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Spatial distribution and abondance of freshwater snails in Lake Kivu, DR Congo side

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Abstract

The main goal of this investigation was to study the distribution of freshwater molluscs in Lake Kivu located in DR Congo side. Mollusca play important role in the public and veterinary health and thus need to be study their distribution continuously. The semi-quantitative surveys carried out during the period of January 2019 to December 2019 has focused on sites selected in lake covering the dry and wet seasons. The choice of these sites was based on the molluscan data available, physical structure of the littoral and structure associated vegetation. The harvesting of snails in the littoral zone of Lake Kivu was done using a plankton net and pliers. The physicochemical parameters of the water at each site were carried out using the standard water quality analysis method. The collected snails were morphologically identified using different identification keys. Biomphalaria species were analyzed for trematode infestation. One thousand three hundred and thirty-six (1,356) snails belonging to seven genera and seven species were recorded during the study. The overall relative percentage of the various snail species recorded was: *Biomphalaria pfeifferi* (50.8 %), *Biomphalaria smithi* (13.1 %), *Gabbielle spirilosa* (11.2 %), *Bulinus tuncatus* (10.2 %), *Lymnea natalensis* (5.7 %), *Helisoma duryi* (2.5 %), *Pila ovata* (1.4), *Melanoides tuberculata* (1.2%), *Lymnea columella* (0.7 %),

Tomchia hendrexyx (0.6 %), *Bulinus forskalii* (0.5 %), *Tomchia ventricosa* and *Physa acuta* (0.4 %), *Tomchia zwellandanensis, Corbicula fluminalis* and *Hydrobia accrensis* (0.3 %), *Lymnae palutris* (0.2 %), *Tomchia kivuensis* and *Segmentorbis kempi* (0.1 %). The present clarified the distribution and seasonal abundance of freshwater snails in Lake Kivu, DRCongo side. Eighteen species of freshwater snails were collected in the malacological survey in the Lake Kivu, DRC side. The observed snail distribution can provide insight into some aspects of the epidemiology of trematode infection in the study area and the potential risks to humans and animals. The implications of these findings for the control of snail-borne trematodes are also discussed.

Keywords: Freshwater snails, distribution, diversity, Lake Kivu. DR Congo

Introduction

East African Rift system is a freshwater biodiversity hotspot with the most endemic taxa such as cichlids and snails (Seehausen 2006; Genner *et al.*, 2007; Schultheiß *et al.*, 2011). In this system, lakes are often millions of years old. Freshwater snails are important parts of the food chain and food web of most freshwater ecosystems. Some of the snails that inhabit fresh waters are known for their medical and veterinary importance. It is estimated that around 350 species are of medical and veterinary importance (Brown, 1994; Yves *et al.*, 2013). The intermediate hosts of human schistosomes belong to three genera: Biomphalaria, Bulinus and Lymnaea. Bulinus species cause urinary schistosomiasis, Biomphalaria species cause intestinal schistosomiasis, and Lymnaea species cause fascioliasis or liver rot in animals (Mello *et al.*, 2006). Snail play important role in the public and veterinary health and thus need to be study their distribution continuously. The majority of studies on snails have focused on those of medical and veterinary importance, while little information on other snail's species is available (Brown, 1994: Abdulkadir *et al*., 2017). Many of these freshwaters contain snail potential intermediate hosts of different species of trematodes. The distribution and abundance of snails are influenced by temperature, food supply, predators, parasites, rainfall, and water composition. Sunlight, aquatic weeds, abundance of microflora, high dissolved oxygen content and seasons also contribute to the abundance of freshwater snails (Hosea *et al.*, 1998). Biotic factors such as the availability and density of aquatic macrophytes have also been reported to play a vital role in the distribution of freshwater snails in different parts of Africa (Ofoezie, 1999). The physico-chemical factors of the waters which are considered the most important factors of the aquatic environment, especially for freshwater snails, are temperature, pH, turbidity, dissolved oxygen, calcium, magnesium and

phosphate (Abbasi *et al.*, 2011; Bagalwa *et al.*, 2022). One of the goals of freshwater ecology is to understand how communities of freshwater species are structured in space and time, and how environmental factors affect their distribution. Several studies suggest that the distribution of freshwater snails will be altered and, in some cases, enhanced by global climate change (Dobson *et al*., 2003; Mas-Coma *et al*., 2009). It is well established that the distribution and abundance of freshwater snails are linked to ecological factors (Brown, 1994). Several factors such as physical, chemical and biological factors are considered to affect the ecology of freshwater snails. A local survey suggests that certain factors are identified are important in each water body for the proliferation of trematode intermediate hosts (Bagalwa *et al.*, 2022). Environmental changes are likely to modify the pattern of distribution of snails and can be used to assess the environment impact (Lafferty, 1997). Physicochemical factors and particularly calcium concentrations are stressed by several authors in temperate or tropical freshwater (McKillop & Harisson 1980; Bagalwa *et al.*, 2022).

Information on snail distribution and infection, ecology and behavior could strengthen the efficiency of control measures against snails of medical and veterinary importance. The relevance of such studies was particularly emphasized in the control of schistosomiasis transmission (Madsen, 1992; Sturrock, 1993). But in Lake Kivu, little studies in snail distribution are focus and transmission risk of waterborne disease are reported. The present investigation aimed at providing information on distribution patterns of molluscan species around the littoral zone of Lake Kivu, DRC side with purpose of the presentation of a list of different snail species collected.

Material and Methods

Sampling and identification of snails

Freshwater snails were collected using a plankton net or collected manually with forceps when viewed monthly over a twelve-month period (January to December 2019) as described by Opisa *et al.*, (2011) from sites where there were human activities. The snails were collected from diverse snail habitats in 27 sites along the Lake Kivu littoral zone (Figure 1).

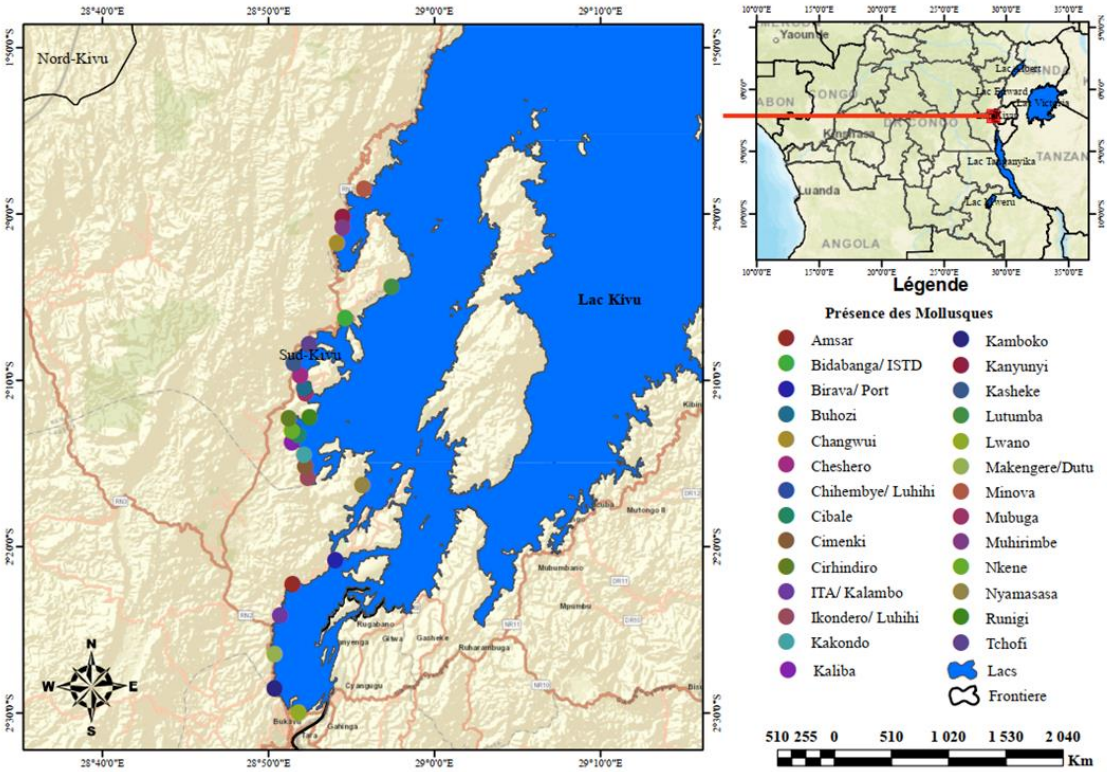

Figure 1. Sampling site localization around Lake Kivu shore in DR Congo side

Each sampling was carried out by three trained snail collectors using standard snail scoops or occasionally by forceps between 09±00 and 12±00 hours for 10 minutes at each site. Collected freshwater snails were transferred to labeled perforated plastic containers and transported to the laboratory of the Department of Biology at the Lwiro Natural Science Research Center (CRSN-Lwiro), sorted and identified to species level using the standard key to morphological characteristics described by Brown (1994).

After identification using key of identification of Brown (1994), snails were separated and *Biomphalaria pfeifferi* were exposed to artificial light to determine possible infection with trematode larvae and Cercariae were identified according to Schell (1970). If there are no cercaria identified ten largest specimens of each mollusc sample in different sites were dissected under a binocular microscope for identification possible infestation.

Determination of the physico-chemical parameters of the freshwater body

Surface water sample was collected once monthly from the sampling site by simple dipping. The sample of the water collected was transported to

the laboratory for chemical analysis of calcium and nutrients (Bagalwa *et al*., 2015). pH, surface water temperature, conductivity and total dissolved solids were determined on site with EC/pH/TDS/Temp COMBO meter (Hanna instruments, Inc.).

Data Analysis

T-test was used to compare the relative abundance of freshwater snails during dry and wet seasons.

All analyses were carried out at alpha level of 0.05 with a *p*-value < 0.05 considered as statistically significant.

Results and Discussion

Species abondance

One thousand three hundred thirty-one (1,331) freshwater snails belonging to six families and nineteen species were collected during the study period. The freshwater snails identified are presented in the table 1.

Table 1. Distribution of the freshwater snail in the littoral zone of Lake Kivu, DR Congo side

Order	Class	Family	Species
Hydrophila	Gasteropoda	Planorbidae	*Biomphalaria pffeiferi*
			Biomphalaria smith
			Helisoma duryii
			Segmentorbis kempi
		Lymneidae	*Lymnae natalensis*
			Lymnae palutris
			Lynmae columella
		Bulinidae	*Bulinus forskalii*
			Bulinus truncates
			Gabbiella spirilosa
		Thiaridae	*Tomchia kivuensis*
			Tomchia hendrexyx
			Tomchia zwellandanensis
			Tomchia ventricose
		Physidae	*Physa acuta*
			Hydrobia accrensis
			Pila ovata
			Melanoides tuberculate
Venerida	Bivalvia	Corbiculidae	*Corbicula fluminalis*

Nineteen species of freshwater snails were sampled in the 28 sites in Lake Kivu, DRCongo side. The family of Thiaridae, Planorbidae, Lymneidae, Thiaridae and Bulinidae have all 4 species of snails. While, the Family of Corbiculidae has only one species of snail. In these families, some

are knowned to be intermediate of schistosomiasis and fasciolosis diseases in the region (Bagalwa & Baluku, 1997; Batumike *et al*., 2014).

Seasonal variation of species abondance of snail at the different sampling site are presented in the figure 2.

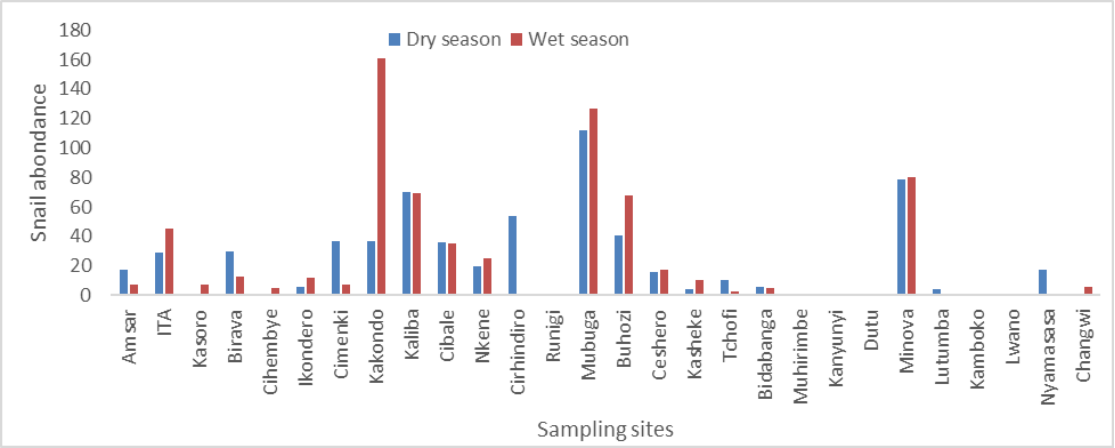

Figure 2. Seasonal variation of species abondance in the sampling sites

High abondance snail species are recorded at Kakondo and Mubuga in wet season. A relatively high abondance were also recorded at Kaliba, Buhozi and Minova. And in general, during the wet season high number of snails were recorded in the majority of sampling sites. A seasonal difference between dry and wet abondance of snails were observed in the sampling sites.

The physical structure of the littoral of lakes is recognized to have an important influence on the density and composition of species communities (Maqboul *et al*., 2014). Indeed, the species richness in those sites varied with seasons as well as the diversification of ecological niches that allow sharing of resources (Brönmark, 1985; Heino, 2000). Statistically there was no significant difference ($p>0.05$) in relative abundance of snail collection during dry and wet season ($t=0.429$, $P=0.6$). The highest index was recorded in the dry season ($H = 2.635$) where all species in the lake sites were sampled, and in the wet season ($H = 2.367$) where some species were collected. The equitability index is higher also in dry season ($e = 0.85$) and low in wet season (0.79). We deduce from these results that the structure of the freshwater molluscs is well balanced in the two seasons.

Seasonal variation of abondance of species in the littoral were recorded and are presented in Table 2.

Table 2. Seasonal variation of abondance of each species in the littoral zone of Lake Kivu

	Dry season	**Wet season**
B. pfeifferi	271	362
B. smithii	93	128
B. truncatus	79	55
B. forskali	0	3
L. natalensis	42	44
L. columella	3	9
L. palutris	2	0
M. tuberculata	14	8
T. kivuensis	1	0
T. hendrexyx	12	0
T. ventricose	6	5
T. zwellendanensis	2	0
G. spirilosa	82	59
H. durnii	5	15
Corbucula sp	10	4
S. kempi	0	1
P. ovata	4	7
P. acuta	2	3

According to this Table 2. A seasonal change in abondance of snail in the littoral zone of lake Kivu are observed. The species *Biomphalaria pfeifferi* and *Biomphalaria smithii* are high in wet season while the species *Bulinus truncatus*, *Gabielle spirilosa* and *Corbicula sp* are highly represented in dry season.

Some snails are positively or negatively correlated in the littoral zone in Lake Kivu as showed in the figure 3.

Figure 3. Pearson correlation between snail's species

	B.__ pfeiffe ri	**B._s mit hii**	**B._tr uncat us**	**B._f orsk ali**	**L._n atale nsis**	**L._co llume lla**	**L._p alut ris**	**M._tu bercul ata**	**T._ki vuen sis**	T._he ndrex yx	T._ve ntrico sa	T._zwel lendane nsis	G._s piril osa	H._ dur nii	Corb ucula _sp	S._ ke mpi	P._ ova ta	P._ acu ta
B.__pfe ifferi	1																	
B._smit hii	0.88**	1																
B._trun catus	-0.1	-0.11*	1															
B._fors kali	0.56	0.71	-0.06***	1														
L._natal ensis	0.58***	0.69	-0.15	0.36	1													
L._collu mella	0.01	0.09**	-0.10**	0.22	0.02***	1												
L._palut ris	-0.15*	-0.11*	-0.09**	-0.05***	-0.18	-0.09**	1											
M._tube rculata	-0.12***	-0.11*	-0.09**	-0.06***	-0.07***	-0.01***	-0.08**	1										
T._kivu ensis	0.00*	-0.06***	-0.06**	-0.04***	0.12*	-0.06**	-0.05***	-0.06***	1									
T._hend rexyx	-0.11	-0.08**	-0.06**	-0.04***	0.08**	0.08**	-0.05***	0.53	-0.04***	1								
T._ventr icosa	-0.11*	-0.08**	-0.06**	-0.04***	0.08**	0.08**	-0.05***	0.53	-0.04	1	1							
T._zwel	-	-	-	-	0.08*	0.08*	-	0.53	-	1	1	1						

lendanensis	0.11***	0.08***	0.06***	0.04***	*	*	0.05***		0.04***									
G._spirilosa	0.16	-0.17	-0.01***	-0.10**	-0.25	-0.15	-0.10**	0.12*	-0.10**	0.00***	0.00***	0.00***	1					
H._durnii	0.15	0.12*	-0.05***	0.02***	0.05***	-0.06***	-0.07***	0.07***	-0.05***	-0.05***	-0.05***	-0.05***	0.03***	1				
Corbucula_sp	-0.08**	-0.08***	-0.06***	-0.04***	-0.13*	-0.06***	-0.05***	0.82	-0.04***	-0.04***	-0.04***	-0.04***	0.14	-0.05***	1			
S._kempi	0.06***	0.00***	-0.06***	-0.04***	-0.04***	-0.06***	-0.05***	0.09**	-0.04***	-0.04***	-0.04***	-0.04***	0.04***	0.99	-0.04***	1		
P._ovata	0.00***	-0.06***	-0.06***	-0.04***	0.12*	-0.06***	-0.05***	-0.06***	1	-0.04***	-0.04***	-0.04***	-0.10**	-0.05***	-0.04***	-0.04***	1	
P._acuta	-0.04***	-0.09**	0.18	-0.05***	0.08***	-0.09**	-0.08**	-0.08**	0.83	-0.05***	-0.05***	-0.05***	-0.10**	-0.03***	-0.05***	-0.05***	0.83	1

Physicochemical parameters

The physicochemical parameters of different sampling sites along the lake Kivu littoral zone is present in Table 4.

Table 4. Physicochemical parameters of different litoral sites along Lake Kivu

	pH	EC	TDS	TP	TN	Ca
Amsar	8.55±0.07	1121.65±58.9	546.7±23.6	0.68±0.5	2.96±3.6	1.0±1
Bidabanga/ISTD	8.8±0	1075±148.5	525±77.8	0.19±0.12	1.15±0.1	0.95±0.78
Birava	8.6±0.04	1067.5±3.5	520±0	0.51±0.24	3.1±3.6	1.41±1.54
Buhozi	8.1±0.85	1072.5±102.5	480±14.1	0.58±0.72	3.5±4.5	1.15±0.21
Ceshero	8.8±0	1250±14.1	610±0.01	0.23±0.28	3.3±4.2	1.01±0.98
Cibale	8.65±0.21	1106.25±8.8	536.25±8.8	0.67±0.57	3.5±4.5	0.62±0.26
Cihembye	8.65±0.21	1016.25±33.6	596.25±122	1.06±0.56	3.52±4.1	0.51±0.13
Cimenki	8.3±0.18	1100±84.9	647.5±109.6	0.81±0.78	3.3±4.3	0.93±0.81
Cirhindiro	8.6±0.14	1250±240.4	605±106.1	0.39±0.48	3.66±4.7	0.88±0.74
Dutu	8.6±0.14	885±205.1	430±99	0.32±0.01	0.71±0.61	1.1±0.99
Ikondero	8.5±0.42	1000±42.4	487.5±24.8	0.53±0.38	3.12±3.9	0.74±0.65
ITA/Pélouse	8.55±0.07	1070±28.3	522.5±10.6	0.65±0.55	3.0±3.8	0.38±0.17
Kakondo	8.45±0.21	975±77.8	601.25±72.5	0.76±0.70	3.43±4.35	0.69±0.44
Kaliba	8.15±0.21	1066.25±19.5	518.75±15.9	0.94±0.93	3.59±4.48	0.75±0.49
Kamboko	8.8±0.14	1075±49.5	525±21.2	0.29±0.01	0.57±0.46	1.1±0.85
Kanyunyi	8.7±0	1100±0	540±0.01	0.21±0.01	0.82±0.01	1.2±0.01
Kasheke	8.8±0	1220±339.4	590±155.6	0.13±0.01	1.06±0.02	1±0.99
Kasoro	8.6±0	970±141.4	470±70.7	0.24±0.12	3.16±3.8	0.64±0.51
Lutumba	8.55±0.07	940±99	455±49.5	0.27±0.07	0.72±0.59	1±0.85
Lwano	8.8±0.14	1005±35.4	490±14.1	0.16±0.2	0.63±0.62	0.85±0.64
Minova	7.5±0.14	1660±452.5	735±106.1	0.34±0.24	1.77±1.88	2.05±2.19
Mubuga	8.05±0.78	1005±35.4	532.5±74.3	0.5±0.7	3.42±4.43	1.52±1.53
Muhirimbe	8.75±0.07	1080±99	525±49.5	0.16±0.1	0.82±0.37	1.1±0.85
Nkene	8.25±0.64	821.65±172	400±84.9	1.02±0.89	3.94±4.8	1.05±1.06
Nyamasasa	8.6±0.28	1340±452	515±21.2	0.16±0.21	0.83±0.79	0.95±0.78
Runingi	8.5±0.15	960±35	475±14	0.27±0.7	0.82±2.3	1±1.1
Tchofi	8.8±0.14	1095±261.6	535±134.4	0.1±0.14	0.85±0.29	0.75±0.35
Changwi	8.5±0	1100±0.1	540±0.1	0.3±0.01	1.08±0.01	0.4±0.01

It has been reported that Total Dissolved Solids (TDS) has been reported to impair water clarity and reduce the passage of light, causing water bodies to heat rapidly and increase heat retention capacity (Environmental Protection Agency, EPA, 2012). High TDS can lead to oxygen depletion, a situation that leads to asphyxiation in the aquatic habitat and reduced abundance of some species of snails (Salawu and Odaibo,

2012). The present study revealed that the abundance of live *Bulinus truncatus* and *Biomphalaria pfeifferi* was significantly correlated with TDS. This parameter can be described as an important factor in the abundance of snails. Several research studies have identified pH values between 5.0 and 9.3 as being optimal for the survival of snails (Wanjala e*t al.*, 2013; Amoah *et al.*, 2017). Therefore, the pH values recorded in this study were within the tolerance limits of the snail species. The non-significant relationships observed reflect the fact that pH has little influence on snail abundance and may not be a key determinant of snail abundance in Lake Kivu, as also indicated in the Oyan reservoir and in Babati district in Tanzania (Ofoezie, 1999; Lydig, 2009).

Among the physico-chemical variables measured in this study, the water temperature seems to be the main determining parameter of the abundance of snails. The positive association between snail abundance and water temperature observed in our study is consistent with observations made by other authors (Wanjala *et al.*, 2013; Opisa *et al.*, 2011; Amoah *et al.*, 2017) who observed that water temperature was positively correlated with the abundance of living *Biomphalaria pfeifferi* and *Bulinus truncatus*. This indicates that increasing water temperature to tolerable levels may play an important role in host snail habitat by ensuring the availability of food and aquatic weeds (Lydig, 2009) and/or enriching the microhabitat of juvenile snails to ensure their faster growth and development (Wanjala *et al.*, 2013). Mortality of *Biomphalaria pfeifferi* also increases with increasing temperature. Woolhouse did not establish a distinct relationship between the mortality rate of *Biomphalaria pfeifferi* and temperature, probably because the temperature recorded in his study was between 18 and 25°C (Woolhouse, 1992). Thus, water temperature can be described as a key determinant of *Biomphalaria pfeifferi* abundance, as reported by Opisa et al. (2011). But the increase in conductivity values probably leads to a decrease in dissolved oxygen which negatively influences the abundance of snails (Salawu, & Odaibo, 2012).

Snails' infection with *Schistosoma mansoni* larvae

Parasitology investigation of snail *Biomphalaria pfeifferi* the intermediate host of *Schistosoma mansoni* in the region was conducted and the result is presented in Table 4.

Table 4. Parasitology of *Biomphalaria pfeifferi* around Lake Kivu

	Biomphalaria pfeifferi	***Parasites***	***%***
Amsar	2		
Birava	5		
Buhozi	85	4	4.71
Ceshero	11		
Changwi	2		
Cibale	36		
Cihembye	2		
Cirhindiro	8		
Ikondero	4		
Kakondo	114		
Kaliba	84	4	4.76
Kasheke	8		
Minova	108	11	10.19
Mubuga	141	1	0.71
Nkene	22		
Nyamasasa	1		

High rate of infection of snail *Biomphalaria pfeifferi* was recorded at the site located at Minova (10.19 %). Four sites in the littoral zone of Lake Kivu contained snail infected by *Schistosoma mansoni*. Some sites contained snail *Biomphalaria pfeifferi* was not infected. The infection rate in Lake Kivu is low to the one recorded in Ruzizi plain as reported by Baluku *et al.*, (1999). The difference was probably due to ecological characteristic of the studies area. The high air temperature recorded in Ruzizi is among the cause of high rate of infection of snail (Baluku and Bagalwa, 2021).

Conclusion

Nineteen species of freshwater snails were identified in the littoral zone of Lake Kivu during the survey, including 4 species which are known as intermediate hosts of schistosomiasis. The physical structure of the Lake Kivu coastline has an important influence on the density and composition of species communities. The species richness in the different sites varies according to the seasons. A high specific richness is recorded in the wet season for species such as *Biomphalaria pfeifferi* and *Biomphalaria smith* while a high specific richness for the species *Bulinus truncatus*, *Gabielle spirilosa* and *Corbicula sp* is recorded in the dry season. The high infection rate of the snail *Biomphalaria pfeifferi* was recorded in the site located in Minova. TDS and temperature have been identified as environmental factors limiting the abundance of snail intermediate hosts. Further study should be

conducted to assess the prevalence of trematode infection within the local community surrounding the Lake Kivu catchment.

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Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

References:

1. Abbasi I., Charles H. and Robbert F. S., 2011. Differentiation of Schistosoma haematobium from Related Schistosome by PCR Amplying an Inter Repeat Sequence. American Journal of Tropical Medical Hygiene, **79,** 590-595. doi: 10.4269/ajtmh.2012.12-0243
2. Abdulkadir F. M., Maikaje D. B. and Umar Y. A. 2017. Ecology and Distribution of Freshwater Snails in Gimbawa Dam, Kaduna State, Nigeria. Nigerian Journal of Chemical Research, 22, 2, 98 – 106. DOI: 10.9734/AJEE/2018/v8i430078
3. Amoah L. A. O., Anyan W. K., Aboagye-Antwi F., Abonie S., Tettey M. D. and Bosompem K. M. 2017. Environmental Factors and their Influence on Seasonal Variations of Schistosomiasis Intermediate Snail Hosts Abundance in Weija Lake, Ghana. Journal of Advocacy, Research and Education, 4, 2, 68 – 80. http://www.kadint.net/our-journal.html
4. Bagalwa M. and Baluku B., 1997. Distribution des mollusques hôtes intermédiaires des schistosomoses humains à Katana, Sud – Kivu, Est du Zaïre. Méd Trop. 57, 369 – 372.
5. Bagalwa M., Batumike C., Ndegeyi K., Bashwira S. and Baluku B., 2022. Distribution of snail fauna and its relationship with some physicochemical parameters in aquatic ecosystems of Irhambi Katana and Bugorhe sub-county (Southern Kivu Province, DR Congo). Journal of Biodiversity and Environmental Sciences, 20, 3, 9-20
6. Bagalwa M., Majaliwa J. G. M., Kansiime F., Bashwira S., Tenywa M. and Karume, K. 2015. Sediment and nutrient loads into river Lwiro, in the Lake Kivu basin, Democratic Republic of Congo. Int. J. Biol. Chem. Sci., Vol. 9, 3, 1678 – 1690. DOI: 10.4314/ijbcs.v9i3.46

7. Baluku B. and Bagalwa M., 2021. Schistosomiase: Une maladie parasitaire endémique en République Démocratique du Congo. Harmattan, collection études africaines, 118p.
8. Baluku B., Bagalwa M. and Basabose K., 1999. Enquêtes malacologique et parasitologique sur la schistosomiase à *Schistosoma mansoni* dans les camps des réfugiés situés dans la plaine de la Ruzizi, Est de la République Démocratique du Congo. Méd. Trop., 59: 39 – 42. PMID: 9612779
9. Batumike C., Bagalwa M., Ndegeyi K., Baluku B. and Bahizire K. 2014. Contribution à l'inventaire et écologie des espèces des mollusques dulcicole des petits cours d'eau de Lwiro et ses environs, Est de la RD Congo. International Journal of Innovation and Applied Studies, 7, 1, 298-308. http://www.ijias.issr-journals.org
10. Brönmark C., 1985. Freshwater snail diversity: effects of pond area, habitat heterogeneity and isolation. Oecologia, 67, 127-131. doi.org/10.1007/BF00378463
11. Brown D.S., 1994. Freshwater snails of Africa and their Medical Importance. London, UK: Taylor and Francis.
12. Dobson A., Kutz S., Pascual M. and Winfree R. 2003. Pathogens and parasites in a changing climate. In L. Hannah and T. Lovejoy (eds.): Climate change and biodiversity: synergistic impacts. Advances in applied biodiversity science 4: 33–38. Center for Applied Biodiversity Science, Conservation International, Washington DC
13. Environmental Protection Agency, 2012. Total solids: what are solids and why are they important. Retrieved from http//www.water.epa.gov/type/rsl/…/vms58.cfm.
14. Genner M. J., Nichols P., Carvalho G., Robinson R. L., Shaw P. W., Smith A. and Turner G. F., 2007. Evolution of a cichlid fish in a Lake Malawi satellite lake. Proceedings of the Royal Society Series B--Biological Sciences 274. 2249-2257. doi: 10.1098/rspb.2007.0619
15. Heino J., 2000. Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry. Hydrobiologia, 418, 229-242. DOI: 10.1023/A:1003969217686
16. Hosea Z. Y, Ogbogu V. C. and Agbede R. I. S., 1998. Snail distribution and habitat preferences in Zaria area, Nigeria. Paper presented at 22 nd annual conference of The Nigerian Society for Parasitology on the 4th -7th Nov., 1998 at the University of Benin, Benin City, Nigeria. p. 33
17. Lafferty K. D., 1997. Environmental parasitology : what can parasites tell us about human impacts on the environment ? Parasitology Today 13: 251–255. doi: 10.1016/s0169-4758(97)01072-7.

18. Lydig A., 2009. Factors conditioning the distribution of fresh water pulmonates, *Biomphalaria spp.*, *Bulinus spp.*, and *Lymnea spp.*, in Babati District, Tanzania. Bachelor's Thesis, Södertörn University School of Life Science.
19. Madsen H., 1992. Ecological studies on the intermediate host snails and the relevance to Schistosomiasis control. Memórias do Instituto Oswaldo Cruz, Rio de Janeiro 87: 249–253. doi: 10.1590/s0074-02761992000800039.
20. Maquboul A., Aoujdad R., Fadli M. and Fekhaoui M., 2014. Distribution of freshwater snails in the temporary pond of Annasser in Ouergha watershed, Morocco. International Journal of Fisheries and aquatic studies, 2, 3, 18 – 22
21. Mas-Coma S. Valero, M. A. and Bargues M. D., 2009. Climate change effects on trematodiases, with emphasis on zoonotic fascioliasis and schistosomiasis. Veterinary Parasitology 163: 264–280. doi: 10.1016/j.vetpar.2009.03.024.
22. Mckillop W.B. and Harrison A.D. 1980. Hydrobiological studies of eastern Lesser Antillean islands. V. St Lucia: freshwater habitats, water chemistry and distribution of freshwater molluscs. Archiv fur Hydrobiologie 3: 25 1-290
23. Mello-Silva C.C., Vilar M.M., Vasconcellos M.C., Pinheiro J. and Rodrigues M.L.A., 2006. Physiological Changes in Biomphalaria glabrata Say, 1818 (Pulmonata: Planorbidae) Caused by Sub-Lethal Concentrations of the Latex of Euphorbia splendens var. Hislopii N.E.B (Euphorbiaceae). Memórias do Instituto Oswaldo Cruz, 101, 3-8. http://dx.doi.org/10.1590/S0074-02762006000100002.
24. Ofoezie I. E., 1999. Distribution of freshwater snails in the man-made Oyan Reservoir, Ogun State, Nigeria. Hydrobiologia, 416, 181-191. DOI: 10.1023/A:1003875706638
25. Opisa, S., Odiera, M., Walter, G. Z. O., Jura Karanja, D. M. S. and Munjinzi, R. N. M., 2011. Malocological survey ad Geographical distribution of vector snail for Schistosomiasis within informal settlement of Kisumu City, Western Kenya. *Parasites and vector*, 4:226. doi.org/10.1186/1756-3305-4-226
26. Salawu O. T. and Odaibo A., 2012. Preliminary study on ecology of Bulinus jousseaumei in Schistosoma haematobium endemic rural community of Nigeria. *African Journal of Ecology, 51*, 441–446. doi.org/10.1111/aje.12054

27. Schell S., 1970. How to Know the Trematodes, WMC Brown Co. Publisher, Dubuque, 355 pp.
28. Schultheib R., Ndeo W. O., Malikwisha M., Marek C., Böbneck U. and Albrecht C. 2011. Freshwater Molluscs of the Eastern Congo: Notes on Taxonomy, Biogeography and Conservation. African Invertebrates, 52, 2, 265-284 doi: 10.5733/afin.052.0204
29. Seehausen O., 2006. African cichlid fish: a model system in adaptive radiation research. Proceedings of the Royal Society of London, Series B--Biological Sciences 273. 1987-1998. doi.org/10.1098/rspb.2006.3539
30. Sturrock R. F., 1993. The intermediate host and host parasite relationships. In: Human Schistosomiasis, (eds) P. Jordan, G. Webbe & R.F. Sturrock, pp. 33–85. CAB International, Wallingford.
31. Wanjala P. M., Battan M. K. and Luoba I. A. 2013. Ecology of Biomphalaria pfeifferi in Budalangi Endemic Focus of Western Kenya. *Research Journal of Biological Sciences, 8*(3), 74-82. DOI: 10.36478/rjbsci.2013.74.82
32. Woolhouse M. E. J., 1992. Population Biology of the Freshwater Snail Biomphalaria pfeifferi in the Zimbabwe Highveld. *Journal of Applied Ecology, 29*(3), 687-694. doi.org/10.2307/2404477
33. Yves B. K., Edia E. O., Felix K. K., Cyrille K. N., Dramane D. and Allassana O., 2013. Spatial Distribution Africa pattern of freshwater Mollusks in Me, Agenby and Banco Basin (Ivory Coast; West). *Bulletin of Environment, Pharmacology and Life Sciences*, 2, 12, 146 – 151.