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Distribution and diversity of freshwater snails of public health importance in Kubanni reservoir and weir/sediment trap, Zaria, Nigeria

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ABSTRACT

Due to survival of intermediate hosts of parasites causing schistosomiasis and fascioliasis under changing environmental conditions, this research was conducted to investigate the distribution and diversity of freshwater snails between March and June, 2017. Physicochemical parameters were analyzed according to the standard operating procedures for the examination of water and wastewater. Snails were sampled using an Ekman grab from different sites in each reservoir, counted and identified using standard identification guide. A total of 108 snails were collected and identified in Kubanni reservoir comprising *Biomphalaria* sp. (48.15%), *Lymnaea* sp. (39.81%), and *Bulinus* sp. (12.04%), whereas in Weir, 141 snails which comprised *Biomphalaria* sp. (53.19%), *Lymnaea* sp. (24.11%), and *Bulinus* sp. (22.70%) were collected. Shannon–Weiner diversity index for Kubanni and Weir were 0.97 and 1.02, respectively. The variation in physicochemical parameters between the reservoirs shows no significant difference ($p > 0.05$), except for electrical conductivity ($p = 0.0015$), total dissolved solid ($p = 0.0016$), biochemical oxygen demand ($p = 0.0004$), and concentration of phosphate (PO_4; $p = 0.026$). The three snail species obtained were common to the two reservoirs; however, species diversity was higher in Weir than Kubanni reservoir. The presence of these snails in the two reservoirs could pose a serious threat to humans coming in contact with these reservoirs, in their role as intermediate hosts of parasites that cause schistosomiasis and fascioliasis.

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Introduction

Schistosomiasis and fascioliasis continue to be parasitic scourges of humanity. Snails that serve as intermediate hosts of parasites that cause these two diseases thrive in nature under diverse and changing environmental conditions [1]. Molluscs are extremely important organisms of many ecological communities [2], and they prove immensely beneficial economically and medically [3].

Schistosomiasis and fascioliasis are both neglected tropical diseases and affect primarily populations in tropical developing countries [4]. Global burden of schistosomiasis has been estimated to be 4–5 million disability-adjusted life years [5] with the great majority of the world's burden concentrated in the African continent [6,7].

Chemotherapy is the main means used in control programs of schistosomiasis, due to the absence of vaccine as a prophylactic measure [8,9]. Praziquantel (PZQ) has been used as the drug of choice for the treatment of schistosomiasis since the 1970s. PZQ therapeutic efficiency is restricted to adult worms as it controls only morbidity and does not prevent reinfection [9].

It was reported from a study carried out in 2013 that over 62 million individuals representing more than 39% of people requiring preventive chemotherapy in the top ten African countries which have the peak prevalence of the schistosomiasis were Nigerians; among these, less than 6% had the preventive chemotherapy [10].

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Worldwide, over 700 million domestic ruminants are at risk with cases of fascioliasis in temperate regions, such as Australia, Great Britain, Europe, America, Eastern Africa, Asia, the Middle East, and Sub-Saharan Africa [11]. Human populations are not also left out, with about 17 million people who have been reported with the cases of fascioliasis [12]. The route of transmission is through consumption of infective metacercaria-contaminated raw vegetables and drinking water. Majority of the cases were in Europe, Africa, Asia, America, and Oceania [12,13].

The development of fascioliasis is evidently dependent on characteristics of an environment, as infection of both the hosts (definitive and intermediate) comprises an association with external aquatic ecosystem [14]. A recent study conducted in Zaria, Nigeria, revealed 48.0% of total prevalence of fascioliasis [14]. Aquatic ecosystems such as lakes and reservoirs serve as a good environment for the snail intermediate host of schistosomiasis and fascioliasis. The presence of human and animal is interrelated with the occurrence and spread of these suitable intermediate host snails, thus paving way for the transmission of the diseases [15].

Freshwater snails belonging to the genus *Biomphalaria* and *Bulinus* and *Lymnaea* are common species of the subfamily Planorbidae and Lymnaeidae, respectively, and are widely distributed throughout the Sub-Saharan Africa [15]. 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 [16].

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 the tropical and subtropical regions of the world [17]. *Biomphalaria pfeifferi* and *Bulinus globosus* serve as an intermediate host of *Schistosoma* parasites causing human schistosomiasis [18]. Species belonging to the genus *Lymnaea* (*Lymnaea natalensis*) transmits *Fasciola* parasites to animals and man causing fascioliasis [18].

A surveillance of these freshwater-borne diseases involved the identification of active and potential transmission sites. Human interaction with infected water body such as washing, swimming, fishing, farming, and drinking might predispose the user to infection by these parasites [19].

The ecology of these microorganisms is considered to be affected by the environmental factors such as surface water physicochemical parameters [20]. The water temperature, transparency, pH, dissolved oxygen, and calcium ion (Ca^{+2}) concentrations are among water parameters known to operate in lake ecosystems. These factors combined would determine water quality and may, in general, affect the population of freshwater gastropods [2]. Therefore, the aim of this study was to evaluate the distribution and diversity of snails of public health importance in a reservoir and weir/sediment trap, in relation to some of the physicochemical parameters.

Materials and Methods

Study areas

Kubanni reservoir (Fig. 1) generally called "A.B.U dam" is located on 11^0 08' N and 7^0 39' E South of Ahmadu Bello University, Samaru campus, Zaria, and 11^0 02' N and 7^0 10' E, with an elevation of 643.43 m above the sea level. The reservoir receives runoff and domestic wastewaters from within the campus, nearby irrigation farms, and Samaru community. The reservoir's two major tributaries are the Kampagi and Samaru streams [21].

Weir/sediment trap is located on 11^0 09' 77''N and 7^0 38' 831'' E south of Ahmadu Bello University, Samaru campus, Zaria, behind the A.B.U. press with an elevation of 656.5 m above the sea level. The reservoir is formed to filter waste substance and sediment trap before the water gets to Kubanni reservoir. It also receives runoff and domestic wastewaters from nearby farms and Samaru community.

Sample collection

Samplings were done from March to June 2017, along the two reservoirs based on accessibility. This period of sampling was chosen to capture snails at the peak of dry season and beginning of wet season. The two seasonal periods showed changes in the ecosystems under study based on the quantity of water and inflow of water from other nearby sources [1].

Collection, sorting, and identification of snail samples

Snail vectors were sampled from the littoral zones of the reservoirs between the hours of 8.00 a.m and 9.00 a.m by collecting bottom sediment using Ekman's grab model (number 923), measuring 19 cm ×14 cm with an area of 0.0266 m^2. Three grab hauls were collected twice in a month each from

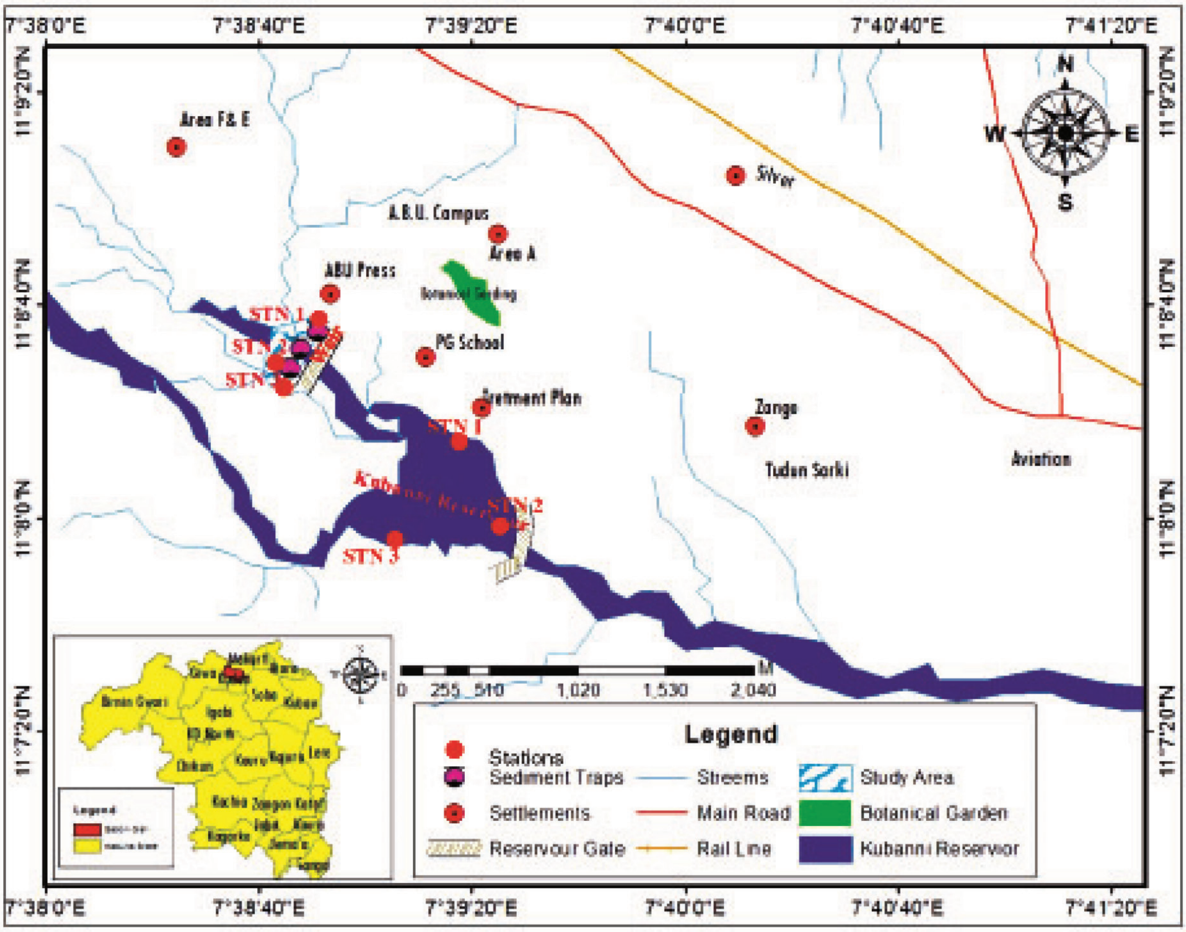

Figure 1. The location of Kubanni reservoir and Weir/sediment trap.

three sampling stations which were selected based on accessibility and anthropogenic activities in the stations, emptied into prelabeled polythene bags, and taken to the laboratory for sorting and identification. The collected sediments were washed and filtered through a mesh sieve, and the snail samples encountered were collected. Snails found at the river bank were also handpicked. All snails recovered were kept in sample container, counted and identified using identification keys of East and Central African freshwater snails of medical and veterinary importance [22].

Collection of water samples and analysis of physicochemical parameters

An in situ determination of surface water parameters such as temperature, pH, electrical conductivity, and total dissolved solid was performed using HANNA portable combined waterproof tester (model HI 98129). The HANNA portable combined waterproof tester was dipped into the water directly, and the parameters were measured and recorded. Water samples for the determination of DO, biochemical oxygen demand (BOD), calcium (Ca^{+2}), hardness, phosphate (PO_4), nitrate (NO_3), and alkalinity were collected in a transparent and amber-colored 250-ml reagent bottles, treated on the field by the addition of manganese sulfate ($MnSO_4$) to fix the oxygen in water samples, and analyzed according to the standard procedures [23].

Data analysis

Student's *t*-test was used to test the significant difference in the physicochemical parameters between the two reservoirs. Principal component analysis (PCA) loadings were used to determine the influence of physicochemical parameters on the abundance of snails of public health importance. Cluster analysis (CA) was used to compare monthly abundance of the snails. Shannon–Weiner diversity index (H') was employed to determine the diversity of the snails in each reservoir.

Student's t-test was determined using Statistical Analysis System (SAS) version 9.1.3, and PCA loadings, CA, and H' were measured using Paleontological Statistics Software Package (PAST) V.2.17c.

Results

Physicochemical parameters, snail abundance, and diversity

In this study, maximum surface water pH (9.22±0.28), calcium hardness (3.20 ± 0.18 mg/l), dissolved oxygen (6.76 ± 0.33 mg/l), and alkalinity (2.73 ± 0.17 mg/l) were recorded in Kubanni reservoir, whereas maximum surface water temperature (27.45°C ± 0.31°C), electrical conductivity (201.92 ± 10.39 μs/cm), total dissolved solids (102.75 ± 6.05 ppm), biological oxygen demand (0.92 ± 0.06 mg/l), phosphate (4.47 ± 0.50 mg/l), and nitrate (26.47 ± 1.81 mg/l) were recorded in Weir/sediment trap.

Student's t-test at $p < 0.05$ shows a significant variation in electrical conductivity (EC), total dissolved solid (TDS), BOD, and phosphate between the two water bodies (Table 1).

A total of 108 snails were collected from Kubanni reservoir, of which 52 (48.15%) were *B. pfeifferi*, 43 (39.81%) were *L. natalensis,* and 13 (12.04%) were *B. globosus*, with a Shannon–Weiner diversity index of 0.97, whereas in Weir/sediment trap, a total of 141 snails were recorded, of which 75 (53.19%) were *B. pfeifferi*, 34 (24.11%) *L. natalensis,* and 32(22.70%) *B. globosus*, with the Shannon–Weiner diversity index of 1.02.

The two water bodies (Kubanni and Weir) have similar species of snails of public health importance which include *B. globosus*, *L. natalensis,* and *B. pfeifferi*. A summary of abundance and diversity of the species of snails recorded in the two aquatic ecosystems (Kubanni and Weir) are presented in Table 2.

The influence of physicochemical parameters on the abundance and diversity of snails of public health importance using PCA loadings is presented in figure 2 and figure 3. 88.41% and 88.84% of total variation were observed for Kubanni reservoir and Weir/sediment trap, respectively.

Figures 4 and 5 represent similarities in monthly abundance of freshwater snails in Kubanni reservoir and Weir/sediment trap, respectively.

Discussion

In this study, Kubanni and Weir have a substantial population of aquatic snails of public health importance. The presence of freshwater gastropods in the two aquatic ecosystems under study suggests the possibility of parasitic transmission in these ecosystems [19]; it can also serve as an index of pollution of a water body. The availability of the same species composition of snails in both the water bodies may be due to the similarity in ecological activities such as mode of nutrition, roles at a particular trophic level, irrigation farming, washing, and bathing within the water bodies which support the existence of these snails. A high abundance of

Table 1. Physicochemical parameters of Kubanni reservoir and Weir/sediment trap.

	T(°C)	pH	EC (μs/cm)	TDS ppm)	Ca+^{2} (mg/l)	DO (mg/l)	BOD (mg/l)	PO_4^- (mg/l)	NO_3^- (mg/l)	ALK (mg/l)	HAR (mg/l)
R1	27.13 ± 0.51	9.22 ± 0.28	157.42 ± 5.27	77.50 ± 2.28	3.20 ± 0.18	6.76 ± 0.33	0.53 ± 0.07	3.05 ± 0.28	25.40 ± 1.66	2.73 ± 0.17	115.2 ± 0.08
R2	27.45 ± 0.31	9.05 ± 0.32	201.92 ± 10.39	102.75 ± 6.05	3.08 ± 0.16	5.63 ± 0.50	0.92 ± 0.06	4.47 ± 0.50	26.47 ± 1.81	2.47 ± 0.20	115.2 ± 0.11
P-value	0.6015	0.6891	0.0015	0.0016	0.6317	0.0782	0.0004	0.0263	0.6679	0.341	0.9515

T (°C) = Temperature, pH = Potential of hydrogen, EC = Electrical conductivity, TDS = Total dissolved solids, Ca^{+2} = Calcium, DO = Dissolved oxygen, BOD = Biological oxygen demand, PO_4 = Phosphate, NO_3 = Nitrate, ALK = Total alkalinity, HAR = Total hardness. R1 = Kubanni reservoir, R2 = Weir/sediment trap.

Table 2. Abundance and Shannon–Weiner diversity index of snail vectors in Kubanni reservoir and Weir/sediment trap.

	Kubanni reservoir					Weir/sediment trap				
	March	April	May	June	Total (%)	March	April	May	June	Total (%)
Biomphalaria pfeifferi	23	14	11	4	52 (48.15)	26	30	10	9	75 (53.19)
Lymnaea natalensis	16	13	8	6	43 (39.81)	15	12	5	2	34 (24.11)
Bulinus globosus	6	4	2	1	13 (12.04)	17	5	10	0	32 (22.70)
Total	45	31	21	11	108 (100)	58	47	25	11	141 (100)
Shannon–Weiner diversity index (H')					**0.97**					**1.02**

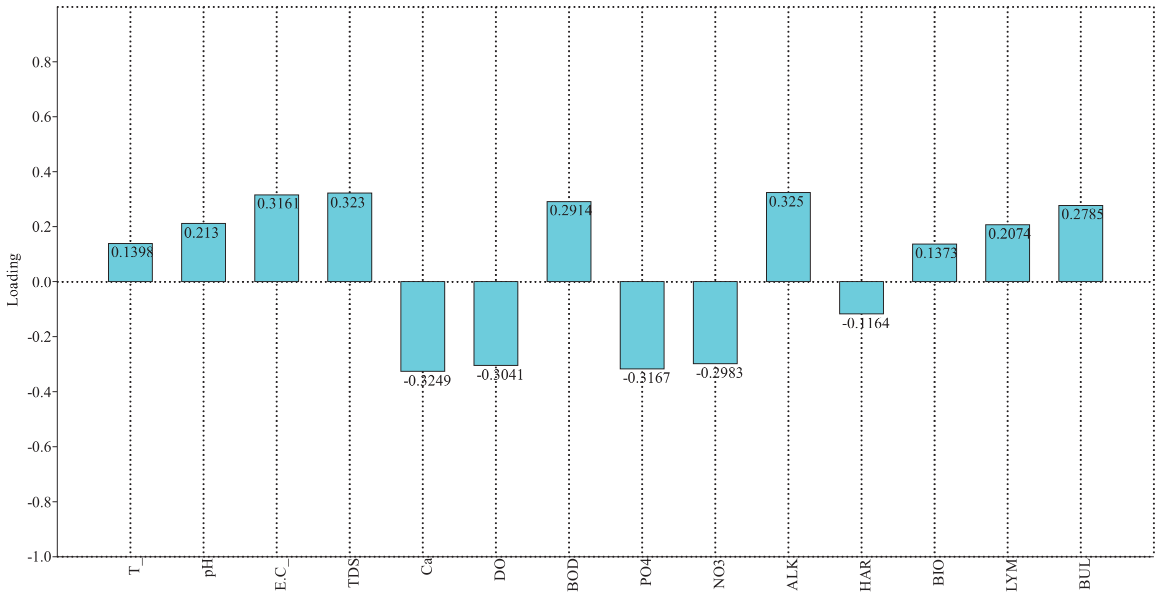

Figure 2. PCA loadings for physicochemical parameters and snails of public health importance in Kubanni reservoir. pH = Potential of hydrogen, T(˚C) = Surface water temperature, ALK (mg/l) = Total alkalinity, EC (µs/cm) = Electrical conductivity, TDS (ppm) = Total dissolved solids, DO (mg/l) = Dissolved oxygen, BOD (mg/l) = Biological oxygen demand, HAR (mg/l) = Total hardness, PO_4 (mg/l) = Phosphate, NO_3 (mg/l) = Nitrate, BUL = *Bulinus globosus*, BIO = *Biomphalaria pfeifferi,* LYM = *Lymnaea natalensis.*

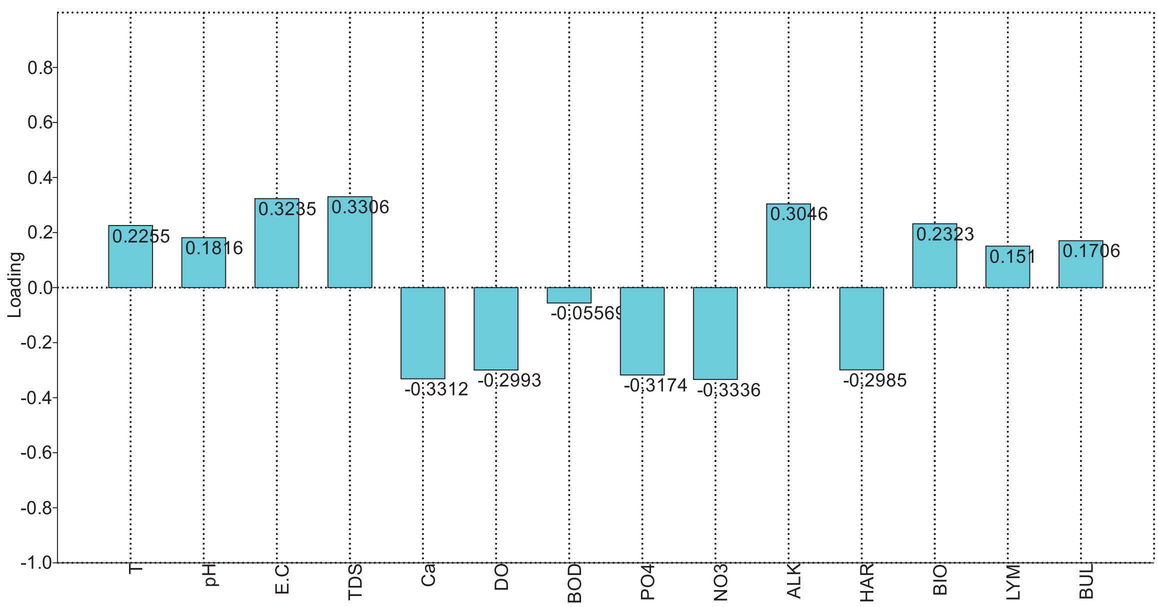

Figure 3. Principal Component Analysis (PCA) loadings for physicochemical parameters and snails of public health importance in Weir/sediment trap. pH = Potential of hydrogen, T(˚C) = Surface water temperature, ALK (mg/l) = Total alkalinity, EC (µs/cm) = Electrical conductivity, TDS (ppm) = Total dissolve solids, DO (mg/l) = Dissolve oxygen, BOD (mg/l) = Biological oxygen demand, HAR (mg/l) = Total hardness, PO_4 (mg/l) = Phosphate, NO_3 (mg/l) = Nitrate, BUL = *Bulinus globosus*, BIO = *Biomphalaria pfeifferi,* LYM = *Lymnaea natalensis.*

the snails was recorded at Weir. This can be as a result of undisturbed nature of the Weir and even nature of sediment distribution across the depth, which is caused by less wave action near the water surface [1]. The abundance and diversity of living organisms in aquatic environment usually vary with changes in physicochemical parameters as an index to give the nature and state of the ecological

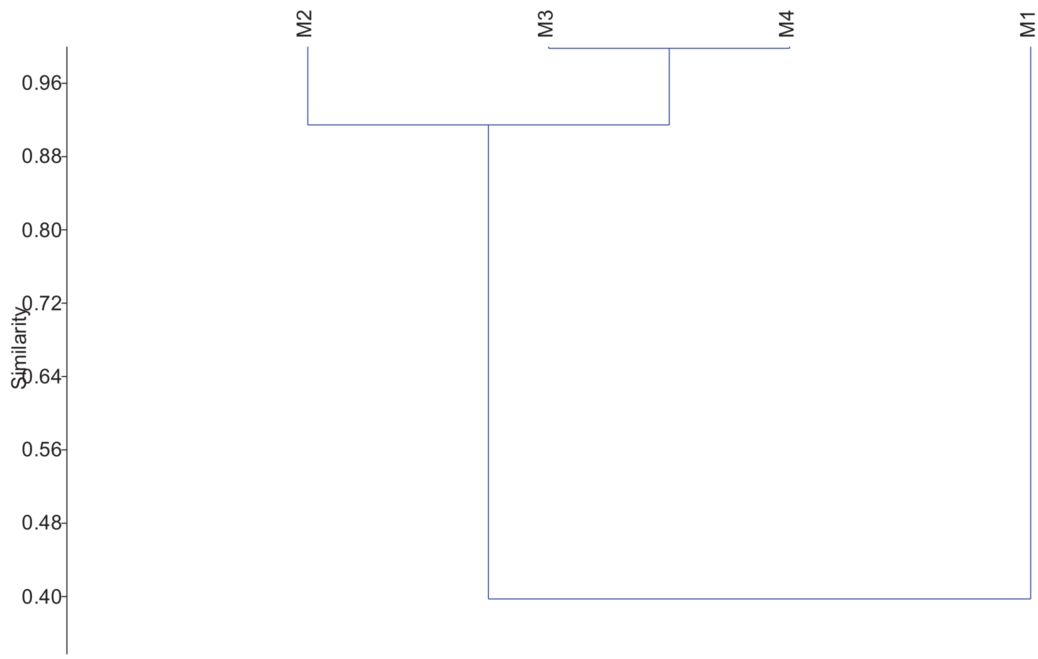

Figure 4. Cluster analysis dendrogram based on monthly abundance of snails of public health importance in Kubanni reservoir. M1 = March, M2 = April, M3 = May, M4 = June.

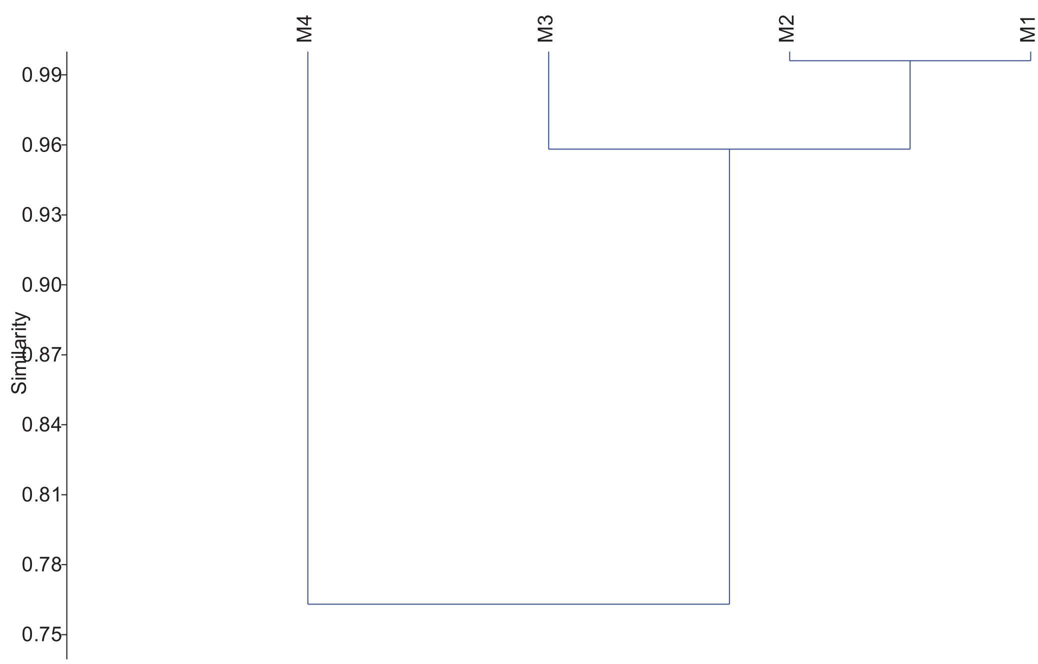

Figure 5. Cluster analysis dendrogram based on monthly abundance of snails of public health importance in Weir/sediment trap. M1 = March, M2 = April, M3 = May, M4 = June.

condition [1]. In other words, the physicochemical parameters are used as biomonitors of pollution or nature of a particular water body.

The low values of Shannon–Weiner diversity index in relation to the three snails of public health importance in the two reservoirs can be linked to pollution level of the two reservoirs. A value of this index above three (3) indicates clean water, whereas values lower than three indicates pollution [24], and the higher the value, the greater the diversity.

A significant variation of EC, TDS, BOD, and phosphate between the two water bodies can be a result of slight differences in anthropogenic activities such as dumping of refuse, irrigation, grazing, fishing, washing, and bathing observed at the catchment and in the water bodies. The variation in the electrical conductivity has been shown to influence the abundance of snail species in the water bodies [25].

The mean conductivity values recorded in Kubanni and Weir/sediment trap (157.42 ± 3.97 and 201.92 ± 3.79 μs/cm, respectively) show that the conductivity level of both the water bodies is intermediate. Conductivity levels below 50 μs/cm are regarded as low; those between 50 and 600 μs/cm are medium, whereas those above 600 μs/cm are high [26].

The difference in EC and TDS between the two water bodies can be attributed to difference in water volume with Weir having low water volume compared to Kubanni reservoir. The variation in DO and BOD in the two water bodies could be related to high temperature, high rate of decomposition, and high consumption of the dissolved oxygen through respiration by aquatic organisms. Our results are in line with the findings of Alhassan [27], where he worked on macrobenthic invertebrate composition in relation to some physicochemical characteristics of Makwaye and Kubanni reservoirs. He reported a significant mean monthly variation in DO and BOD and influence of temperature on such variation.

The variation in phosphate concentration in the water bodies may probably be associated with leaching and inflow of nitrophosphate fertilizers commonly used by farmers from near farmlands into the water bodies. The importance of soluble phosphorous transport in agricultural runoff as an immediate source of phosphorus for biological uptake, thereby accelerating the eutrophication of surface waters, has been well reviewed [28].

In Kubanni reservoir, PCA loadings showed that the first two components (components 1 and 2) accounted for 88.41% of the total variation observed. The three snails of medical importance were positively correlated with pH, EC, TDS, alkalinity, BOD, and temperature and negatively correlated with the other physicochemical parameters. A positive correlation exists between *L. natalensis* (r = 0.2074), *B. globosus* (r = 0.2785), and BOD (r = 0.2914), whereas surface water temperature (r = 0.1398) and *B. pfeifferi* (r = 0.1373) also had a positive correlation as observed in PCA loadings.

For Weir/sediment trap, the first two components with the highest variation accounted for 88.84% of the total variation that were observed. The three snails were positively correlated with surface water temperature, pH, EC, TDS, and alkalinity and negatively correlated with other physicochemical parameters determined in this study. However, a strong association was observed between *B. globosus* (r = 0.1706), *L. natalensis* (0.1510), and pH (0.1816), and the same was applied to *B. pfeifferi* (0.2323) and surface water temperature (0.2255).

The pH, EC, TDS, alkalinity, BOD, and temperature influenced the presence, abundance, and diversity of the snails in the two reservoirs as revealed by a positive correlation between the mentioned physicochemical parameters and snail composition. The ability of these snails to be found in polluted environment can be as a result of their tolerance to pollutants in polluted water bodies due to anthropogenic activities [1], and their high abundance could be a common feature of organically polluted water bodies [29].

In Kubanni reservoir, cluster analysis dendrogram using correlation as similarity index shows that there is a distinct dissimilarity in monthly abundance of snails between March and the other three months, i.e., April, May, and June with similarity index of 0.40. March, April, and May were similar in terms of abundance of the snails with similarity index of 0.91, whereas May and June were also similar with an index of 0.98. For Weir/sediment trap, distinct dissimilarity was observed between June and the other three months, i.e., March, April, and May with similarity index of 0.76. March, April, and May were similar in terms of abundance of the snails with similarity index of 0.96, but similarity between March and April was stronger with an index of 0.99.

Dissimilarity that exists in total monthly abundance of the snails between March and other months in Kubanni reservoir and June and the other months in Weir could be linked to nature and level of human water contact activities, fluctuation in water flow, recharge and discharge of water in the water bodies, differences in physicochemical characteristics of the two reservoirs, and seasonal influence on the health of the reservoirs [30,31].

Conclusion

This study established that both the reservoirs have the same species composition of snails of public health importance. The total percentage composition of the snails of public health importance (*B. pfeifferi*, *B. globosus,* and *L. natalensis*) in Weir is higher compared to Kubanni reservoir. Significant variations exist in EC, TDS, BOD, and phosphate-phosphorus as recorded in the two reservoirs.

There is an influence of physicochemical parameters of Kubanni and Weir on the abundance and diversity of snails of public health importance recorded in the two reservoirs. However, a positive correlation exists between the snails and some physicochemical parameters in both the reservoirs. Physicochemical properties such as pH, EC, TDS, alkalinity, BOD, and temperature have a significant influence on the abundance of the snails. Dissimilarity in the total monthly abundance of the snails also exists, between March and the other three months, i.e., April, May, and June in Kubanni reservoir and June and the other three months, i.e., March, April, and May in Weir.

The presence of the three species of snails that are of public health importance in the study areas may constitute a predisposing factor to schistosomiasis and fascioliasis. Therefore, repetitive measurements of environmental variables should be carried out on the reservoirs to monitor the change in composition of these snails and recommend preventive measures to people coming in contact with these two reservoirs.

Statement of novelty

This study has established the similarity and differences in the two aquatic ecosystems for the first time. The sediment trap was created recently, and this is the first report on its status in terms of physicochemical parameters and abundance of snails of public health importance. Furthermore, influence of the natural settings of this environment on the distribution of these snails was reported for the first time in the sediment trap and was compared with what was established at Kubanni reservoir being a reservoir (ahead) on the same stretch with the sediment trap. The possibility of a serious threat to humans coming in contact with these reservoirs was also established in this research because of the role of the intermediate hosts (snails) in causation of schistosomiasis and fascioliasis (two important diseases of public health importance).

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Conflict of interests

The authors declared that they have no conflict of interest.

Authors' contribution

Abdullahi Bala Alhassan initiated the initial draft of the manuscript and literature review and gave the manuscript, its present outlook, and data analysis. Abdulsalam Abidemi initiated the work, field collection of the water samples, snail species, and analysis of the physicochemical parameters; Ibrahim Madu Katsallah Gadzama gave the main idea of the study and made the initial corrections to the main research. Ramatu Idris Sha'aba overhauled the overall manuscript and took part in final correction of the manuscript. Yunusa Adamu Wada designed the research to highlight its public health importance.

References

[1] Alhassan AB, Balarabe ML, Gadzama IMK, Idris SR, Wada YA, Yusuf A, et al. Influence of physico-chemical parameters on the intermediate host of *Schistosoma haematobium* and *Schistosoma mansoni* in Makwaye and Kubanni Reservoirs, Zaria, Nigeria. J Adv Vet Anim Res 2017; 4(4):363–70.

[2] Sharma KK, Komal B, Minakshi S. Diversity and distribution of Mollusca in relation to the physico-chemical profile of Gho-Manhasan stream, Jammu. India. Int J Biodivers Conserv 2014; 5(4):240–9.

[3] Wosu LO. Commercial snail farming in West-Africa—a guide. ApExpess Publishers, NSukka-Nigeria, 162 p, 2003.

[4] Hess J, Keiser J, Gasser G. Toward organometallic antischistosomal drug candidates, Schistosomiasis. Future Med Chem 2015; 7:821–30.

[5] World Health Organization. Prevention and control of schistosomiasis and soil-transmitted helminthiasis. World Health Organ Tech Rep Ser 2002; 912 (i–vi):1–57 (back cover).

[6] Utzinger J, Raso G, Brooker S, De Savigny D, Tanner M, Ornbjerg N, et al. Schistosomiasis and neglected tropical diseases: towards integrated and sustainable control and a word of caution. Parasitology 2009; 136(13):1859–74.

[7] Elmorshedy H, Tanner M, Bergquist RN, Sharaf S, Barakat R. Prophylactic effect of artemether on human *Schistosoma mansoni* among Egyptian children: a randomized controlled trial. *Acta Trop* 2016; 158:52–8.

[8] Colley DG, Bustinduy AL, Secor WE, King CH. Human schistosomiasis. Lancet 2014; 383(9936):2253–64.

[9] de Oliveira RN, dos Santos KR, Mendes TMF, Garcia VL, Oliveira ASS, Jeraldo VLS, et al. Sesquiterpenes evaluation on *Schistosoma mansoni*: survival,

excretory system and membrane integrity. Biomed Pharmacother 2017; 90:813–20.

[10] Abdulkadir A, Ahmed M, Abubakar B, Suleiman I, Yusuf I, Imam I, et al. Prevalence of urinary schistosomiasis in Nigeria, 1994–2015: Systematic review and meta-analysis. Afr J Urol 2017; 23(4).

[11] Piedrafita D, Spithill TW, Smith RE, Raadsma HW. Improving animal and human health through understanding liver fluke immunology. Parasite Immunol 2010; 32:572–81.

[12] Khan M, Rahman AA, Ahsan S, Ehsan A, Dhand N, Ward MP, et al. Bovine fascioliasis risk factors and space-time clusters in Mymensingh, Bangladesh. Vet Parasitol 2017; 9:104–9.

[13] Fentie T, Erqou S, Gedefaw M, Desta A. Epidemiology of human fascioliasis and intestinal parasitosis among schoolchildren in Lake Tana Basin, Northwest Ethiopia. Trans R Soc Trop Med Hyg 2013; 107:480–6.

[14] Isah UM. Studies on the prevalence of fascioliasis among ruminant animals in northern Bauchi state, north-eastern Nigeria. Parasite Epidemiol Control 2019; 5:80–90.

[15] WHO. Atlas of global distribution of schistosomiasis. World Health Organization, Washington, DC, 1667 p, 2010.

[16] Utzinger J, Tanner M. Microhabitat preferences of *Biomphalaria pfeifferi* and *Lymnaea natalensis* in natural and man-made habitat in southeastern Tanzania. Memorias d Instituto Oswaldo Cruz 2000; 95:287–94.

[17] Jordan P, Webbe G, Sturrock RF. Human schistosomiasis. 3rd edition, CAB International, Oxford, UK, 335 p, 1993.

[18] Dida GO, Gelder FB, Anyona DN, Matano S, Abuom PO, Adoka SO, et al. Distribution and abundance of schistosomiasis and fascioliasis host snails along the Mara River in Kenya and Tanzania. Infect Ecol Epidemiology 2014; 10:34–42.

[19] Ikpeze OO, Obikwelu ME. Factors affecting seasonal abundance of gastropods of public health importance found at Agulu Lake shorelines in Nigeria. Int J Pure Appl Biosci 2016; 4(2):91–102.

[19] Garg RK, Rao RJ, Saksena DN. Correlation of molluscan diversity with physico-chemical characteristics of water of Ramsagar reservoir. India Int J Biodivers Conserv 2009; 6:202–7.

[20] Abolude DS, Davis OA, Avong DW. Level of heavy metals in fresh water crab (*Cardiso maguahumi*) obtained from Ahmadu Bello University Reservoir, Zaria Nigeria. Int J Anim Vet Adv 2009; 1(2):54–8.

[21] Mandahl-Barth G. Key to the identification of east and central African freshwater snails of medical and veterinary importance. Bull World Health Organ 1962; 27:135–50.

[22] APHA (American Public Health Association). Standard methods for the examination of water and waste water. 2nd edition, American Public Health Association Inc., New York, 1193 p, 2005.

[24] Maiti SK. Handbook of Methods in Environmental Studies: Water and Wastewater Analysis. Second Edition ABD Publishers B-46, Natraj Nagar, Imliwala Phatak Jaipur, India. 2004; 1:255−258.

[25] Gadzama IMK, Muhammad R, Dariya S, Tabita GS. Comparative metal analysis of the soft tissues of three species of *Anodonta* (Class: Bivalvia) from Kubanni lake in Zaria, Nigeria. J Environ Sci Toxicol Food Technol 2014; 6(3):18–23.

[26] Anago IJ, Esenowo IK, Ugwumba AA. The Physicochemical and Plankton Diversity of Awba Reservoir, University of Ibadan, Ibadan. Nig Res J Environ Earth Sci 2014; 5(1):638–44.

[27] Alhassan AB. Macrobenthic invertebrates composition in relation to some physico-chemical characteristics of Makwaye and Kubanni reservoirs in Zaria, Nigeria. A thesis submitted to the school of postgraduate studies, Ahmadu Bello University, Zaria, Nigeria, pp 21–46 2015.

[28] Matagi SV. The effects of Pollution on Benthic Macroinvertebrates in a Uganda Stream. Hydrobiologia 1996; 137(4):54–69.

[29] Atobatele OE, Ugwumba OA. Seasonal variation in the Physico-chemistry of a Small Tropical Reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). Afr J Biotechnol 2008; 7(12):62–171.

[30] Alhassan AB, Balarabe ML, Gadzama IMK, et al. Assessment of some heavy metals in macrobenthic invertebrate and water samples collected from Kubanni reservoir Zaria, Nigeria. FUW Trends Sci Tech J 2016; 1(1):55−60.

[31] Okoli EI, Odaibo AB. Urinary Schistosomiasis among school children in Ibadan, an urban community in Southwestern Nigeria. Trop Med Int Health 2002; 4(4):308–15.