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Spatial distribution, abundance and infestation rate of freshwater intermediate host snails in Lake Kivu, DR Congo side

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Abstract

Molluscs play an important role in public and veterinary health, making the continuous study of their distribution essential. The main goal of this investigation was to examine the distribution of freshwater molluscs in Lake Kivu, located on the DR Congo side. Semi-quantitative surveys conducted from January to December 2019 focused on selected sites within the lake, covering both the dry and wet seasons. Snails in the littoral zone of Lake Kivu were collected using a plankton net and pliers. The physicochemical parameters of the water at each site were measured using standard water quality analysis methods. The collected snails were morphologically identified using various identification keys. Biomphalaria species were analyzed (cercariometry) for trematode infestation. A total of 1,331 snails belonging to seven genera and 18 species were recorded during the study. The relative abundance of the recorded snail species was as follows: *Biomphalaria pfeifferi* (49.6%), *Biomphalaria smithi* (16.6%), *Gabbiella spirilosa* (10.6%), *Bulinus truncatus* (10.1%), *Lymnaea natalensis* (6.5%), *Helisoma duryi* (1.5%), *Pila ovata* and *Tomichia ventricosa* (0.8% each), *Melanoides tuberculata* (1.7%), *Lymnaea columella* and *Tomichia hendrexyx*

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(0.9% each), *Bulinus forskalii* and *Tomichia zwellandanensis* (0.9% each), Physa acuta (0.4%), Corbicula fluminalis (1.1%), Lymnaea palustris (0.2%), Tomichia kivuensis and Segmentorbis kempi (0.1% each). This study clarified the distribution and seasonal abundance of freshwater snails in Lake Kivu, DR Congo. Eighteen species of freshwater snails were identified during the malacological survey. The observed snail distribution provides insights into the epidemiology of trematode infections in the study area and highlights potential risks to human and animal health. The implications of these findings for controlling snail-borne trematodes are also discussed.

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

Introduction

The East African Rift system is a freshwater biodiversity hotspot with numerous endemic taxa, including cichlids and snails (Seehausen, 2006; Genner et al., 2007; Schultheiß et al., 2011). In this system, many lakes are millions of years old. Freshwater snails are vital components of the food chain and food web in most freshwater ecosystems. Some freshwater snails are also known for their medical and veterinary importance. It is estimated that around 350 species have medical and veterinary significance (Brown, 1994; Yves et al., 2013).

The intermediate hosts of human schistosomes belong to three genera: *Biomphalaria*, *Bulinus*, and *Lymnaea*. *Bulinus* species are associated with urinary schistosomiasis, *Biomphalaria* species with intestinal schistosomiasis, and *Lymnaea* species with fascioliasis or liver rot in animals (Mello et al., 2006). Snails play an important role in public and veterinary health, necessitating continuous studies of their distribution. They are potential intermediate hosts for trematode species in freshwater habitats.

The majority of studies on snails have focused on species of medical and veterinary importance, while there is limited information on other snail species, such as *Gabiella*, *Melanoides*, and *Tomichia*, which are known to cause zoonotic diseases (Brown, 1994; Abdulkadir et al., 2017). Environmental changes are likely to alter the distribution patterns of snails and can be used to assess environmental impacts (Lafferty, 1997). Physico-chemical factors, particularly calcium concentrations, have been emphasized by several authors in temperate and tropical freshwater ecosystems (McKillop & Harrison, 1980; Bagalwa et al., 2022).

Information on snail distribution, infection, ecology, and behavior could enhance the efficiency of control measures against snails of medical and veterinary importance. The importance of such studies has been particularly emphasized in the control of schistosomiasis transmission (Madsen, 1992; Sturrock, 1993). The distribution and abundance of snails are influenced by

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various factors, including food supply, predators, parasites, rainfall, and water composition. Additionally, sunlight, aquatic weeds, the abundance of microflora, high dissolved oxygen content, and seasonal changes 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). Physico-chemical factors in the water, which are considered the most significant environmental influences on freshwater snails, include temperature, pH, turbidity, dissolved oxygen, calcium, magnesium, and phosphate levels (Abbasi et al., 2011; Bagalwa et al., 2022). One of the primary 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 closely linked to ecological factors (Brown, 1994). A local survey has identified specific factors that are important in each water body for the proliferation of trematode intermediate hosts (Bagalwa et al., 2022).

The present investigation aims to provide information on the distribution patterns of molluscan species around the littoral zone of Lake Kivu, on the DRC side, with the purpose of presenting a list of the different snail species collected.

Material and Methods

Sampling and identification of snails

Freshwater snails were collected using a plankton net or manually with forceps during monthly surveys conducted over a twelve-month period (January to December 2019), as described by Opisa et al. (2011). The collection was carried out at sites with human activities. Snails were gathered from various habitats at 27 locations along the littoral zone of Lake Kivu (Figure 1).

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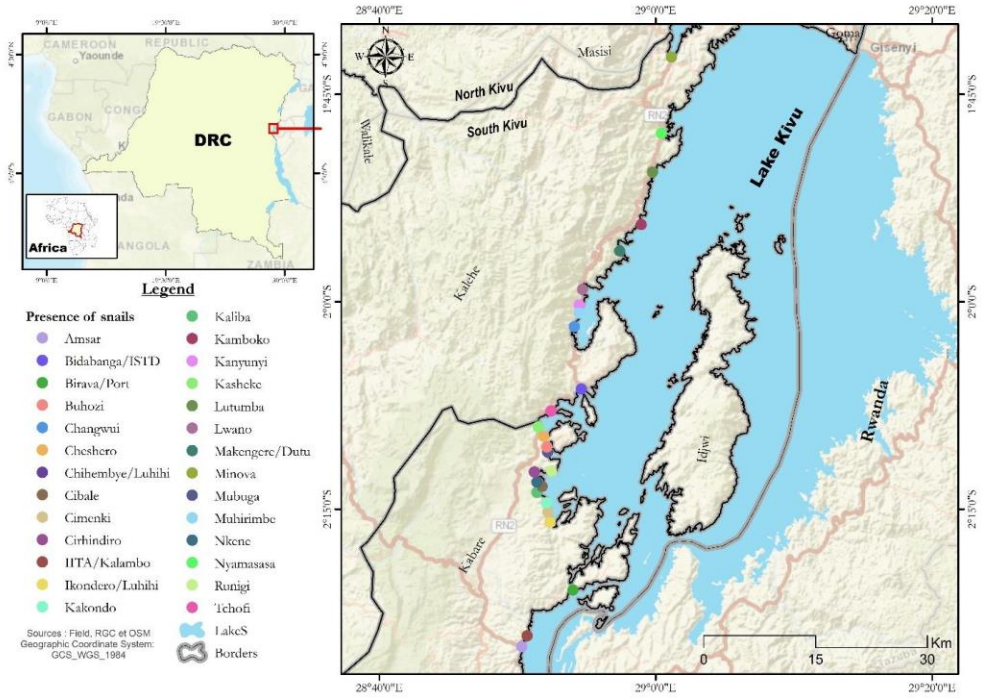

Figure 1. Localization of sampling sites along the DR Congo shore of Lake Kivu

Each sampling was conducted by three trained snail collectors using standard snail scoops or, occasionally, 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). In the laboratory, snails were sorted and identified to the species level using the standard morphological key described by Brown (1994).

After identification using Brown's (1994) key, the snails were separated, and *Biomphalaria pfeifferi* specimens were exposed to artificial light to check for possible trematode larvae infections. Cercariae were identified based on the criteria described by Schell (1970). If no cercariae were identified, the ten largest specimens of each mollusk sample from different sites were dissected under a binocular microscope to assess possible infestations.

Determination of the Physico-Chemical Parameters of the Freshwater Body

Surface water samples were collected once a month from each sampling site using the simple dipping method. The collected water samples were transported to the laboratory for chemical analysis of calcium and nutrients (Bagalwa et al., 2015). pH, surface water temperature, conductivity,

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and total dissolved solids were measured on-site using an EC/pH/TDS/Temp COMBO meter (Hanna Instruments, Inc.).

Data Analysis

A t-test was used to compare the relative abundance of freshwater snails between the dry and wet seasons. All analyses were conducted at an alpha level of 0.05, with a p-value < 0.05 considered statistically significant.

Results and Discussion

Species abundance

The freshwater snails identified are presented in Table 1. A total of 1,331 freshwater snails, belonging to 6 families and 18 species, were collected during the study period.

Table 1. Distribution of freshwater snails 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 truncata
			Gabbiella spirilosa
		Thiaridae	*Tomchia kivuensis*
			Tomchia hendrexyx
			Tomchia zwellandanensis
			Tomchia ventricose
		Physidae	*Physa acuta*
			Pila ovata
			Melanoides tuberculata
Venerida	Bivalvia	Corbiculidae	*Corbicula fluminalis*

The families *Thiaridae, Planorbidae, Lymnaeidae,* and *Bulinidae* each include four species of snails, while the family *Corbiculidae* has only one species. Species diversity and abundance varied between sites and across seasons.

The seasonal variation in snail species abundance at the different sampling sites is presented in Figure 2.

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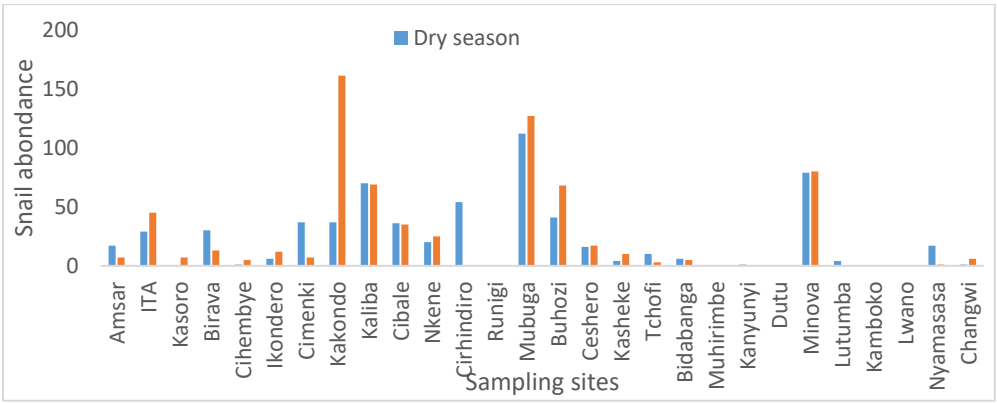

Figure 2. Seasonal variation in species abundance at sampling sites

High abundance (161–127 specimens) of snail species was recorded at Kakondo and Mubuga during the wet season. Relatively high abundance (239, 198, 159, 139, and 109 specimens) was also observed at Mubunga, Kakondo, Minova, Kaliba, and Buhozi. In general, a high number of snails (703 specimens) were recorded across the majority of sampling sites during the wet season. A significant seasonal difference in snail abundance between the dry and wet seasons was observed at the sampling sites ($p < 0.05$).

The physical structure of the lake's littoral zone is recognized as having an important influence on the density and composition of species communities (Maqboul et al., 2014). Species richness at these sites varied with seasons, reflecting the diversification of ecological niches that allow resource sharing (Brönmark, 1985; Heino, 2000).

Statistical analysis revealed a significant difference ($p < 0.05$) in the relative abundance of snail collections between the dry and wet seasons ($t = 2.1018$, $p < 0.05$). The highest Shannon index was recorded during the dry season ($H = 2.635$), when all species in the lake sites were sampled. In the wet season, a Shannon index of $H = 2.367$ was recorded, reflecting the collection of fewer species. The equitability index was also higher in the dry season ($e = 0.85$) compared to the wet season ($e = 0.79$). These results suggest that the structure of freshwater mollusk communities is not well balanced across the two seasons.

The seasonal variation in species abundance in the littoral zone was recorded and is presented in Table 2.

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Table 2. Seasonal Variation in the Abundance of Each Species in the Littoral Zone of Lake Kivu

	Dry season	Wet season
Biomphalaria pffeiferi	271	362
Biomphalaria smith	93	128
Bulinus truncatus	79	55
Bulinus forskalii	0	3
Lymnae natalensis	42	44
Lynmae columella	3	9
Lymnae palutris	2	0
Melanoides tuberculata	14	8
Tomchia kivuensis	1	0
Tomchia hendrexyx	12	0
Tomchia ventricosa	6	5
Tomchia zwellandanensis	2	0
Gabbiella spirilosa	82	59
Helisoma duryii	5	15
Corbicula fluminalis	10	4
Segmentorbis kempi	0	1
Pila ovata	4	7
Physa acuta	2	3

According to **Table 2**, a seasonal change in the abundance of snails in the littoral zone of Lake Kivu was observed. The species *Biomphalaria pfeifferi* and *Biomphalaria smithii* were more abundant during the wet season, while *Bulinus truncatus*, *Gabielle spirilosa*, and *Corbicula* sp. were highly represented during the dry season.

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Figure 3. Pearson correlation between snail's species

	B.__pfeifferi	**B._smithii**	**B._truncatus**	**B._forskali**	**L._natalensis**	**L._collumella**	**L._palutris**	**M._tuberculata**	**T._kivuensis**	T._hendrexyx	T._ventricosa	T._zwellendanensis	G._spirilosa	H._durnii	Corbuculasp	S._kempi	P._ovata	P._acuta
B.__pfeifferi	1																	
B._smithii	0.88**	1																
B._truncatus	-0.1	-0.11*	1															
B._forskali	0.56	0.71	-0.06***	1														
L._natalensis	0.58***	0.69	-0.15	0.36	1													
L._collumella	0.01	0.09**	-0.10**	0.22	0.02***	1												
L._palutris	-0.15*	-0.11*	-0.09**	-0.05***	-0.18	-0.09**	1											
M._tuberculata	-0.12***	-0.11*	-0.09**	-0.06***	-0.07***	-0.01***	-0.08**	1										
T._kivuensis	0.00*	-0.06***	-0.06***	-0.04***	0.12*	-0.06***	-0.05***	-0.06***	1									
T._hendrexyx	-0.11	-0.08**	-0.06***	-0.04***	0.08**	0.08**	-0.05***	0.53	-0.04***	1								
T._ventricosa	-0.11*	-0.08**	-0.06***	-0.04***	0.08**	0.08**	-0.05***	0.53	-0.04	1	1							
T._zwellendanensis	-0.11*	-0.08**	-0.06***	-0.04***	0.08**	0.08**	-0.05***	0.53	-0.04***	1	1	1						
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					

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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			
Corbicula_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

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Physicochemical parameters

The physicochemical parameters of the different sampling sites along the littoral zone of Lake Kivu are presented in Table 3.

Table 3. Physicochemical parameters of different littoral sites along Lake Kivu

	Potential Hydrogen (pH)	Electric conductibility (µS/cm)	Total Dissolved Solid (mg/L)	Total Phosphorous (µmol/L)	Total nitrogen (µmol/L)	Calcium (mg/L)
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) impair water clarity and reduce the passage of light, causing water bodies to heat up rapidly and increasing their heat retention capacity (Environmental Protection Agency, EPA, 2012). High TDS can lead to oxygen depletion, which may result in asphyxiation in the aquatic habitat and reduced abundance of some snail species (Salawu and Odaibo, 2012). Several studies have identified pH values between 5.0 and 9.3 as optimal for the survival of snails (Wanjala et 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 suggest that pH has little influence on snail abundance

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and may not be a key determinant of snail abundance in Lake Kivu, as also indicated in the Oyan Reservoir and Babati District in Tanzania (Ofoezie, 1999; Lydig, 2009).

Among the physicochemical variables measured in this study, water temperature appears to be the main determining factor for snail abundance. The positive association between snail abundance and water temperature observed in our study is consistent with findings by other authors (Wanjala et al., 2013; Opisa et al., 2011; Amoah et al., 2017), who noted that water temperature was positively correlated with the abundance of *Biomphalaria pfeifferi* and *Bulinus truncatus*. This suggests that increasing water temperature to tolerable levels may play an important role in the habitat of host snails by ensuring the availability of food and aquatic weeds (Lydig, 2009) and/or enriching the microhabitat of juvenile snails, promoting faster growth and development (Wanjala et al., 2013). Mortality of *Biomphalaria pfeifferi* also increases with rising temperatures. Woolhouse did not establish a distinct relationship between the mortality rate of *Biomphalaria pfeifferi* and temperature, probably because the temperatures recorded in his study ranged from 18 to 25°C (Woolhouse, 1992). Thus, water temperature can be considered a key determinant of *Biomphalaria pfeifferi* abundance, as reported by Opisa et al. (2011). However, the increase in conductivity values likely leads to a decrease in dissolved oxygen, which negatively affects the abundance of snails (Salawu & Odaibo, 2012).

Snails' infection with *Schistosoma mansoni* larvae

Parasitological investigation of *Biomphalaria pfeifferi*, the intermediate host of *Schistosoma mansoni* in the region, was conducted, and the results are 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		

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A high rate of infection in *Biomphalaria pfeifferi* snails was recorded at the site located in Minova (10.19%). Four sites in the littoral zone of Lake Kivu contained snails infected with *Schistosoma mansoni*. Some sites contained *Biomphalaria pfeifferi* snails that were not infected. The infection rate in Lake Kivu is lower than the one recorded in the Ruzizi plain, as reported by Baluku et al. (1999). This difference is likely due to the ecological characteristics of the study areas. The high air temperature recorded in Ruzizi is one of the factors contributing to the higher infection rate in snails (Baluku and Bagalwa, 2021).

Conclusion

Eighteen species of freshwater snails were identified in the littoral zone of Lake Kivu during the survey, including four species 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. Species richness in the different sites varies according to the seasons. High species richness is recorded in the wet season for species such as *Biomphalaria pfeifferi* and *Biomphalaria smithii*, while high species richness for *Bulinus truncatus*, *Gabielle spirilosa*, and *Corbicula* sp. is recorded in the dry season. The highest infection rate of *Biomphalaria pfeifferi* snails was recorded at the site located in Minova. TDS and temperature have been identified as environmental factors limiting the abundance of snail intermediate hosts. Further studies should be conducted to assess the prevalence of trematode infections within the local community surrounding the Lake Kivu catchment.

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