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Research Article
Population Abundance and Bionomics of Snail Intermediate Hosts of Trematode Parasites in Nasarawa State, Nigeria

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Abstract
Background and Objective: Snail intermediate hosts play active role in the transmission of trematode parasites. Hence, this study assessed 105 water bodies across Nasarawa State, Nigeria for snail hosts bionomics and abundance between July, 2012 and August, 2013. **Methodology:** Snail hosts were sampled monthly in water bodies across Nasarawa State. Snail sampling was done using hand-held scooping net for 45 min and identified using shell morphology. They were screened for patent infection through exposure to sunlight individually for 2 h in a petri-dish that contains aged tap water and checked for cercarial shedding in the laboratory under a dissecting microscope. Identification was confirmed at the Natural History Museum, London snail reference laboratory. Vegetation samples were collected from each sampling site and identified. The physico-chemical parameters including pH, dissolved oxygen, conductivity and temperature of water bodies sampled for snails were obtained using hand-held meter (Combo-Hanna). **Results:** A total of 977 snail hosts were collected from the studied sites. Five different snail hosts of trematode parasites including *Bulinus globosus*, *Bulinus forskalii*, *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Indoplanorbis exutus* were sampled. Highest snail collection was 153 (15.66%) in Akwanga Local Government Area, followed by 138 (14.12%) in Lafia LGA and the least was 12 (1.23%) in Nasarawa Eggon LGA. Percentage distribution of the five snail hosts population is as follows: *B. globosus* (50.15%), *B. forskalii* (23.75%), *L. natalensis* (15.15%), *B. pfeifferi* (7.47%) and *I. exutus* (3.48%). Using R Console software version 3.2.2, one way ANOVA shows significant difference in snail's mean abundance across species (F_{520} = 20.48, adjusted R^2 = 0.1295, p<0.0001). The pH is only significant parameter influencing the pooled abundance of the five identified snail hosts in the studied water bodies across Nasarawa State. Influence of physico-chemical parameters on individual species abundance shows that temperature was significant for *B. globosus* abundance, pH was significant for *B. forskalii*, *B. pfeifferi* and *L. natalensis* while pH and dissolved oxygen were significant for *I. exutus* abundance in the sampled water bodies. **Conclusion:** Information on snail bionomics is vital for effective snail control programme.

Key words: Population, abundance, bionomics, snail intermediate hosts

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Snails are invertebrate animals found in freshwater and other ecological niches[1]. Some of these snails (especially the freshwater species of the subclass Pulmonata) are important in the epidemiology of snail-borne diseases in the tropic and subtropic regions of the world because they are known to serve as intermediate host of parasites of medical and veterinary importance[2].

The continued transmission of schistosomiasis and other snail-borne diseases are enhanced by the distribution of snail intermediate hosts that are required for the trematode parasites to thrive in areas characterized with continued neglect, poor sanitation and lack of quality infrastructure such as sanitary facilities and access to good potable water sources[3-6].

The implementation of preventive chemotherapy is the major control effort in place to reduce the morbidity of schistosomiasis that is endemic in many parts of Nigeria but has not been very successful due to re-infection after treatment[7,8]. Though, several studies[7,9-12] and intervention measures have been carried out to curtail the distribution and transmission of the snail-borne diseases caused by trematode parasites in Nigeria. However, there is dearth of reliable data on snail intermediate hosts distribution, abundance and bionomics in most areas known to be endemic for schistosomiasis and other snail-borne diseases in Nigeria.

Snail intermediate hosts are important in the epidemiology of schistosomiasis and other snail-borne diseases[2] because of their unique role in facilitating the development of the infective cercariae which penetrate human skin in water for further development[13].

Hence, this makes snail host studies crucial for effective control of schistosomiasis and other snail-borne diseases whose control and elimination is one of the main goals of the World Health Organization as declared in the resolution passed at the World Health Assembly (WHA 65.21) in 2012.

Therefore, this study assessed the population abundance and bionomics of snail intermediate hosts of trematode parasites in Nasarawa State, Nigeria with a view to providing information that will help initiate and set-up an effective snail host control programme in Nasarawa state.

MATERIALS AND METHODS

Study area: The study was carried out in 105 water bodies across 12 local government areas of Nasarawa state, North central Nigeria (Fig. 1). The LGAs surveyed for snail intermediate hosts include; Awe, Akwanga, Karu, Keana, Keffi, Kokona, Lafia, Nasarawa, Nasarawa-Eggon, Obi, Toto and Wamba LGAs. Nasarawa State has a total land area of 27,137.8 km^2 and it shares borders in the west with the Federal Capital Territory, Abuja, in North with Nasarawa state lies within the Guinea Savannah region and has tropical climate with moderate rainfall (annual mean rainfall of 1311:75 cm). The state is made up of plain lands and hills measuring up to 300 ft a.s.l., at some points (http://www.canuk. org.uk/about nigeria.aspx., 2011).

Snail sampling: Snail intermediate hosts were sampled monthly from 105 water bodies across 12 LGAs of Nasarawa state, North central Nigeria between July, 2012 and August, 2013. The sites were visited in the morning for snail hosts collection. Snail sampling was done using hand-held scooping net (diameter: 18 cm and 0.2 mm mesh) supported by a frame mounted on a 2 m long handle for 45 min in each of the water bodies sampled for collection. Manual search with visual inspection and hand-picking was also employed along the length of the water bodies at various sites. Collections were made in water bodies with visible water contacts and areas without apparent water contacts were also sampled for snails. Collected snails were transported to the laboratory where they were washed, identified and snail host population was recorded for each site.

Screening for patent infection: The snails were exposed to sunlight individually for 2 h in a petri-dish that contains aged tap water. They were screened for cercarial shedding in the laboratory under a dissecting microscope.

Morphological identification of vector snails: The snails were identified using shell morphology according to Brown and Kristensen[14]. This was achieved by holding the snail shell with the apex (pointed edge) pointing upward. When the aperture (shell opening below the body whorl) opens to the right, it is termed dextral but when the aperture opens to the left it is termed sinitral. More so, the sculptural marking on the snail shell was considered during identification. Other shell components considered during identification include number of whorls, shape of the shell, type of apex (sharp or blunt) and shape of the peristome on the aperture. The snail intermediate hosts identification was confirmed at the Department of Life Sciences snail reference laboratory, Natural History Museum, Cromwell road, London.

Sampling of vegetation from the water bodies: Vegetation samples were collected from each sampling site and

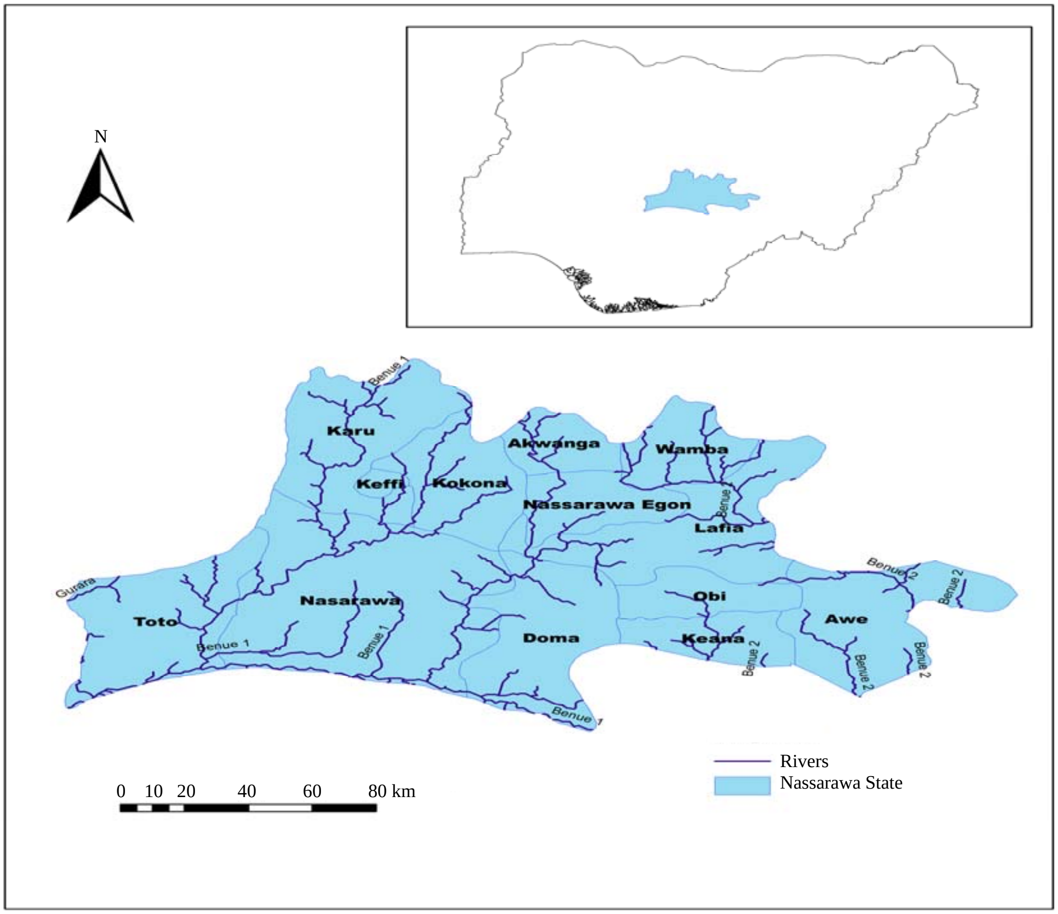

Fig. 1: Map of Nigeria showing Nasarawa state

identified. Identification of aquatic vegetation samples collected from the sampling sites was carried out according to Arbonnier[15] and was confirmed using reference specimen from the Department of Botany, Benue State University, Makurdi, Benue State, Nigeria.

Water physico-chemical parameters: The physico-chemical parameters including pH, dissolved oxygen, conductivity and temperature of water bodies sampled for freshwater snail intermediate hosts were obtained by dipping the hand-held portable meter (Combo HANNA, USA) inside the water bodies for 5 min staying in one spot while the meter reading is taken and recorded. The physico-chemical parameters for each sampling site were recorded accordingly.

Data analysis: Data obtained was analyzed using R Console software version 3.2.2. One way analysis of variance (ANOVA) was used to compare the mean abundance of snails between snail species. Two way analysis of variance (ANOVA) was used to determine the abundance of snails in relation to snail species and physico-chemical parameters. Pearson's product-moment correlation was used to determine the association between the numbers of snails and physico-chemical parameters. The $p<0.05$ was considered statistically significant. In addition, SPSS software (version 17, USA) was used to carry out descriptive analysis of the study.

RESULTS

Distribution and abundance of snail intermediate hosts in selected water bodies in Nasarawa state: A total of 977 freshwater snail intermediate hosts were collected from the 105 studied water bodies sampled for snails in the 12 LGAs across Nasarawa state between July, 2012 and August, 2013. Five different snail hosts of trematode parasites including *Bulinus globosus*, *Bulinus forskalii*, *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Indoplanorbis exutus* were identified using shell morphology shown in Fig. 2. Highest snail abundance of 153 (15.66%) were collected from 14 water

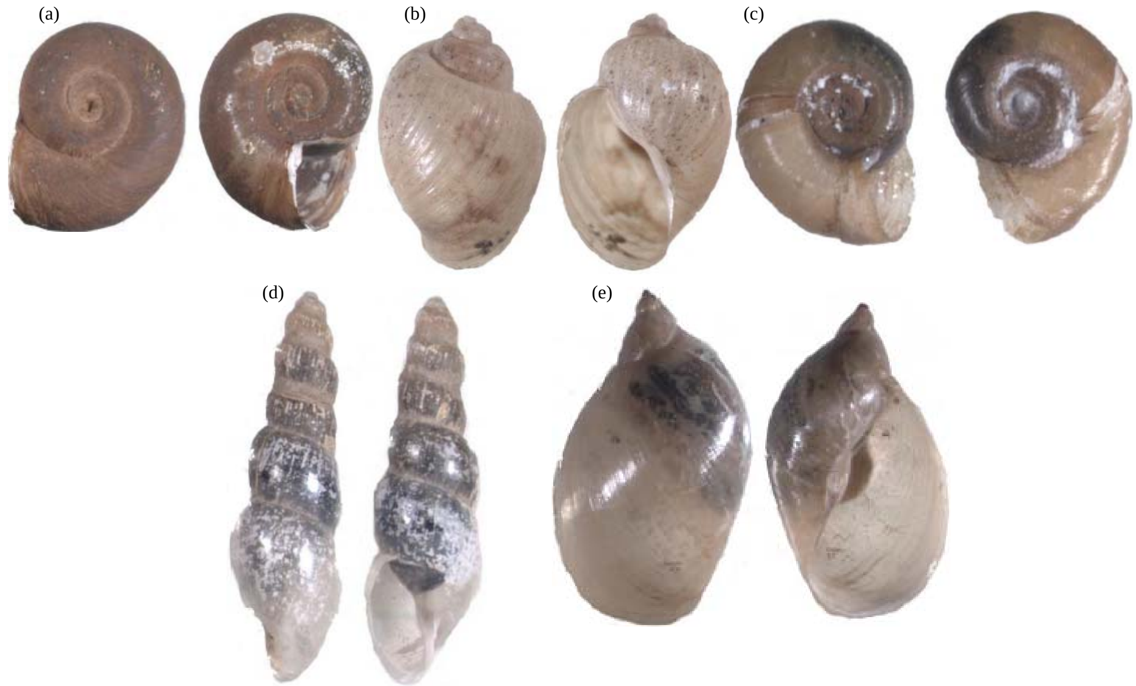

Fig. 2(a-e): Shell samples of snail intermediate hosts snails sampled in water bodies across Nasarawa state, Nigeria, (a) *Biomphalaria pfeifferi*, (b) *Bulinus globosus*, (c) *Indoplanorbis exutus*, (d) *Bulinus forskalii* and (e) *Lymnaea natalensis*

Table 1: Snail hosts population collected from sampling sites across Nasarawa state

LGA	No. of location	*B. globosus*	*B. forskalii*	*B. pfeifferi*	*L. natalensis*	*L. exutus*	Total
Awe	3	15	20	13	0	0	48
Obi	5	8	17	0	3	0	28
Lafia	10	22	30	18	37	31	138
Akwanga	14	51	56	11	35	0	153
Keffi	12	43	28	4	13	0	88
N. Eggon	1	11	0	1	0	0	12
Wamba	9	54	12	21	37	3	127
Keana	11	47	2	0	1	0	50
Kokona	10	63	48	0	7	0	118
Karu	10	33	4	0	6	0	43
Nasarawa	10	66	1	0	7	0	74
Toto	10	77	14	5	2	0	98
Total	105	490 (50.15%)	232 (23.75%)	73 (7.47%)	148 (15.15%)	34 (3.48%)	977

bodies in Akwanga local government area, 138 (14.12%) from 10 water bodies in Lafia LGA and 12 (1.23%) from one water body in Nasarawa Eggon LGA respectively as shown in Table 1. The percentage population distribution of the five snail intermediate hosts depicted *B. globosus* (50.15%), *B. forskalii* (23.75%), *L. natalensis* (15.15%), *B. pfeifferi* (7.47%) and *L. exutus* (3.48%) as shown in Table 1. However, there was a significant difference (F_{520} = 20.48, adjusted R^2 = 0.1295, $p<0.0001$) in the mean population abundance of snails in relation to species (Fig. 3).

Relationship between abundance of snail hosts and physico-chemical parameters: The relationship between overall abundance of snail hosts and physico-chemical parameters revealed that pH is the only significant parameter (t = 1.2799, df = 103, p = 0.2034, r = 0.1251254) influencing abundance of snails in water bodies in Nasarawa state (Fig. 3b). However, there was a negative relationship between temperature (t = -0.78008, df = 103, p = 0.4371, r = -0.07663712), conductivity (t = -1.6071, df = 103, p = 0.1111, r = -0.1564073) and dissolved

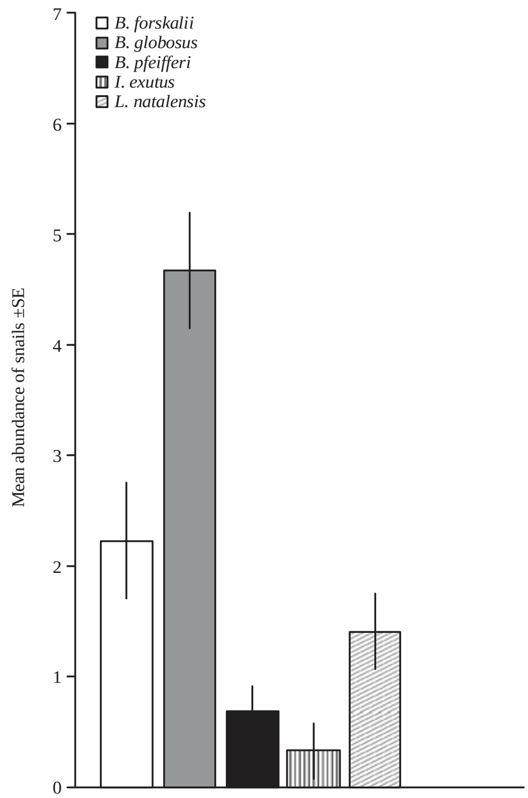

Fig. 3: Mean abundance of snail hosts in selected water bodies of Nasarawa state

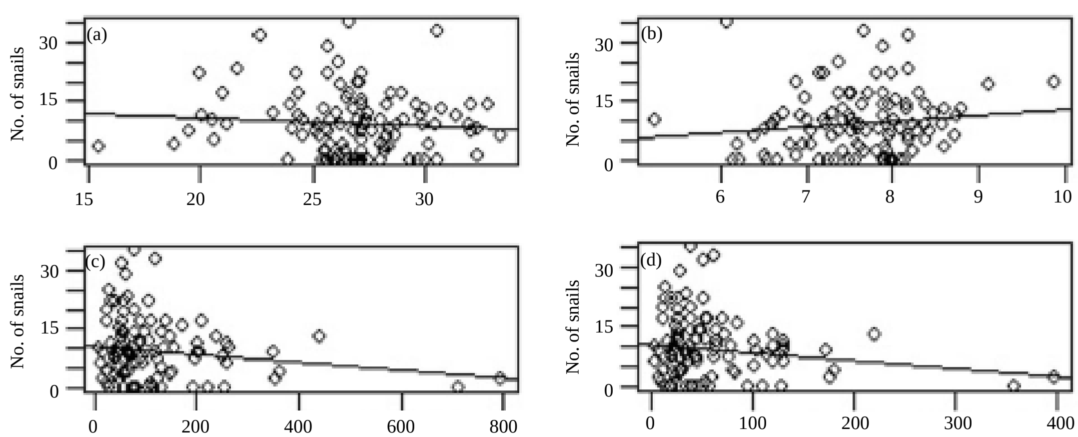

Fig. 4(a-d): Association between abundance of snail hosts and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (μS) and (d) Dissolved oxygen (ppm)

oxygen (t = -1.6162, df = 103, p = 0.1091, r = -0.1572659) on abundance of snails (Fig. 4a, c, d).

Relationship between individual snail abundance and physico-chemical parameters: The influence of physico-chemical parameters on individual snail's abundance depicted temperature to be significant for *B. globosus* (t = 0.18054, df = 103, p = 0.8571, r = 0.01778615) as shown in Fig. 5a. However, there was negative relationship between abundance of *B. globosus* and pH (t = -1.2215, df = 103, p = 0.2247, r = -0.119497), conductivity (t = -0.87934, df = 103, p = 0.3813, r = -0.08632097) and dissolved oxygen (t = -0.80974, df = 103, p = 0.42, r = -0.07953352) as shown in Fig. 5b-d, only pH positively influenced *B. forskalii*, *B. pfeifferi*,

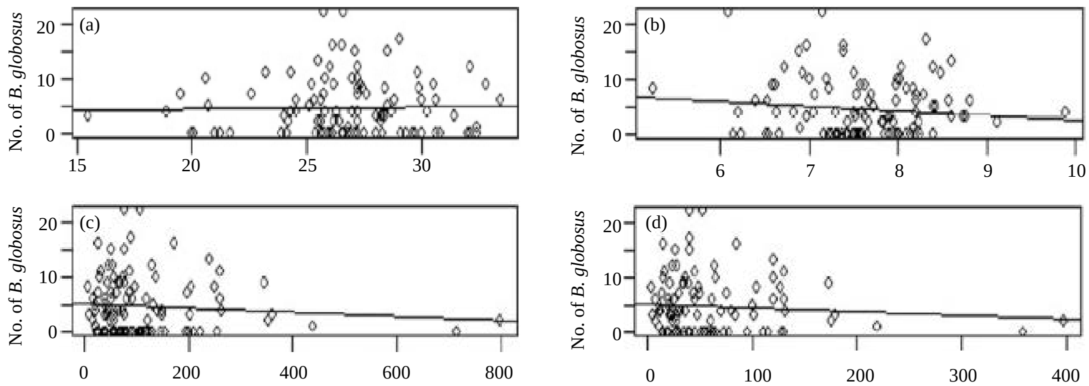

Fig. 5(a-d): Association between abundance of *B. globosus* and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (μS) and (d) Dissolved oxygen (ppm)

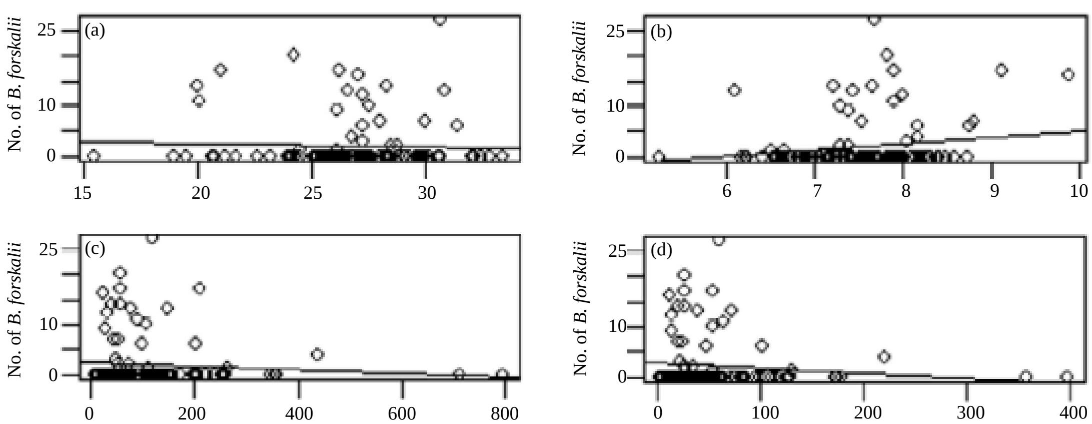

Fig. 6(a-d): Association between abundance of *B. forskalii* and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (μS) and (d) Dissolved oxygen (ppm)

L. natalensis, while *L. exutus* associated positively with pH and dissolved oxygen as shown in Fig. 5-9, respectively.

The relationship between abundance of *B. forskalii* show positive relationship with pH (t = 1.7405, df = 103, p = 0.08476, r = 0.1690258) as shown in Fig. 6b. However, there was negative relationship between abundance of *B. forskalii* and temperature (t = -0.37604, df = 103, p = 0.7077, r = -0.03702709), conductivity (t = -0.8889, df = 103, p = 0.3761, r = -0.08725173) and dissolved oxygen (t = -1.2513, df = 103, p = 0.2136, r = -0.1223722) as shown in Fig. 6a, c and d respectively.

The relationship between abundance of *B. pfeifferi* show positive relationship with pH (t = 0.78966, df = 103, p = 0.4315, r = 0.0775727) as shown in Fig. 7b. However, there was negative relationship between abundance of *B. pfeifferi* and temperature (t = -0.68815, df = 103, p = 0.4929, r = -0.06765054), conductivity (t = -0.10506, df = 103, p = 0.9165, r = -0.01035155) and dissolved oxygen (t = -0.11369, df = 103, p = 0.9097, r = -0.01120115) as shown in Fig. 7a, c and d respectively.

The relationship between abundance of *L. natalensis* show positive relationship with pH (t = 1.0074, df = 103, p = 0.3161, r = 0.09877464) as shown in Fig. 8b. However, there was negative relationship between abundance of *L. natalensis* and temperature (t = -0.34155, df = 103, p = 0.7334, r = -0.03363489), conductivity (t = -0.74611, df = 103, p = 0.4573, r = -0.07331823) and dissolved oxygen (t = -0.56748, df = 103, p = 0.5716, r = -0.05582867) as shown in Fig. 8a, c and d respectively.

The relationship between abundance of *L. exutus* show positive relationship with pH (t = 0.94449, df = 103,

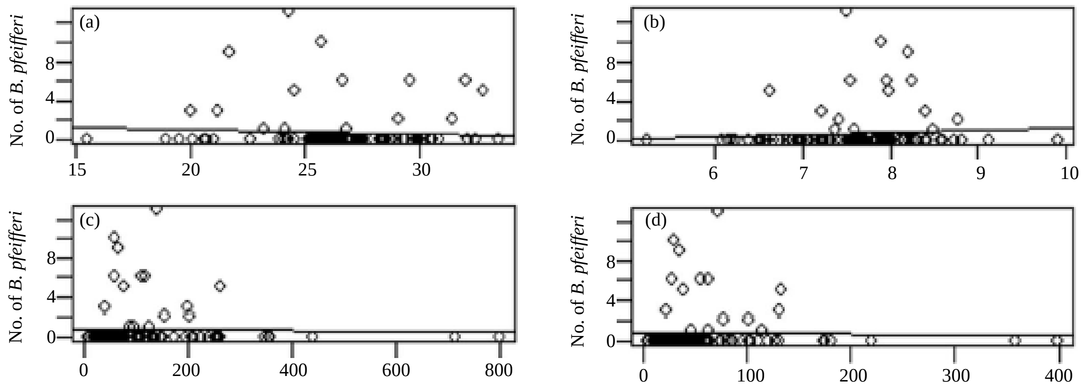

Fig. 7(a-d): Association between abundance of *B. pfeifferi* and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (µS) and (d) Dissolved oxygen (ppm)

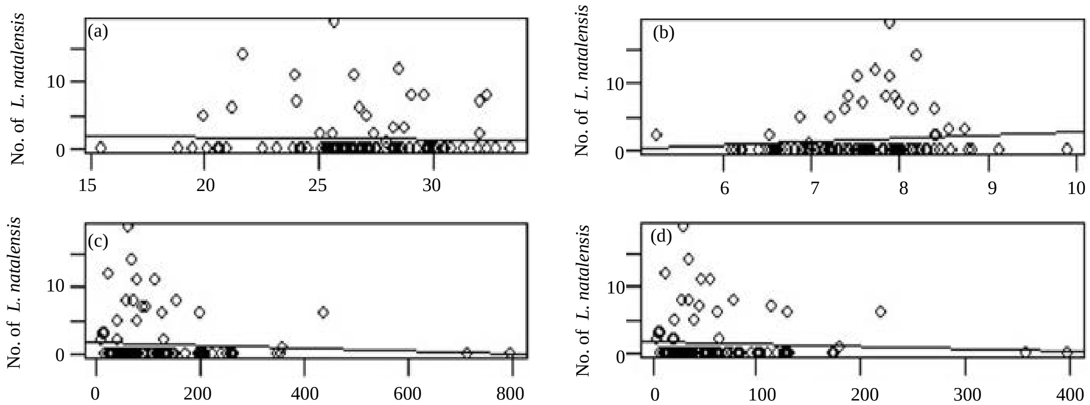

Fig. 8(a-d): Association between abundance of *L. natalensis* and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (µS) and (d) Dissolved oxygen (ppm)

Table 2: Snail hosts distribution in five habitats sampled in Nasarawa state

	Habitats					
Snail species	River	Stream	Pool	Dam	Waterfall	Total
Bulinus globosus	264	196	3	17	10	490
Bulinus forskalii	98	108	14	0	12	232
Biomphalaria pfeifferi	20	50	3	0	0	73
Lymnaea natalensis	49	93	6	0	0	148
Indoplanorbis exutus	28	6	0	0	0	34
Total	459 (46.98%)	453 (46.37%)	26 (2.66%)	17 (1.74%)	22 (2.25%)	977

$p = 0.3471$, $r = 0.09266254$) as shown in Fig. 8b. However, there was negative relationship between abundance of *L. exutus* and temperature ($t = -1.0302$, $df = 103$, $p = 0.3053$, $r = -0.1009874$, Fig. 9a). Conductivity ($t = -0.30554$, $df = 103$, $p = 0.7606$, $r = -0.03009178$, Fig. 9c) and dissolved oxygen ($t = 0.037408$, $df = 103$, $p = 0.9702$, $r = 0.003685925$, Fig. 9d) as shown in Fig. 9a, c and d respectively.

Monthly distribution and population of snail intermediate hosts in water bodies sampled across 12 LGAs in Nasarawa state are shown in Fig. 10 and 11 respectively. Snail collection was highest in June, 2013 while the least collection was made in October, 2012.

The distribution chart indicates that *B. globosus* occurred highest, it was found in all the 12 local government areas surveyed for snail intermediate hosts of trematode parasites across Nasarawa state while *I. exutus* only occurred in three studied sites across two local government areas of Nasarawa state.

Table 2 shows that (459) 46.98% snails were collected from the rivers, streams 453 (46.37%), pools

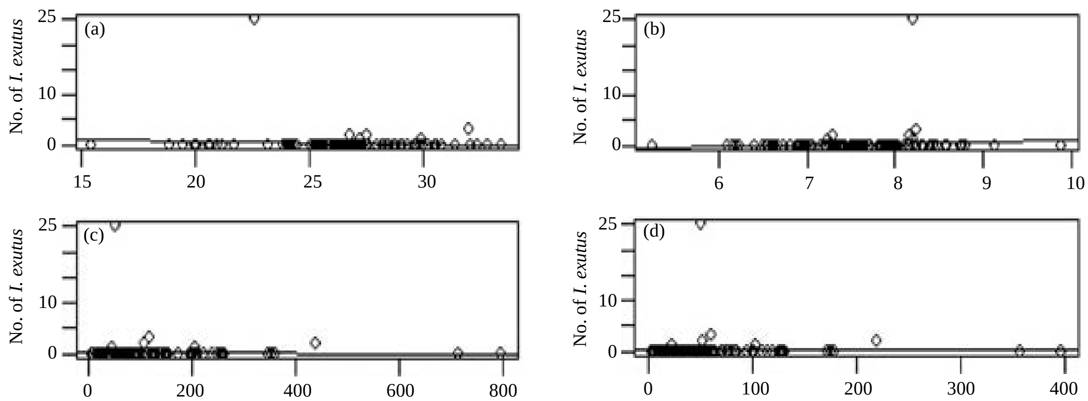

Fig. 9(a-d): Association between abundance of *I. exutus* and physico-chemical parameters, (a) Temperature (°C), (b) pH, (c) Conductivity (µS) and (d) Dissolved oxygen (ppm)

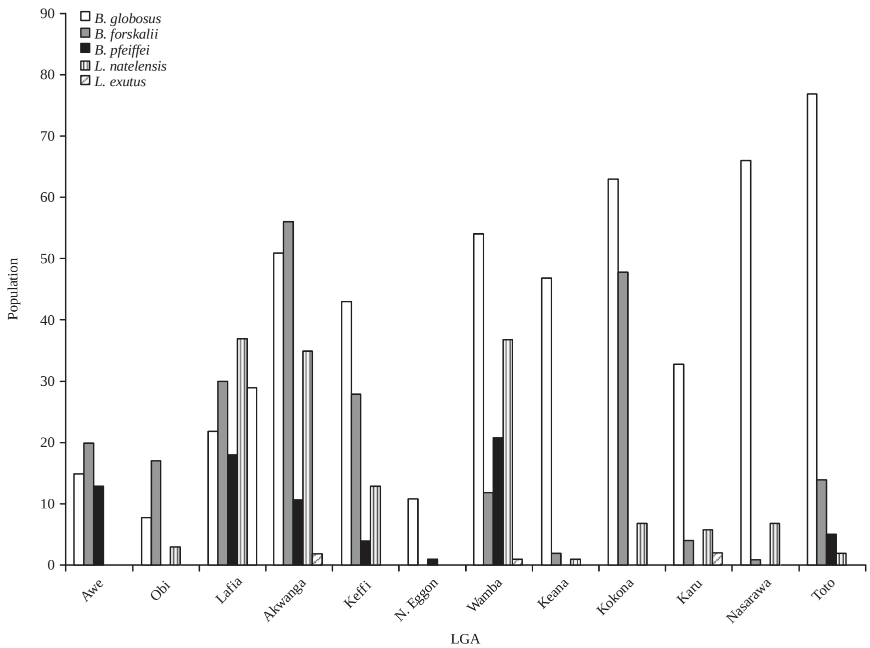

Fig. 10: Population of snail intermediate hosts across 12 LGAs surveyed in Nasarawa state

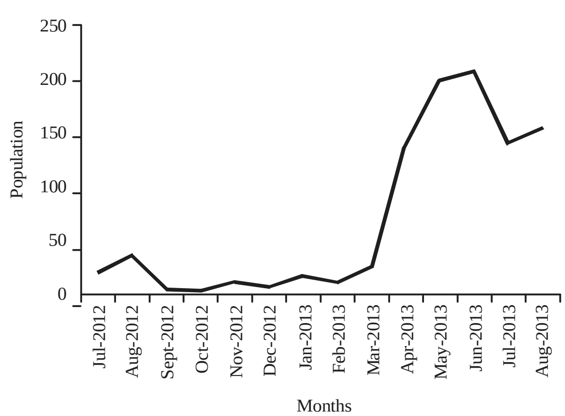

Fig. 11: Monthly distribution of snail intermediate hosts snails in Nasarawa State

Table 3: Different snail sizes and shell types collected in water bodies across Nasarawa State

Snail species	Mean shell sizes (mm)	Shell types	Characteristics
Bulinus globosus	4.4×3.0	Globose (Sinistral)	Height and width of shell are about the same
Bulinus forskalii	5.0×2.5	Turetted (Sinistral)	Height is many times greater than the width
Biomphalaria pfeifferi	4.6×3.7	Discoid	Shell is coiled in one plane
Lymnaea natalensis	5.0×2.7	Conical (Dextral)	Height of shell is larger than the width and the spire is cone shaped
Indoplanorbis exutus	4.9×4.5	Discoid	Shell is coiled in one plane

Table 4: Vegetation samples identified at sites sampled for snail intermediate hosts across Nasarawa state

Plant species
Ipomoea aquatic
Azolla punata
Nymphaea lotus
Acroceras zizanoides
Mimosa pudica
Panicum muticum
Pistia stratiotes
Ludwigia spp.
Diplazia esculentum
Commelina diffusa
Echinochloa colonum
Convolvulus arvensis
Panotum spp.
Elaeis guineensis

26 (2.66%), waterfall 22 (2.25%) and dam 17 (1.74%) across Nasarawa state.

The morphology of the identified snail hosts is summarized in Table 3, the summary shows the mean shell sizes, characteristics and shell types and these include globose, turreted, discoid and conical shells. Aquatic plant species collected from the sites sampled for snail intermediate hosts are shown in Table 4.

DISCUSSION

Narasawa state is known to be endemic for schistosomiasis[16,17], which is a major public health concern among the snail-borne diseases. Pulmonate snail hosts play active role in the continued transmission of these snail-borne diseases in environment where there is lack of basic infrastructure and also facilitated by human activities[18].

The pooled abundance of the five snail intermediate hosts identified in this study is influenced by pH of the water bodies sampled for their presence and abundance. Assessment of water physico-chemical parameters on individual snail host shows that temperature was significant for *B. globosus* abundance in water bodies sampled in Nasarawa state. Giovanelli *et al.*[19] emphasized the effects of temperature on snail population, which could have adverse effects on snail intermediate hosts abundance and distribution at extreme periods. In addition, temperature is recognized as important in the freshwater biotope, especially its influence on snail hosts distribution and abundance[20]. The pH was significant for *B. forskalii*, *B. pfeifferi* and *L. natalensis* while pH and dissolved oxygen were significant for *L. exutus* abundance in the sampled water bodies. Dissolved oxygen play significant role in the population abundance of freshwater snails, if there is low dissolved oxygen in water, the feeding rate of the snails might be affected and this may result to death if it happens for a long period[21]. The distribution and abundance of snail intermediate hosts may be attributed to the availability of food materials and aquatic plants used as oviposition sites, 14 aquatic plants were identified at sites where snail hosts were sampled. Water bodies rich in organic and silt matters are known to support populations of macro-invertebrates because of reduction in water current and serves as substratum for attachment by the snails, which help them from being washed away by water current[22]. The favourable effect of vegetation on snail habitat preference was confirmed by the fact that most snails in their various habitats were attached to aquatic plants. Imafidon[23], Obureke *et al.*[24] and Amali[25] had previously reported the influence of aquatic vegetations on the distribution of snails of medical importance.

The reduction in the snail population at the beginning of this study in July, 2012 to early 2013 was due to flooding experienced in most part of Nigeria including Nasarawa state which extended to late raining season of that year. This might have washed the snail hosts away. However, they resurfaced at the start of the rains in 2013.

The lack of infected snail hosts among the population of the five snail hosts of trematode parasites identified is quite surprising but the presence of these important snail species in water bodies sampled at communities of Nasarawa state poses serious danger and risk of potential transmission of snail-borne diseases across the state. Therefore, it is important to educate the inhabitants of the communities where these water bodies are found on the need to embrace good sanitary culture and avoid indiscriminate disposal of human wastes into them. Should an infected person dispose their waste into these water bodies with the right snail hosts, this could trigger the transmission of snail-borne diseases in such areas.

Our inability to identify snail intermediate hosts with molecular method is the limitation of this study. However, we will improve on this aspect in future studies but it is also important to stress that studying the bionomics and population abundance of freshwater snail intermediate hosts improves our understanding on the ecology and population dynamics of these important snail species. Assessing freshwater snail intermediate hosts bionomics is essential to understanding their ecology and distribution pattern on local scales across the country. In addition, such information is important because the different environmental and physico-chemical factors play important role in their survival across the different environment where they are found[26].

CONCLUSION

Hence, such information is needed to plan effective snail control programme in order to complement schistosomiasis and other snail-borne diseases control programme in Nasarawa state.

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