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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)

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Abstract

A study was carried in order to determine the distribution and physicochemical preferences characteristics of three species of aquatic snails (*Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Physa acuta*). Samples of snails and water were collected monthly during 2015 to 2017 at 54 sites locateted in Irhambi/Katana and Bugorhe sub-counties, DR Congo. Analysis of the data revealed that the some physicochemical of water in different sites effect on the distribution of the freshwater snails *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Physa acuta*. The coefficients of correlation (r) between snail populations and physicochemical parameters are significant correlated with pH, TP and current velocity. A Canonical Correspondence Analysis (CCA) reveals associations between the distribution patterns of freshwater snail species *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Physa acuta* and the concentration of TP and pH. The levels and the type of variables differ from species to species. Species characteristic can help increase our understanding of aquatic mollusc and their importance in ecological and biological studies. Further detailed studies on each of these individual parameters are needed.

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Introduction

Aquatic snails play an important role in freshwater ecosystem and some of them transmit serious diseases to human, animals and fish. They are used as indicator organisms for biological monitoring and in hazard and risk assessment (Borcherding and Volpers, 1994). They play major roles in the public and veterinary health and they need to be deeply investigated (Supian and Ikhwanuddin, 2002). The composition and spatial relationships of aquatic communities are related to the habitat structure and variation of environmental factors (Pérez-Quintero, 2011). One of the goals of freshwater ecology is to understand how communities of freshwater species are structured and how environmental factors affect their distribution. According to Pemola *et al.* (2015), snail communities are influenced by the prevailing physicochemical parameters, which determine their abundance, occurrence and seasonal variations. The physicochemical parameters include a number of factors such as dissolved oxygen, pH, water temperature, calcium ion, physical nature of the substratum, depth, current velocity and nutritive content of the water body (Duft *et al.*, 2007; Rai and Jauhari, 2016).

Ecologists and epidemiologists are increasingly challenged to understand how large-scale agents of environmental change affect host-pathogen interactions (Johnson *et al.*, 2007). In freshwater ecosystems, eutrophication is a widespread and growing problem with sharply negative effects on water quality, but indirect effects on human and wildlife diseases (Johnson *et al.*, 2007). Nutrient promotes algal growth, leading to an increase in the density and biomass of snail hosts, thereby enhancing parasite transmission into snails. Infected snails with high resource availability are also expected to produce more parasite cercariae, increasing the risk of infection and pathology to human and amphibian (Johnson *et al.*, 2007; Struijs *et al.*, 2010).

The comparative studies in aquatic snail have revealed that species' distributions are restricted by environmental conditions (Bagalwa and Baluku, 1997). The ecology of freshwater snails is considered to be affected by environmental abiotic factors like physico-chemical parameters and as a consequence to affect abundance of the snail population as well as occurrence of snail (Gupta and Khajuria 2004; Malik and Bharti 2005; Garg *et al.*, 2009) and also influenced by other factors like availability of food, competition, predator-prey interactions (Ofoezie, 1999). Excessive nutrient (phosphorus and nitrogen) loss from watersheds is frequently associated with degraded water quality in streams (Yan *et al.*, 2007) and so the distribution of snail.

Abiotic factors of aquatic system play significant role in altering the snail population/infection rate as well as fecundity of snail (Johnson *et al.*, 2007). Studies have been conducted on aquatic flora and fauna associated with the freshwater snail *Lymnaea acuminata* in Kham river at Aurangabad revealed that pH, temperature and stream discharge were the dominant factors affecting the community structure in streams (Townsend *et al.*, 1983; Pizarro *et al.*, 2010).

A little information is known about the ecological preferences of snail in Katana region, DRCongo. The reasons of the actual distribution of snail in the different aquatic ecosystem in this region are not well documented. The aquatic ecosystem in the region are subjected to anthropogenic disturbance due to sewage draining by canals coming from the neighboring cities. This disturbance represents a menace for the aquatic ecosystem integrity and their communities.

Besides these, freshwater snails are also recognized as vector of different type of trematode parasites, causing various diseases *viz.*, Shistosomiasis, Fasciolosis, Amphistosomiasis, etc. to the human beings and their livestock. They play significant role in public and veterinary health (Choubisa 2008; Devkota *et al.*, 2011; Rai and Jauhan, 2016).

The present study is an attempt to investigate the relationship between the physicochemical parameters and the abundance of snails in aquatic ecosystems in Irhambi/Katana and Bugorhe sub-counties.

Data was collected in the sub-counties of Irhambi/Katana and Bugorhe from January 2015 to December 2017 in order to obtain information on aquatic snail diversity and physicochemical characteristics in different ecosystems.

Materials and methods

Study area

The investigation was performed at 54 selected sampling sites in Irhambi/Katana and Bugorhe sub-counties, DRCongo. This region is located in the territory of Kabare, 50 km north of the city of Bukavu. It includes both the localities of the groups of Irhambi and Bugorhe flooded by the rivers Lwiro, Cirhanyobowa, Langa, Nyabarongo and their tributaries such as the rivers Nyabichesa, Kabindi, Kalengo, Birunga, Choga, Kayumaga, Kisima Ciduha, Kashukabatware, Nkene , Busengura, Kamirihembe, Choga and others. It extends between 28 ° 45 'to 28 ° 85' east longitude and 2 ° 15 'to 2 ° 30' south latitude with altitudes ranging between 1470 m and 2200 m altitude (edge of the PNKB), over an area of 41 km2 (Fig. 1).

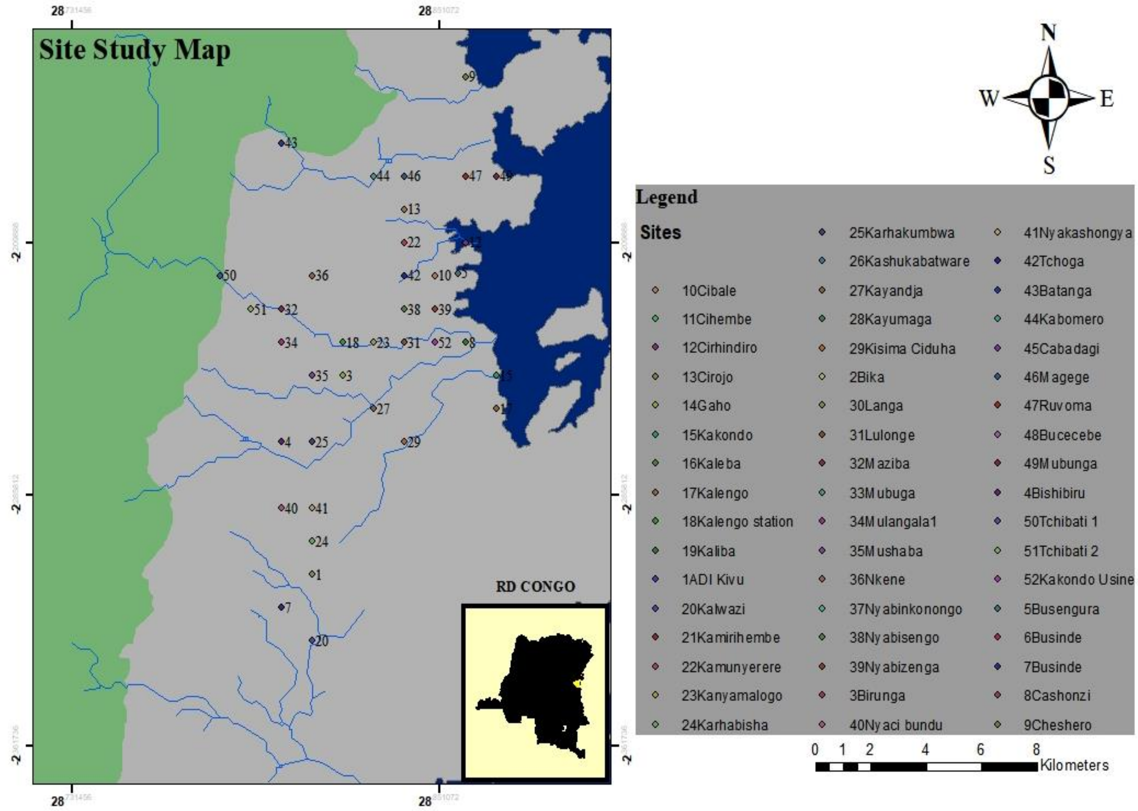

Fig. 1. Localization of sampling site in Lake Kivu watershed in Irhambi/katana and Bugorhe.

The streams have made the area threatening and rocky by cutting through the chain of mountains one by one because of heavily rains and altitude in this watershed. In the present study, water and snail samples were collected of various aquatic ecosystems. It is covered with volcanic soil and is formed by alternating hills and valleys and enjoys a humid tropical climate including a long 9-month rain season (September to May) and a short dry season of 3 months (June August). The average annual air temperature is 19.5 ° C and the relative humidity varies between 68% and 75% providing a favorable climate for agricultural diversity (Balagizi *et al.*, 2013).

The vegetation consists of a grassy mountain savanna dominated by highly diversified grasses and some shrubs. This vegetation has replaced a primitive vegetation consisting of primary forest *Albizia grandibracteata* whose relics are still visible in the Mugeri, Kakondo and Lwiro stations (Bagalwa *et al.*, 2016).

Snail data collection

Monthly snail sampling was made during January 2015 to December 2017 using the standards method developed by Olivier and Scheiderman (1956) by counting the number of snails that can be collected by one or more experienced collectors who search the marked area systematically for a measured interval of time. Snails were collected by dip nets and also by hand for 10 minutes. Snails were identified and counted using a binocular microscope. Identification of snail's species was done with the help of standard keys Brown, (1994).

Physicochemical Analysis

Water samples for physicochemical analyses were collected monthly from each sampling sites using prewashed polyethylene bottles. Water temperature (°C) and pH were measured in the field by using HANNA multi-parameter instrument. Dissolved oxygen (DOmgl^{-1}) was analyzed using Winkler methods after fixing the oxygen in the field. The levels of TN (µmol^{-1}), TP (µmol^{-1}) and Ca^{+2} (mgl^{-1}) were analyzed in the laboratory in the sampling water according to standard methods (Golterman *et al.*, 1978; APHA, 2005; Wetzel and Liken, 2001). All materials were deposited in the laboratory of Malacology of the "Centre de Recherche en Sciences Naturelles de Lwiro".

Others environmental parameters such as current velocity, depth, vegetation and substratum at the sites were recorded also using flow measurement methods and observations in the field (Bagalwa *et al.*, 2016).

Statistical Analysis

The relationships between snail abundance and eight physicochemical parameters were examined by applied correlation and Principal Components Analysis (PCA). Pearson Correlation analysis was performed to determine if there were any correlation between the physicochemical variables and the number of individual species of the three snails. PCA is an ordination method effective in directly revealing correlations between the spatial structure of communities and environmental factors that might be responsible for that structure (Ter Braak and Smilauer, 2002).

Results and discussion

Composition and distribution of snail species

Snails are distributed in many habitats with their highly adaptation abilities. We found snails in river, streams, pond and in the Lake Kivu. 19 species was recorded during the sampling period in these freshwaters of Katana region. Because of the high adaptation capabilities to the snails, a wide distribution in adapted areas has been observed. Snails were sampled in 44 sampling sites over 54 sites choses in Irhambi/Katana and Bugorhe sub-counties (Fig. 2).

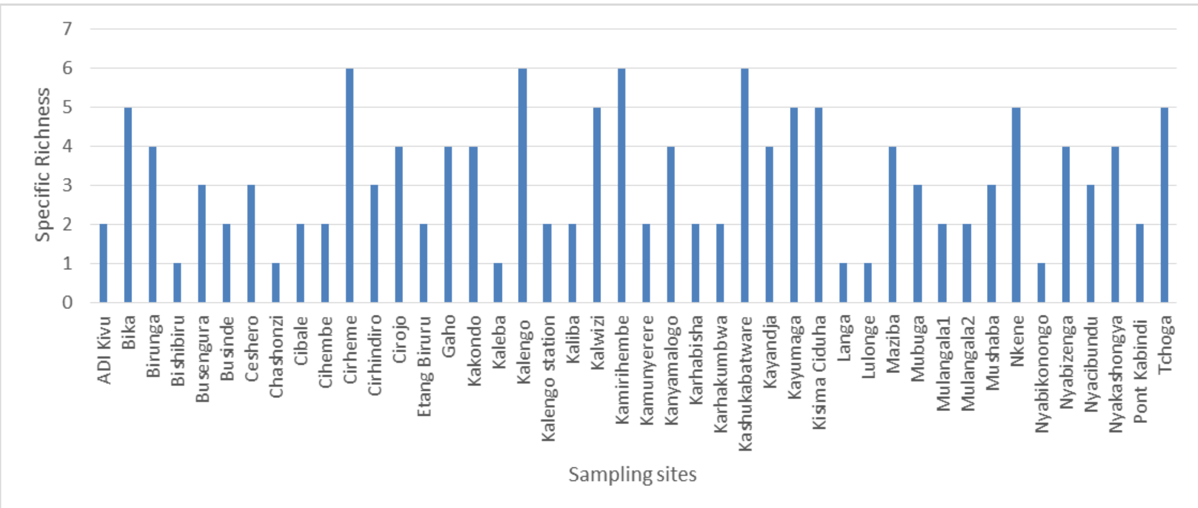

Fig. 2. Variation of the species richness of molluscan communities collected from different study sites during the investigation period.

High specific richness (6 species) was recorded in 4 sites (Kalengo, Cirheme, Kamirihembe and Kashukabatware). Some sites doesn't content snail during our sampling period (10 sites). Among the snails collected three intermediate host of diseases were investigated. The three snails are *Biomphalaria pfeifferi* intermediate host of *Schistosoma mansoni*, *Lymnae natalensis* host of *Fasciola gigantica* and *Physa acuta* host potential of *Schistosoma hoematobium*.

The highest densities of *Biomphalaria pfeifferi, Lymnae natalensis* and *Physa acuta* were recorded in the pond of Bika (126, 139 and 126 ind/10 minutes of sampling respectively). These densities were not significantly different between the different sites (ANOVA one-way; $p > 0.05$). This difference in species richness was probably due to the ecology of species and environmental factors as also observed in Banco River and Bia River (N'Zi *et al.*, 2008; Anoh, 2002; Camara *et al.*, 2009). Some parameters as TSS can have detrimental effect on snail in decreasing visibility in water.

Biomphalaria pfeifferi and Lymnaea natalensis, are sympatric snail in the region. Their presence in many aquatic ecosystem was already demonstrated by others authors (Bagalwa and Baluku, 1997). *Physa acuta* is an invasive species occurring in the region recently (Batumike *et al.*, 2014). This species distribution was related to the variation in habitat conditions in sampling sites.

The high density of *Biomphalaria pfeifferi, Lymnaea natalensis* and *Physa acuta* in several sites was due to a good level of pH, TP and TN concentrations, low current velocity of water and decomposed vegetal detritus. This observation corroborated the results of March *et al.* (2001), and Usio and Townsend (2001), which showed the importance of plant material decomposition in streams to abundance of macroinvertebrates.

The three snail are herbivorous and feed on diatoms algae which are abundant in open sites and rich in decomposed material (Brown, 1994).

These species seems to tolerate in sites unfavorable conditions such as low dissolved oxygen and significant organic matter, as suggested by Cumberlidge (2005). Snails have different levels of sensitivity to pollution and many abiotic factors in the river ecosystem as observed by Rosenberg and Resh (1993), but the three snail species have the some tolerance in these studies. *Physa acuta* which is a introduce species or invasive species has concurrence the others snails and occurring in many sites with the two snails species (Batumike *et al.*, 2014). This show that this snail will occupy many sites in the future.

Environmental variables

pH was basic in all the sampling sites with a mean of 7.6 (6.75 - 8.48) and a variation between sampling sites. Several research works have identified pH values within 5.0-9.3 to be optimum for snail survival (Wanjala *et al.*, 2013). Hence pH values recorded in this study were within the tolerance limits of snail species. There are non-significant relationships observed between pH and snail abundance or little influence only were noted due to the variations in sites as reported also by Lydig, (2009).

Temperature played an important role in the physicochemical and physiological behavior of the aquatic system (Alaka, 2014). Variation of water temperature, were ranged between 14.63 °C and 30.33 °C at the various sampling sites in Irhambi/Katana and Bugorhe ecosystems. Sites with high temperature were preferred by snail populations. The high temperature was probably due to the accumulation of plant detritus on the bottom providing useful shelters for various freshwater macroinvertebrates, because of the increase in temperature inside these as a result of decaying processes as found also by Spyra, (2010). The role of plant detritus in the life of freshwater snails was only rarely discussed in recent literature concerning the water bodies of an anthropogenic origin. Linda *et al.*, (2017) also found that aquatic plants in the habitats of snail have influence snail occurrence and population densities as observed in the different sites in the sampling sites of Irhambi/Katana and Bugorhe ecosystems.

The lowest dissolved oxygen values recorded was 3.28mg/L and the highest values were 10.37mg/L. This result was almost within the range mentioned by Njoku-Tony, (2011), who found that the desired concentration of DO for snails ranged between 2.2 - 8.5mg/L. This study has also revealed a significant variation in the values of DO across the ecosystems of Irhambi/Katana and Bugorhe. Variation of DO in the ecosystems shown difference in distribution of snail in the region. At high DO pulmonate snail were not found. Ofoezie (1999) found a positive influence on the density of all pulmonate snail species and a negative influence on the density of the prosobranch species on DO contrary to the founding of this study. The effect of DO was also found in Egypt in Giza and Kafr El-Shiekh Governorates sampling sites (El Deeb *et al.*, 2017).

The concentration of calcium in water show a low concentration was about 0.37mg/L and the high concentration about 1.33mg/L. Many freshwater systems exhibit fluctuations in calcium concentration over time. Williams (1970) found greater fluctuations of 6.2 to 101.0mg/L Ca^{2+} at study sites in central Africa. In the sampling sites in Irhambi/Katana and Bugorhe ecosystems, concentrations of calcium were less compared to others ecosystems in tropical regions. Snail are considered a calciphile and exhibits reduced growth and survival in environments containing less than 20mg/L Ca^{2+} (Delesman and Lukowiak, 2010). Freshwater gastropods may experience considerable fluctuations in calcium concentration in natural conditions over the period of a year.

Aquatic ecosystem receives substantial nutrient inputs, including both nitrogen (N) and phosphorus (P), in many parts of the world. The mean values of TP in all the sampling sites was about 0.09 (0.01 - 0.33)µmole/L and for TN 0.50 (0.12 - 6.03)µmole/L. The two nutrients are important factor controlling phytoplankton biomass the main food of freshwater snails. The variation of concentration in different ecosystem affected the distribution of snail (Dodds and Smith, 2016).

Another limiting factor for snail distribution in the studied was the water current velocity and the depth. The mean depth in the sampling site was about 64.8 cm (0.05 - 19.3 cm) and the current velocity was 0.63 m/s (0-1.83 m/s). All the snails species encountered at those environments were found mostly in ecosystems which have slower water flow than those from big streams as also found by Giovanelli *et al.*, 2005).

Relationships between environmental variables and snails abundance

The relationship between snail abundance and some physicochemical parameters are presented in Table 1.

Table 1. Spearman correlation of snail densities and physicochemical parameters of sampling sites in Irhambi/Katana and Bugorhe sub-county.

0	Temp	pH	DO	Ca^{+2}	TP	TN	Depth	Veloc	Bio	Physa	Lymn
Temp	0										
pH	0.17	0									
DO	-0.40*	-0.03	0								
Ca^{+2}	0.47*	0.01	-0.22	0							
TP	0.13	0.11	-0.11	0.09	0						
TN	0.07	0.07	-0.11	0.22	-0.08	0					
Depth	-0.22	0.01	0.24	-0.33	0.01	0.10	0				
Veloc.	-0.38**	-0.25*	-0.04	-0.28*	-0.13	0.13	0.43**	0			
Bio	0.17	0.30*	-0.11	0.17	0.45**	0.06	-0.15	-0.36**	0		
Physa	0.07	0.28*	-0.10	-0.03	0.49***	0.00	-0.07	-0.27*	0.91***	0	
Lymn	0.14	0.30*	-0.10	0.05	0.50***	0.02	-0.05	-0.32*	0.94***	0.97***	0

*** : Very significant at $p < 0.000$, **: Significant at $p < 0.05$), *: Significant at $p < 0.01$

The correlation analysis shows that there are negative correlations between water current velocity and temperature, pH, DO, Ca^{+2} and abundance of snail (*Biomphalaria pfeifferi*, *Physa acuta* and *Lymnea natalensis*) in the aquatic ecosystem and positive correlation with depth.

Spearman correlation analysis indicates that *Biomphalaria pfeifferi, Lymnaea natalensis* and *Physa acuta* were significantly influenced by pH, TP and current velocity.

Abdel, (1958) observed a specific relationships between snail abundance and a suite of abiotic factors such as total dissolved solids, pH, water temperature and dissolved oxygen. But, in the study conducted by Spyra (2014) in woodland ponds in Poland, pH was no correlated with abundance of snail. *Biomphalaria pfeifferi, Lymnaea natalensis* and *Physa acuta* were most frequently encountered in water bodies polluted by high amounts of human and animal excrements, as well as domestic sewage.

The abundance of organic matter (TP and TN) increases the concentration of detritus and possibly aids in the proliferation of epiphytic algae diet of *Biomphalaria pfeifferi, Lymnaea natalensis* and *Physa acuta* (Baluku, 1987; Spyra, 2014). This was also observed in others studies (Madsen, 1992). Spearman correlation between specific richness and the tree snails species were analysis and the result are present in table 2.

Table 2. Spearman correlation between specific richness and the tree snails in sampling sites of Irhambi/Katana and Bugorhe sub-county.

	Biomphalaria	Physa	Lymnaea	Specific richness
Biomphalaria	0			
Physa	0.91***	0		
Lymnaea	0.94***	0.97***	0	
Specific richness	0.44**	0.36**	0.38**	0

*** : Very significant at p < 0.000, **: Significant at p<0.05)

The specific richness is significant correlated with the three snail's species. According to Simboura et Zenetos (2002), the specific richness is function of the type of substratum, depth and salinity. This positive correlation shows that the tree snails species has the some habitat preference. *Physa acuta* is specie which was recently collected in this area, but with this result it can be conclude that this specie is now taking the same place as *Biomphalaria pfeifferi* and *Lymneae natalensis* which was already none as sympatric species (Baluku, 1987; Batumike *et al.*, 2014).

The PCA of the abundance of the three snail's species and some environmental parameters of sampling sites are presnt in fig. 2.

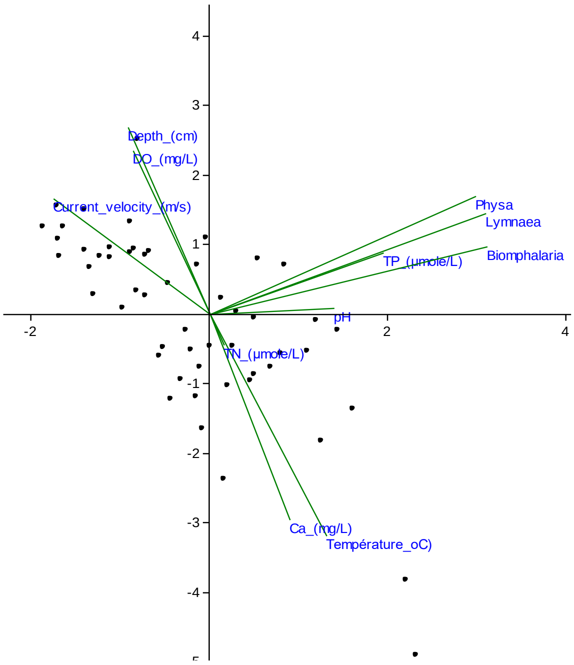

Fig. 3. PCA showing species and some physicochemical parameters in sampling sites of Irhambi/Katana and Bugorhe sub-counties.

The results of PCA revealed that the relationships between the three snail species and their habitat conditions follow mainly the first two axes (Fig. 3). Current velocity, DO and depth are negatively correlated to abundance of snails *Biomphalaria pfeifferi*, *Lymnae natalensis* and *Physa acuta*. DO is one of the major component, which is required for the metabolic activity of snails (Watten, 2004). The decreases in concentration of DO with increase in temperature in aquatic ecosystem are observed in our result as also proved by Singh and Singh (2009).

pH of water is one of the important factors that directly or indirectly influence the metabolic activities and thereby the growth and abundance of freshwater snails. In general, the aquatic organisms are affected by pH because most of their metabolic activities are pH dependent (Abdel, 1958; Joosse, 1984). Gallordo *et al.* (1994) and Dillon (2000) also in their studies confirm that pH is a determining factor for snail species. Not only low pH (pH <6) hampers the development of snail, it is also reported that the low pH could be fatal to them (Hart and Fuller, 1974). Zeybek *et al.*, (2012) found that there is a positive correlation between *B. pseudemmericia* and pH values as revealed also in our studies. In this study, pH was basic and allow metabolic activities to take place and favorited the abundance of snail.

Concentration of TN is not influencing the abundance of snails as showing in the fig. 3. These may be because in tropical water the Nitrogen is not a limiting nutrient. Nitrogen is important for algal growth in aquatic ecosystem. The result of this study shows that snail was not present in sites with low temperature, high content of DO, high velocity and low aquatic vegetation. This was confirmed in the others works and supports the findings of earlier workers (Yi-Jiun *et al.*, 2007).

According to Şahin and Zeybek (2014), the species belong to pulmonata were positively correlated with Ca^{+2} (P < 0.05) and water temperature except *Acroloxus lacustris*. This was contrary to our funding, because Ca^{+2} and temperature was not correlated to any species of snail investigated. Calcium is the primary component of a snail shell (Briers, 2003; Rycken *et al.*, 2003). The concentration of the calcium in aquatic ecosystem was generally high in a volcanic region (Bagalwa *et al.*, 2015).

Studies on biotic and abiotic factors influencing the distribution of the snail it was pointed out that many factors affect the distribution of snail, but there was a specific relationships between snail abundance and the abundance of co-occurring snails *(Physa acuta*) and others *Biomphalaria pfeifferi* and *Lymnae natalensis*), as well as a suite of abiotic factors (pH, TP and current velocity) in this region. There is a bit similarity between the findings of present study and with regard to occurrence of *Lymnaea acuminata* (Nagare and Dummalod, 2012) but the difference exists if the coexisting biotic community is taken into consideration.

Several studies have investigated the relationship between snail species with environmental factors by using PCA (César *et al.*, 2012; Strzelec *et al.*, 2014). According to PCA diagram obtained in this study, total phosphorus, speed velocity and pH are often considered as major factors determining the distributions of freshwater snails in Irhambi/Katana and Bugorhe sub-county.

Conclusively, these results are still limited and can't be generalized to many species and sites with different ecological situations. However, the levels and the type of such variables differ from species to species knowledge on species characteristic can help increase our understanding of aquatic mollusc and their importance in ecological and biological studies. Further detailed studies on each of these individual parameters are needed. The present findings could be utilized by future researchers and ecologists as supplementary in means of control intermediate host of disease.

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