression equation and R squared were analyzed for each graph.

RESULTS

A total of 718 Pulmonate snails were collected from the five water bodies across south-western Nigeria (Table 1-3). *Biomphalaria pfeifferi* snails were seen in only three sites out of the five sites sampled, where 204 snails were collected.

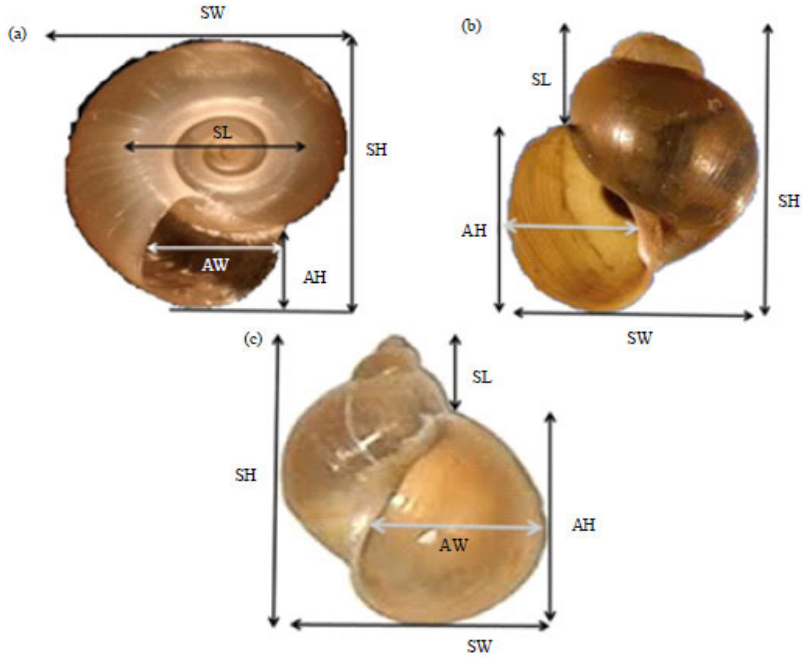

Fig. 2(a-c): Measurements made on the shells of (a) *Biomphalaria pfeifferi*, (b) *Bulinus globosus* and (c) *Lymnaea natalensis*

Table 1: Location, number of snails and measurement of 6 characters of *Biomphalaria pfeifferi* (n = 204)

Locations	Eko-Endo lake	Osun river	Eleyele lake
States	Osun state	Osun state	Osun state
No. of snails	64	26	114
Characters (X±SE)			
SH	2.47±0.13 (1.30-3.90)	2.06±0.16 (1.30-3.95)	2.82±0.13 (1.80-3.95)
SW	7.98±0.26 (6.00-10.20)	7.56±0.25 (6.00-11.00)	8.65±0.24 (5.00-12.00)
AH	2.28±0.12 (1.00-3.65)	1.83±0.15 (1.00-3.90)	2.95±0.12 (1.50-3.90)
AW	2.76±0.09 (1.90-3.70)	2.67±0.09 (1.85-3.50)	3.12±0.08 (2.00-4.00)
SL	2.06±0.14 (0.90-3.70)	1.51±0.18 (0.80-3.70)	2.46±0.11 (1.50-3.90)
AC	8.89±0.27 (7.00-11.70)	8.08±0.35 (6.00-12.20)	9.85±0.29 (7.00-14.00)

SH: Shell height, SW: Shell width, AH: Aperture height, AW: Aperture width, SL: Spiral length, AC: Aperture circumference

Table 2: Location, number of snails and measurement of 6 characters of *Bulinus globosus* (n = 316)

Locations	Orori river	Bareke river	Eko-Endo lake	Osun river	Eleyele lake
States	Ogun state	Ogun state	Osun state	Osun state	Oyo state
No. of snails	60	50	68	24	114
Characters (X±SE)					
SH	9.48±0.45 (5.10-13.00)	8.38±0.62 (5.00-14.00)	10.56±1.19 (4.00-12.80)	6.88±0.41 (5.20-9.20)	8.87±0.36 (5.00-14.00)
SW	5.86±0.39 (1.90-8.50)	4.47±0.47 (1.50-9.30)	6.53±0.98 (1.50-8.50)	4.33±0.38 (2.50-6.10)	5.19±0.32 (1.50-9.30)
AH	6.70±0.48 (2.00-10.00)	5.47±0.53 (2.00-9.50)	7.71±1.01 (2.00-10.00)	4.76±0.42 (3.00-7.10)	6.10±0.36 (2.00-10.00)
AW	3.59±0.24 (1.20-5.30)	3.13±0.26 (0.90-5.50)	4.17±0.47 (1.70-5.30)	2.77±0.30 (1.80-4.10)	3.34±0.18 (0.90-5.50)
SL	2.56±0.17 (1.00-4.00)	2.44±0.27 (0.60-6.00)	2.34±0.35 (0.50-3.00)	1.16±0.12 (0.70-1.80)	2.38±0.16 (0.60-6.00)
AC	17.85±1.30 (4.50-24.90)	16.92±1.51 (4.00-26.00)	21.74±1.66 (12.00-24.10)	18.89±0.89 (15.00-4.00)	18.12±0.92 (4.00-26.00)

SH: Shell height, SW: Shell width, AH: Aperture height, AW: Aperture width, SL: Spiral length,

AC: Aperture circumference

The highest number of *B. pfeifferi* (100 snails) were collected from Eleyele Lake in Oyo state, while 28 snails were collected from Osun River (Table 1) *Biomphalaria globosus* species were seen in the entire sites sampled with total number of 316 snails collected with the highest number (114 snails) collected from Eleyele lake and the lowest (24 snails) from Osun River (Table 2).

Table 3: Location, number of snails and measurement of 6 characters of *Lymnaea natalensis* (n = 198)

Location	Eko-Endo lake	Osun river	Eleyele lake
State	Osun State	Osun State	Oyo State
No. of snails	35	14	50
Characters (X±SE)			
SH	13.30±0.41 (9.00-19.00)	11.39±0.29 (8.80-14.00)	13.04±0.32 (9.00-19.00)
SW	7.89±0.23 (5.50-10.00)	7.96±0.21 (5.50-10.00)	7.84±0.21 (5.00-11.20)
AH	9.12±0.27 (5.80-12.00)	6.72±0.17 (4.70-8.40)	8.97±0.21 (5.80-12.00)
AW	5.22±0.13 (4.00-6.50)	4.60±0.10 (4.00-6.00)	5.11±0.11 (4.00-7.00)
SL	4.30±0.11 (3.00-6.00)	3.61±0.14 (1.80-5.00)	4.23±0.15 (2.00-7.00)
AC	22.89±0.49 (18.00-29.00)	20.83±0.34 (18.50-5.50)	22.66±0.44 (18.00-30.00)

SH: Shell height, SW: Shell width, AH: Aperture height, AW: Aperture width, SL: Spiral length, AC: Aperture circumference

Lymnaea natalensis were seen in only three sites, with 198 snails collected (Table 3).

The *B. pfeifferi* morphological parameters measured are presented in Table 1. The snails from Eleyele Lake had the highest shell height (2.82±0.13), shell width (8.65±0.24), aperture height (2.95±0.12), aperture width (3.12±0.08), spiral length (2.46±0.11) and aperture circumference (8.08±0.35), while those from Osun River had the least shell height (2.06±0.16), shell width (7.56±0.25), aperture height (1.83±0.15), aperture width (2.67±0.09), spiral length (1.51±0.18) and aperture circumference (9.85±0.29). *Biomphalaria globosus* morphological parameters measured are presented in Table 2.The snails from Eko-Endo Lake had the highest shell height (10.56±1.19), shell width (6.53±0.98), aperture height (7.71±1.01), aperture width (4.17±0.47) and aperture circumference (21.74±1.66) while, the once from Orori River had the highest spiral length (2.56±0.17). The least shell height (6.88±0.41), shell width (4.33±0.38), aperture width (2.77±0.30) were observed from snails collected from Osun River, while the least spiral length (2.38±0.16) and aperture circumference (18.12±0.92) were observed from snails collected from Eleyele Lake. The least aperture height (6.70±0.48) was observed from snails collected from Orori River. Morphological parameters measured on *L. natalensis* are presented in Table 3. The snails from Eko-Endo Lake had the highest shell height (13.30±0.41), aperture height (9.12±0.27), aperture width (5.22±0.13), spiral length (4.30±0.11) and aperture circumference (22.89±0.49), while the once from Osun River had the highest shell width (7.96±0.21). The snails from Osun River had the least shell height (11.39±0.29), aperture height (6.72±0.17), aperture width (4.60±0.10), spiral length (3.61±0.14) and aperture circumference (20.83±0.34). The least shell width was observed from snails from Eleyele Lake.

The relationship of snail species' shell length to shell width, aperture length to aperture width show linearity (Fig. 3-4). The highest and lowest coefficient of determinant (R-square) for aperture length against aperture width and shell length against shell width was observed for *B. globosus* and *B. pfeifferi*, respectively.

DISCUSSION

Mollusca are large part of the global invertebrate fauna of freshwater and marine habitats (Strong *et al*., 2008). Thus identifying these snails is of value to Zoologists, Malacologists and Conchologists because of the role they perform as intermediate hosts of the larvae of variety of trematode parasites that cause diseases of humans and animals (Appleton, 1996; Correa *et al*., 2010). Besides, the taxonomic information obtained from snail shells can be used in deducing and interpreting evolutionary history and relationship between species (Chiu *et al*., 2002).

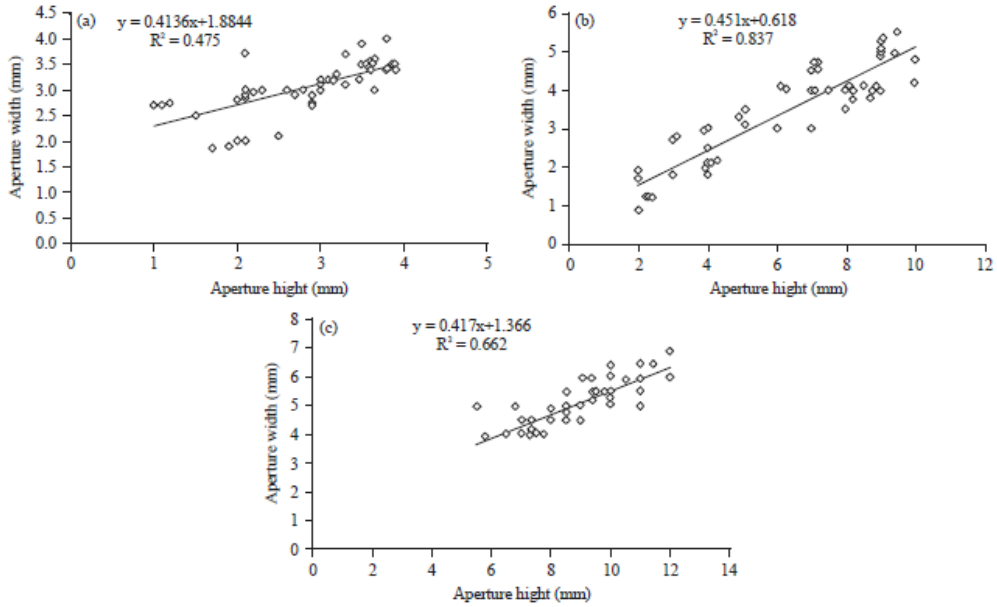

Fig. 3(a-c): Relationship of aperture length to aperture width of (a) *Biomphalaria pfeifferi,* (b) *Bulinus globosus* and (c) *Lymnaea natalensis*

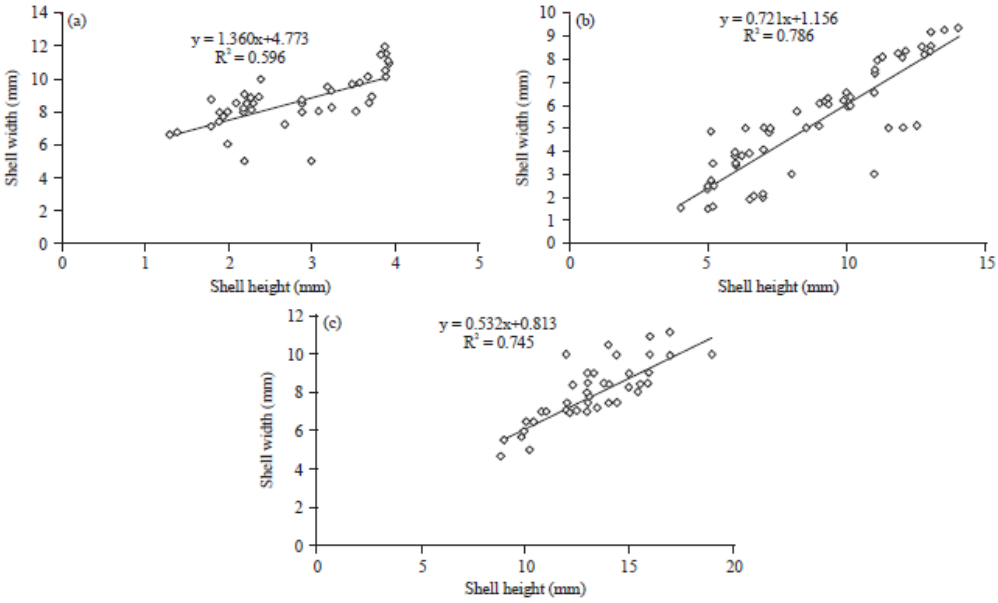

Fig. 4(a-c): Relationship of shell length to shell width of (a) *Biomphalaria pfeifferi*, (b) *Bulinus globosus* and (c) *Lymnaea natalensis*

Moreover, malacological studies that confirm the presence of snail species that have being incriminated as medically or veterinary important species could explain the presence, potential risk and/or the spread of diseases such as schistosomiasis and fascioliasis to areas that were not formally endemic for these diseases (De Kock *et al*., 2004). The spread of schistosomiasis and fascioliasis in most African countries particularly to areas where the disease was not endemic has been attributed to the presence of the intermediate snail vector populating man-made habitats, such as irrigation canals and small dams, which have been known to serve as sites for disease transmission (Adenowo *et al*., 2015). Various studies have shown that the presence of snail intermediate host may determine the prevalence and explain the increased transmission of trematode infections in these areas. Thus, the determination of the distribution of the snail intermediate hosts of molluscan-borne diseases through e.g., shell morphology represent an important advance for epidemiological studies that are central to making public health-control decisions for control of snail vectors of trematode infections (Ibikounle *et al*., 2008). There is need for better documentation of these snail species in an endemic country like Nigeria where there is paucity of information from endemic sites. This work therefore, sought to employ seven morphological parameters of snail shell in identification of three snail vectors from five water bodies in South-Western Nigeria.

Although, no report exists of schistosomiasis around Eleyele Lake, the presence of both *B. pfeifferi* and *B. globosus* in the lake may pose the risk of the disease being introduced to the surrounding communities in the future. This is because fishing and other agricultural activities are being carry out daily, therefore allowing human water contact. Studies of populations living in areas endemic for schistosomiasis have shown that unavoidable contact with water for farming, fishing and recreation have led to increased transmission of schistosomiasis (Olubode *et al*., 2011). Despite the fact that there are no reports of human schistosomiasis in communities around Eleyele lake, PCR analysis of water

samples collected from this Lake indicated the presence of *S. haematobium* cercariae (Akande *et al*., 2012).

Some water bodies like Eko-Endo Lake, Osun River and Eleyele Lake are rich in molluscan fauna. These water bodies habour the three pulmonate snails studied in this work. *Biomphalaria pfeifferi* and *B. globosus* are found in waters across Sub-Sahara Africa where their role as intermediate hosts in the transmission of human schistosomiasis are well documented (Mandahl-Barth, 1962; Brown, 1980; Gryseels, 1989; Jordan *et al*., 1993; WHO., 1995; Dejong *et al*., 2003). *Lymnaea natalensis* is also found throughout Africa with a wider distribution, occurring from north to south of the continent (Appleton *et al*., 2009). The three pulmonate snails studied are well distributed and are abundant in Nigeria, particularly in the South (Ndifon and Ukoli, 1989) which could account for the high endemicity of schistosomiasis, fascioliasis and other molluscan-borne diseases in this region of country (Brown, 1980; Ndifon and Ukoli, 1989). Our study observations indicate *B. globosus* to have the widest distribution based on the water bodies sampled and was the most abundant species. This may explain why *S. haematobium* has wider distribution than *S. mansoni* around the studied area since its intermediate vector is *B. globosus* (WHO., 2010).

We observed that Eleyele and Eko-Endo Lakes are rich in terms of molluscan fauna. In addition to the highest numbers of *B. pfeifferi*, *B. globosus* and *L. natalensis* collected from these two sites. We also collected other snail species such as *Melanoides tuberculate* (Prosobranch). However, these were of lesser interest to this work and were not investigated further. Besides, the snail shells collected from these lakes were bigger when compared to those collected from the rivers in this study, though it was not our aim to compare snails collected from the lakes to those collected from rivers. linear relationship was observed when shell length to shell width of each snail species was compared. similar relationship was also observed for aperture length when compared to aperture width. This pattern of association has been observed in many studies, both among freshwater (Chiu *et al*., 2002; Elkarmi and Ismail, 2007) and marine snail species (Ismail *et al*., 2000).

This study presents the morphological features of the shell of *B. pfeifferi*, *B. globosus* and *L. natalensis* from five sites from South-Western Nigeria. The findings in this study should prove useful for snail identification by taxonomist and epidemiological field researchers working around potential transmission sites. Although, shell morphology of snails is rich in taxonomic information (Dung *et al*., 2013; Pesic and Gloer, 2013), studies employing alternative tools such as molecular identification, using housekeeping genes (ITS, COI and 16S), can be used *pari passu* with findings from morphological identification. To this end we are currently characterizing these snails using molecular identification tools, which will further help in delineating these species.

REFERENCES

Abdel-Malek, E., 1958. Distribution of the intermediate hosts of bilharziasis in relation to hydrography; with special reference to the Nile Basin and the Sudan. Bull. World Health Organiz., 18: 691-734.
PubMed | Direct Link |

Adedipe, O.D., E.C. Uwalaka, V.O. Akinseye, O.A. Adediran and S.I.B. Cadmus, 2014. Gastrointestinal Helminths in slaughtered cattle in Ibadan, south-Western Nigeria. J. Vet. Med., Vol. 2014. 10.1155/2014/923561

Adenowo, A.F., B.E. Oyinloye, B.I. Ogunyinka and A.P. Kappo, 2015. Impact of human schistosomiasis in sub-Saharan Africa. Braz. J. Infect. Dis., 19: 196-205.
CrossRef | Direct Link |

Akande, I.S., A.A. Odetola, D.O. Osamudien, M.A. Fowora and E.A. Omonigbehin, 2012. Polymerase Chain Reaction (PCR) investigations of prepatent Schistosoma haematobium cercariae incidence in five water bodies, South West, Nigeria. Afr. J. Med. Med. Sci., 41: 75-80.
PubMed | Direct Link |

Akufongwe, P.F., B. Dondji, V.N. Okwuosa, D.A. Dakul and H.N. Ntonifor, 1995. Observed disparity on schistosome infection rates in field *Biomphalaria pfeifferi* (Krauss) between two areas of the Jos metropolis, Nigeria. Parasite, 2: 89-91.
PubMed | Direct Link |

Appleton, C., M. Ghamizi, A. Jorgensen, T.K. Kristensen, A.S. Stensgaard and D. van Damme, 2009. Lymnaea natalensis. IUCN Red List of Threatened Species (2010.4 ed.), IUCN OCLC 45139101.

Appleton, C.C., 1996. Freshwater Molluscs of Southern Africa: With a Chapter on Bilharzia and Its Snail Hosts. University of Natal Press, Pietermaritzburg, South Africa, ISBN: 9780869809198, Pages: 64.

Babatunde, T.A., S.O. Asaolu and O.A. Sowemimo, 2013. Urinary schistosomiasis among pre-school and school aged children in two peri-urban communities in Southwest Nigeria. J. Parasitol. Vector Biol., 5: 96-101.
Direct Link |

Bandoni, S.M., M. Mulvey, D.K. Koech and E.S. Loker, 1990. Genetic structure of Kenyan populations of *Biomphalaria pfeifferi*(Gastropoda: Planorbidae). J. Mollus. Stud., 56: 383-391.

CrossRef | Direct Link |

Bertin, A., V.H. Ruiz, R. Figueroa and N. Gouin, 2012. The role of spatial processes and environmental determinants in microgeographic shell variation of the freshwater snail *Chilina dombeyana* (Bruguiere, 1789). Naturwissenschaften, 99: 225-232.
CrossRef | Direct Link |

Betterton, C., 1984. Ecological studies on the snail hosts of schistosomiasis in the South Chad Irrigation Project Area, Borno State, northern Nigeria. J. Arid Environ., 7: 43-57.
Direct Link |

Betterton, C., G.T. Ndifon, S.E. Bassey, R.M. Tan and T. Oyeyi, 1988. Schistosomiasis in Kano State, Nigeria. I. Human infections near dam sites and the distribution and habitat preferences of potential snail intermediate hosts. Ann. Trop. Med. Parasitol., 82: 561-570.
PubMed | Direct Link |

Brandt, R.A., 1974. The Non-Marine Aquatic Mollusca of Thailand. Vol. 105, Senckenbergische Naturforschende Gesellschaft, USA., Pages: 423.

Brown, D.S., 1980. Freshwater Snails of Africa and their Medical Importance. Taylor and Francis Ltd., London, UK., Pages: 487.

Chiu, Y.W., H.C. Chen, S.C. Lee and C.A. Chen, 2002. Morphometric analysis of shell and operculum variations in the viviparid snail, *Cipangopaludina chinensis* (Mollusca: Gastropoda), in Taiwan. Zool. Stud., 41: 321-331.
Direct Link |

Correa, A.C., J.S. Escobar, P. Durand, F. Renaud and P. David *et al*., 2010. Bridging gaps in the molecular phylogeny of the Lymnaeidae (Gastropoda: Pulmonata), vectors of Fascioliasis. BMC Evol. Biol., Vol. 10. 10.1186/1471-2148-10-381

De Kock, K.N., C.T. Wolmarans and M. Borman, 2004. Distribution and Habitats of *B. pfeifferi* Snail intermediate host of *S. mansoni* in South Africa. Water SA., 30: 80-87.

Dejong, R.J., J.A.T. Morgan, W.D. Wilson, M.H. Al-Jaser and C.C. Appleton *et al*., 2003. Phylogeography of *Biomphalaria glabrata* and B. *pfeifferi*, important intermediate hosts of *Schistosoma mansoni* in the new and old world tropics. Mol. Ecol., 12: 3041-3056.
CrossRef | Direct Link |

Demian, E.S. and E.G. Kamel, 1972. Growth and population dynamics of *Bulinus truncatus* under semi-field conditions in Egypt. Proc. Egypt. Acad. Sci., 25: 37-60.

Dida, G.O., F.B. Gelder, D.N. Anyona, A.S. Matano and P.O. Abuom *et al*., 2014. Distribution and abundance of schistosomiasis and fascioliasis host snails along the Mara River in Kenya and Tanzania. Infect. Ecol. Epidemiol. 10.3402/iee.v4.24281

Dung, B.T., P.N. Doanh, D.T. The, H.T. Loan, B. Losson and Y. Caron, 2013. Morphological and molecular characterization of lymnaeid snails and their potential role in transmission of *Fasciola* spp. in Vietnam. Korean J. Parasitol., 51: 657-662.
CrossRef | PubMed | Direct Link |

Elkarmi, A.Z. and N.S. Ismail, 2007. Growth models and shell morphometrics of two populations of *Melanoides tuberculata* (Thiaridae) living in hot springs and freshwater pools. J. Limnol., 66: 90-96.
CrossRef | Direct Link |

Goodfriend, G.A., 1986. Variation in land-snail shell form and size and its causes: A review. Syst. Biol., 35: 204-223.
CrossRef | Direct Link |

Gryseels, B., 1989. The relevance of schistosomiasis for public health. Trop. Med. Parasitol., 40: 134-142.
PubMed | Direct Link |

Hassan, A.O., A.O.J. Amoo, O.P. Akinwale, A.M. Deji-Agboola, M.A. Adeleke, P.V. Gyang and A. Oluwadun, 2012. Human water contact activities and urinary schistosomiasis around Erinle and Eko-ende dams. Global Adv. Res. J. Med. Med. Sci., 1: 77-84.
Direct Link |

Hotez, P.J., P.J. Brindley, J.M. Bethony, C.H. King, E.J. Pearce and J. Jacobson, 2008. Helminth infections: The great neglected tropical diseases. J. Clin. Invest., 118: 1311-1321.

CrossRef | Direct Link |

Ibikounle, M., A. Massougbodji, N.G. Sakiti, J.P. Pointier and H. Mone, 2008. Anatomical characters for easy identification between *Biomphalaria pfeifferi*, *Helisoma duryi* and *Indoplanorbis exustus* during field surveys. J. Cell Anim. Biol., 2: 112-117.
Direct Link |

Ismail, N.S., A.Z. Elkarmi and S.M. Al-Moghrabi, 2000. Population structure and shell morphometrics of the corallivorous gastropod *Drupella cornus* (Gastropoda: Prosobranchia) in the Gulf of Aqaba, Red Sea. Ind. J. Mar. Sci., 29: 165-170.
Direct Link |

Jordan, P., G. Webbe and R.F. Sturrock, 1993. Human Schistosomiasis. 3rd Edn., CAB International, Oxford.

Jorgensen, A., L.V.G. Jorgensen, T.K. Kristensen, H. Madsen and J.R. Stothard, 2007. Molecular phylogenetic investigations of *Bulinus* (Gastropoda: Planorbidae) in Lake Malawi with comments on the topological incongruence between DNA loci. Zool. Scripta, 36: 577-585.
CrossRef | Direct Link |

Mahilum, J.J.M. and C.G. Demayo, 2014. Describing lake populations of the golden apple snail, *Pomacea canaliculata* using landmark-based geometric morphometric analysis. J. Entomol. Zool. Stud., 2: 139-144.
Direct Link |

Mandahl-Barth G., 1962. Key to the identification of east and central African freshwater snails of medical and veterinary importance. Bull. World Health Organ., 27: 135-150.
Direct Link |

Morenikeji, O.A. and B.A. Idowu, 2011. Studies on the prevalence of urinary schistosomiasis in Ogun State, south-western Nigeria. West Afr. J. Med., 30: 62-65.
CrossRef | Direct Link |

Ndifon, G.T. and F.M.A. Ukoli, 1989. Ecology of freshwater snails in South-Western Nigeria. I: Distribution and habitat preferences. Hydrobiologia, 171: 231-253.
CrossRef | Direct Link |

Olubode, O.S., R.O. Awodoyin and S. Ogunyemi, 2011. Floral diversity in the wetlands of Apete river, Eleyele lake and Oba dam in Ibadan, Nigeria: Its implication for biodiversity erosion. West Afr. J. Applied Ecol., 18: 109-119.
CrossRef | Direct Link |

Opisa, S., M.R. Odiere, W.G. Jura, D.M. Karanja and P.N. Mwinzi, 2011. Malacological survey and geographical distribution of vector snails for schistosomiasis within informal settlements of Kisumu City, Western Kenya. Parasites Vectors, Vol. 4. 10.1186/1756-3305-4-226

Pace, G.L., 1973. Freshwater snails of Taiwan. Malacol. Rev., 1: 24-31.

Pesic, V. and P. Gloer, 2013. A new freshwater snail genus (Hydrobiidae, Gastropoda) from Montenegro, with a discussion on gastropod diversity and endemism in Skadar Lake. ZooKeys, 281: 69-90.
CrossRef | Direct Link |

Ritchie, L.S., M.G. Radke and F.F. Ferguson, 1962. Populations dynamics of *Australorbis glabratus* in Puerto Rico. Bull. World Health Organiz., 27: 171-181.
Direct Link |

Salawu, O.T. and A.B. Odaibo, 2013. Schistosomiasis among pregnant women in rural communities in Nigeria. Int. J. Gynecol. Obstetrics, 122: 1-4.
CrossRef | Direct Link |

Salawu, O.T. and A.B. Odaibo, 2014. Urogenital schistosomiasis and urological assessment of hematuria in preschool-aged children in rural communities of Nigeria. J. Pediatric Urol., 10: 88-93.
CrossRef | Direct Link |

Schniebs, K., P. Gloer, M.V. Vinarski and A.K. Hundsdoerfer, 2013. Intraspecific morphological and genetic variability in the European freshwater snail *Radix labiata* (Rossmaessler, 1835)(Gastropoda: Basommatophora: Lymnaeidae). Contributions Zool., 82: 55-68.

Direct Link |

Stothard, J.R., P. Bremond, L. Andriamaro, B. Sellin, E. Sellin and D. Rollinson, 2001. *Bulinus* species on madagascar: Molecular evolution, genetic markers and compatibility with *Schistosoma haematobium*. Parasitology, 123: S261-S275.
PubMed | Direct Link |

Strong, E.E., O. Gargominy, W.F. Ponder and P. Bouchet, 2008. Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia, 595: 149-166.
CrossRef | Direct Link |

Sturrock, R.F., 2001. Schistosomiasis epidemiology and control: How did we get here and where should we go? Mem. Inst. Oswaldo Cruz, Reo de Janerio, 96: 17-27.
Direct Link |

Thomas, J.D. and A.I. Tait, 1984. Control of the snail hosts of schistosomiasis by environmental manipulation a field and laboratory appraisal in the Ibadan area, Nigeria. Phil. Trans. R. Soc. Trop. Med. Hyg., 305: 201-253.
CrossRef | Direct Link |

Utzinger, J. and M. Tanner, 2000. Microhabitat preferences of *Biomphalaria pfeifferi* and *Lymnaea natalensis* in a natural and a man-made habitat in southeastern Tanzania. Memorias do Instituto Oswaldo Cruz, 95: 287-294.
CrossRef | Direct Link |

WHO, 1995. Control of foodborne trematode infections. Technical Sheet No. 849, World Health Organization, Geneva, Switzerland.

WHO., 2010. Atlas of global distribution of schistosomiasis. World Health Organization, Washington, DC.

Woolhouse, M.E.J. and S.K. Chandiwana, 1989. Spatial and temporal heterogeneity in the population dynamics of *Bulinus globosus* and *Biomphalaria pfeifferi* and in the epidemiology of their infection with schistosomes. Parasitology, 98: 21-34.
CrossRef | Direct Link |

Woolhouse, M.E.J., 1992. Population biology of the freshwater snail *Biomphalaria pfeifferi* in the Zimbabwe highveld. J. Applied Ecol., 29: 687-694.
CrossRef | Direct Link |

Wullschleger, E.B. and J. Jokela, 2002. Morphological plasticity and divergence in life-history traits between two closely related freshwater snails, *Lymnaea ovata* and *Lymnaea peregra*. J. Mollus. Stud., 68: 1-5.
CrossRef | Direct Link |