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Articles and Statements

Environmental Factors and their Influence on Seasonal Variations of Schistosomiasis Intermediate Snail Hosts Abundance in Weija Lake, Ghana

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Abstract

Schistosomiasis, which remains a key Neglected Tropical Disease, is facilitated by the population dynamics of the intermediate snail host that is reported to be influenced by environmental factors. In Ghana fewer studies on environmental factors have been carried out with the advent of climate change and it predicted influence on the ecology of vectors of diseases that tend to be focal. This study therefore sought to investigate the influence of environmental factors on seasonal variations on intermediate snail hosts abundance. Snails were sampled monthly at a demarcated zone on the Weija Lake near Tomefa, a schistosomiasis endemic community using the scoop net and hand picking techniques. A total of 2,612 snails including 739 dead/empty shells were collected throughout the sampling period. Of this number, 1, 367 (inclusive of 600 dead) *Biomphalaria pfeifferi* and 1, 245 (inclusive of 139 dead) *Bulinus truncatus* were collected. Total dissolved solids, temperature and turbidity significantly influenced snail abundance ($p<0.05$). Five aquatic plant species were found to support both snail species, with *Ceratophyllum* spp being the most common. Snail abundance varied seasonally with TDS, turbidity and temperature identified as important limiting environmental factors to intermediate snail hosts abundance. Aquatic plant species influenced snail abundance by providing shelter, food and sites for oviposition.

Keywords: *Biomphalaria pfeifferi*, *Bulinus truncatus*, Environmental Factors, Intermediate Hosts, Schistosomiasis.

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Introduction

Schistosomiasis is a resurgent parasitic disease widely distributed in the tropical belt of the world (Akande & Odetola, 2013; Ayanda, 2009; Hamed, 2010; World Health Organization [WHO], 1999; Zhou et al., 2008) with the highest proportion in sub-Saharan Africa (Barsoum, Esmat, & El-Baz, 2013; Utzinger, N'Goran, Caffreye, & Keiser, 2011; WHO, 2013). Transmission takes place in areas where intermediate snail hosts are present and human population is frequently in contact with infested water (Sturrock, 1993). This makes the intermediate snail hosts indispensable as they serve as obligatory hosts for the larval stages of schistosome parasites to complete their life cycle (Hamed, 2010; WHO, 1957).

Three snail genera: *Biomphalaria, Bulinus* and *Oncomelenia,* all of the family Planorbidae are mainly responsible for the transmission of schistosomiasis globally (WHO, 1998) but two of them, *Biomphalaria* and *Bulinus* spp. which transmit *Schistosoma mansoni* and *S. haematobium* respectively are responsible for the disease transmission in Africa with Ghana not being an exception (WHO, 1957).

Following the construction of numerous dams across river bodies throughout Ghana (Danso-Appiah, 2009; Grosse, 1993; WHO, 1993; Yirenya-Tawiah Rashid, Futagbi, Aboagye, & Dade, 2011; Zakhary, 1997), the two forms of schistosomiasis became endemic in focal areas of all the ten regions of the country at different prevalence rates according to the International Association for medical Assistance to Travellers (IAMAT, 2012). However, urogenital schistosomiasis is described to be far more prevalent than intestinal schistosomiasis due to its predominant and extensive distribution (Hamed, 2010; McCullough, 1959).

The spatial distribution and transmission pattern of schistosomiasis have been reported by previous works elsewhere to be determined by abiotic and biotic factors (Amsalu, 2010; Marti, Tanner, Degremont, & Freyvogel, 1985; Zhou et al., 2008). Environmental factors like rainfall and temperature, pH, salinity and conductivity, turbidity among others were identified by these works to shape the fecundity and population density of the intermediate hosts (Akande, & Odetola, 2013; Ayanda, 2009; Jordan, & Webb, 1982; Smyth, & Montgomery, 1962). Transmission pattern of schistosomiasis is reported to be seasonal, a situation which results in population densities of schistosome parasites, intermediate snail hosts as well as transmission rates of the parasites varying considerably with the season (Davies, 2004; Grosse, 1993; Ngele et al., 2012).

Biotic factors such as availability and density of aquatic macrophytes have also been reported to play vital roles in the distribution of snails in different parts of Africa (Ofoezie, 1999). These aquatic plants serve as substrates for feeding and oviposition as well as providing protection from high water velocities and predators such as fish and birds (Mott, 2004).

Intermediate snail hosts occur in various fresh water bodies that are subject to changes in environmental conditions. There is therefore the need to understand how intermediate snail hosts abundance will be affected by seasonal changes which mainly influence the prevailing abiotic and biotic factors of their habitats. Again, the period of highest relative abundance must be known if control measures are to be successfully implemented given that the development of an effective control strategy requires the study of population dynamics of the intermediate hosts and its relation to environmental factors (Hussein, Obuid-Allah, Mahmoud, & Fangary, 2011). The purpose of this study was therefore to investigate the influence of seasonal variations on abiotic and biotic factors and their effect on the abundance of intermediate snail hosts.

Materials and Methods

Study site/area

The study was conducted in the Weija Lake at a site near Tomefa, a fishing community about 17 km west of Accra with Global Positioning System coordinates of N 05.57379˚ and W 000.37714˚. Tomefa is one of the schistosomiasis endemic communities located within the buffer zone of the Weija Head works in the Ga South Municipal District. It has a population size of 1,500 people with most of the residents being Ewes (Kaledzi, 2011). The populace has no access to potable drinking water and consequently depend solely on the untreated lake water for recreation, consumption and daily chores. Also, many of the community dwellers have no toilet facilities and therefore excrete faeces and urinate indiscriminately around and along the banks of the lake. These activities predispose them to the schistosome parasites infective to man making the disease endemic in the community.

The community lack access to any health facility and therefore travel long distances across the river or by road to Weija and beyond to receive treatment. The local climate found in Tomefa like the rest of Ghana is tropical with distinct dry (November–March) and rainy (April–October) seasons. The mean annual rainfall in Greater Accra ranges between 10.0 mm and 222.0 mm with the highest amount of rainfall recorded in June. The mean annual temperature ranges between 22°C - 33°C.

Snail Sampling and Collection

The two known intermediate hosts of schistosomiasis in Ghana, *Bulinus* and *Biomphalaria* spp. were sampled along the Weija Lake at Tomefa. This site was chosen on the basis of evidence of the presence of intermediate host snails and extensive human water contact during previous studies by other researchers. Snail sampling was carried out in sites where there were major human water contacts along the bank of the Lake.

Snail collections were done at monthly intervals from June, 2013 to March, 2014 except for November and December, 2013 due to unmotorable access. 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. Snails were collected from only the portion of the lake where prominent human activities are carried out. The same collectors scooped for snails throughout so as to achieve some level of standardized sampling effort.

The scoop net was swept through the lake (an average of four times per sampling section) amassing snails that clung to aquatic plants. Snails found along the bank within sampling area where water contact behaviour was rife were also collected with the aid of forceps, and those found attached to aquatic plants carefully picked using forceps.

Collected snails were washed clean of any debris with distilled water and placed in beakers filled with distilled water to the neck region and then covered with net mesh to prevent snail escape. The snails were then transported to the laboratory, examined and separated into different containers according to their genus. At the laboratory, each genus was transferred into labelled aquaria supplied with aged water with the aid of forceps and counted.

Habitat characteristics of the intermediate host snails were also observed and recorded appropriately with the presence or absence of aquatic plant species noted. All the aquatic weeds associated with the snails that were not easily identified were collected and sent to the herbarium section of Plant and Environmental Biology, University of Ghana for identification.

Physico-Chemical Parameters Assessment

Physical and chemical parameters like temperature, conductivity and salinity, pH, turbidity and total dissolved solids (TDS) of the lake were measured each time of snail sampling.

Temperature, conductivity, TDS and pH were measured in-situ using a multi-parameter tester (HANNA Combo: H 198129; Michigan, USA). The pH electrode/ Temperature sensor/EC or TDS probe of the multi-parameter were immersed into the lake to give the required readings.

A sample of the lake water was also fetched from the sampling site into two 500ml bottles and sent to the laboratory to measure for turbidity and salinity. This was repeated during every snail collection. Salinity was measured using a refractometer (Aquafauna Bio-Marine Inc., model ABMTC; Hawthorne California, USA).

Turbidity of the sample was also measured with a Turbidimeter (24347 HACH model 2100P; Loveland Colorado, U.S.A) having a range from 0.01 to 1000 NTU in automatic range mode and accuracy of ± 2% of reading plus stray light from 0-1000 NTU. Monthly rainfall data within the sampling period were sourced from the client service department of the Ghana Meteorological Agency, Accra.

Data Analysis

After each sample collection, data were coded and edited in MS Excel (2013) and results presented with tables and graphs. The normal Q-Q plot was used to determine the normality of data which informed the choice of test to use. Data were further analysed with the Student *t* test in Statistical Package for Social Scientists (IBM SPSS Statistics 20; New York, USA). Pearson correlation coefficients were also calculated between populations of *Biomphalaria* sp. and *Bulinus*

sp. and environmental factors to assess their relationships. All analyses were carried out at alpha level of 0.05 with a *p*-value < 0.05 considered as statistically significant.

Results

Snail Collection

A total of 2,612 snails consisting of 1,873 (71.07%) live and 739 (28.29%) dead snails or empty shells were collected. Snails collected were identified as *Biomphalaria pfeifferi* and *Bulinus truncatus*. Of the total snail collection, there were more *B. pfeifferi* (1,367) comprising 767 (56.10%) live and 600 (43.89%) dead snails/empty shells than *B. truncatus* (1,245) which also comprised of 1,106 (88.84%) live and 139 (11.16%) dead/empty shells (Figure 1). Significantly, more dead snails/empty shells of *B. pfeifferi* were collected than dead snails/empty shells of *B. truncatus* (t=-2.280, *p*=0.039). Although higher numbers of live *B. truncatus* were collected as compared to live *B. pfeifferi*, no significant difference was observed (t=1.311, *p*= 0.211).

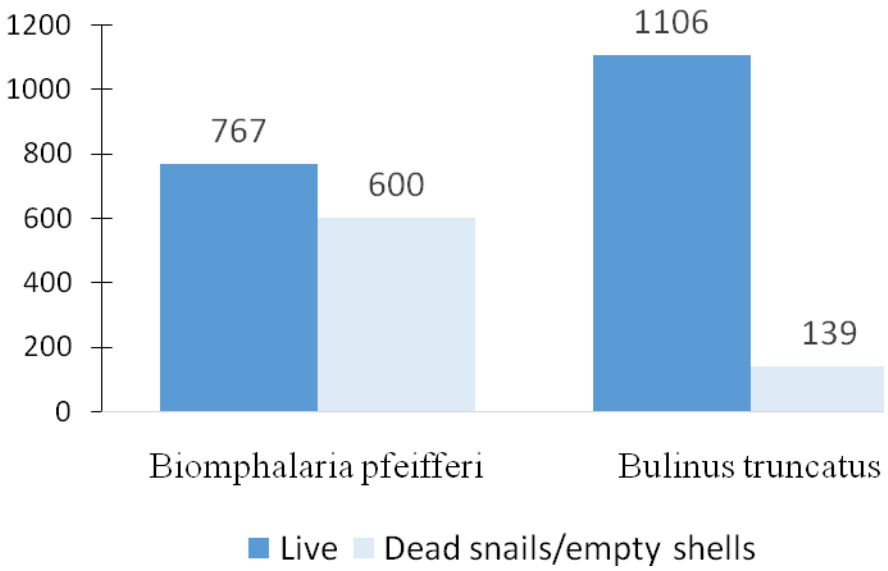

Fig. 1. Relative abundance of *B. pfeifferi* and *B. truncatus* during the study at Tomefa Seasonal Variations in Snail Abundance

Relative abundance of live *B. pfeifferi* and *B. truncatus* varied between the wet (June–October, 2013) and dry (January–March, 2014) seasons (Figure 2). Nonetheless, no significant difference existed between the abundance of live *B. truncatus* and *B. pfeifferi* in the wet (*t*=0.977, *p*=0.357) and dry (*t*=1.056, *p*=0.351) seasons. There were significant differences between the abundance of live *B. truncatus* in the wet (*t*=5.134, *p*=0.007) and dry (*t*=8.143, *p*=0.015) seasons, unlike that of live *B. pfeifferi* which varied significantly only in the dry season (*t*= 5.073, *p*=0.037).

The number of dead snails/empty shells of *B. pfeifferi* and *B. truncatus* also fluctuated between the two seasons with both species recording two peaks; one in the wet season and the other in the dry season as compared to the single peak that was observed in the wet season for live snail species (Figure 2). Dead snails/empty shells of *B. pfeifferi* initially peaked in the late wet season in October with the second peak, which was higher than the first, recorded in February in the dry season (Figure 2).

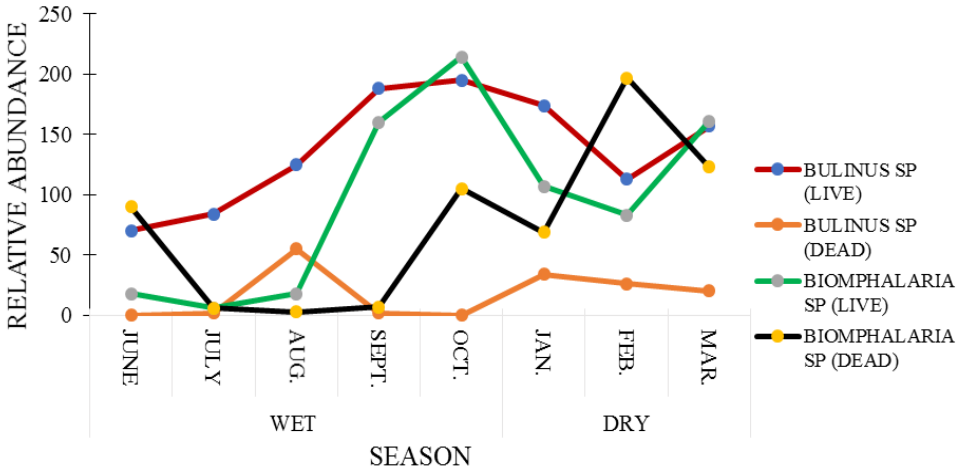

Fig. 2. Relative abundance of live and dead *B. pfeifferi and B. truncatus* in relation to the months of the wet and dry seasons

Significant differences were found in the number of dead snails/empty shells of *B. truncatus* (t=6.576, p=0.022) only in the dry season whereas no significant differences were found in the mean number of dead snails/empty shells of *B. pfeifferi* in both seasons. There was no significant difference between dead snails/empty shells of *B. pfeifferi* and *B. truncatus* even though a higher number of dead snails/empty shells of *B. pfeifferi* was collected compared to *B. truncatus* in the two seasons (p< 0.05).

Altogether, the geometric mean abundance of both snail species was higher in the dry season as compared to the wet season (Figure 3) However, there was no significant difference in snail abundance between the two seasons (t=-1.515, p=0.056).

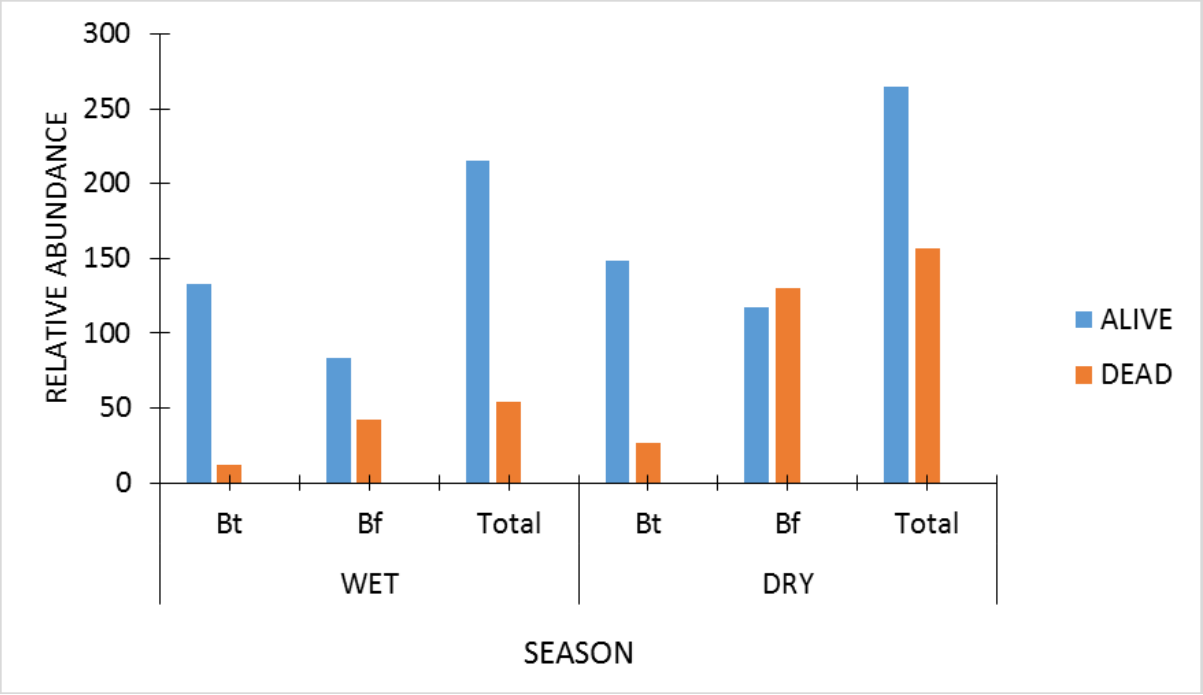

Fig. 3. Relative abundance of live and dead *B. pfeifferi* (Bf) and *B. truncatus* (Bt) in relation to the seasons

Seasonal Variations in Abiotic Factors

Except for salinity values (parts per thousand) that were consistent throughout the entire sampling period, all the other physico-chemical parameters displayed seasonal and monthly variations throughout the two seasons (Table 1).

Table 1. Seasonal and Monthly variations of Physico-Chemical Parameters measured during snail collection in the Weija Lake at Tomefa from June-October, 2013 and January-March, 2014

Season	Month	Physico-Chemical Parameter						
		pH	TDS (ppm)	Conductivity (µS/cm)	Temp. (°C)	Turbidity (NTU)	Salinity (‰)	Rainfall (mm)
Wet	June	8.09	216.0	431.50	28.45	26.00	0.2	110.50
	July.	8.37	202.5	365.75	27.55	19.75	0.2	21.80
	Aug.	8.21	187.5	377.10	25.45	20.25	0.2	14.00
	Sept.	8.39	186.5	372.00	27.70	14.00	0.2	51.10
	Oct.	7.71	176.0	386.00	30.50	12.00	0.2	16.60
	Mean	8.15	193.5	386.47	27.93	18.4	0.2	42.8
Dry	Jan.	8.20	184.5	401.00	30.25	9.50	0.2	5.50
	Feb.	7.51	184.0	401.00	31.00	15.50	0.2	78.10
	Mar.	8.90	187.0	408.25	32.38	12.00	0.2	136.10
	Mean	8.20	185.16	403.41	31.21	12.33	0.2	73.23
	Total Mean	8.17	190.5	392.83	29.16	16.13	0.2	54.21

Table 2. A summary of one sample student *t* test of physico-chemical parameters measured during snail collection at Tomefa

Abiotic Factors	N	Mean	Std. Deviation	*t*	*df*	*p*
pH	8	8.17	0.43	54.112	7	0.000
Temperature (°C)	8	29.16	2.26	36.506	7	0.000
Turbidity (NTU)	8	16.13	5.48	8.317	7	0.000
TDS (ppm)	8	190.50	12.65	42.597	7	0.000
Conductivity (µS/cm)	8	392.83	21.80	50.957	7	0.000
Rainfall (mm)	8	54.21	49.15	3.120	7	0.017

Snail Abundance in Relation to Abiotic Factors

Pearson correlation test used in examining the relationship between measured abiotic factors and snail abundance revealed that some abiotic factors had no significant (p<0.05) influence on the abundance of *B. pfeifferi* and *B. truncatus* during the two seasons.

However, a significantly strong positive correlation was found between water temperature and dead *B. pfeifferi* collected compared to a non-significant relationship found between temperature and dead *B. truncatus* and both snail species collected alive.

There were also significant negative correlations between TDS and live snail species. However, no significant relationships were observed between TDS and number of dead snail species. Similarly, no relationship was observed between salinity and snail abundance since salinity values were constant throughout the sampling period.

Monthly conductivity measurements fluctuated throughout the snail collection period yet a Pearson correlation analyses revealed a non-significant relationship between snail abundance and monthly conductivity values. It also revealed a non-significant relationship between pH and snail abundance. However, abundance of live snail species was negatively but significantly correlated with turbidity with no significant association observed between turbidity and number of dead snails. Amount of rainfall fluctuated throughout the sampling period; nonetheless there was no significant relationship between rainfall and abundance of snail species.

Vegetation that Supported Snails Species

Biomphalaria pfeifferi and *B. truncatus* were found attached to five common aquatic plants namely *Ceratophyllum* spp., *Nymphae* spp., *Neptunia oleracea*, *Typha* spp., and *Polygonum senegalense*. *Ceratophyllum* spp., *Nymphae* spp. and *Typha* spp. were present throughout the sampling period although their densities varied according to the seasons with relatively higher numbers observed in the wet season as compared to the dry season. *Polygonum senegalense* and *Neptunia oleracea* on the other hand were found to support intermediate snail hosts mostly in the wet season (June-October, 2013). Overall, *Ceratophyllum* spp and *Nymphae* spp. supported the largest numbers of the two-snail species even though relatively, more *B. truncatus* were found attached to *Ceratophyllum* spp. Quite a number of B. *pfeifferi* were also picked from the bank of the lake.

Fig. 4a & 4b. *B. pfeifferi* and *B. truncatus* (indicated by arrows) attached to *N. lotus* and *Ceratophyllum* sp. respectively

Bulinus truncatus and *B. pfeifferi* were consistently found attached to the stem of *Nymphae spp*., and the stem and roots of *Typha* spp., *Polygonum senegalense* and *Neptunia oleracea*. On a number of visits, *B. pfeifferi* and *B. truncatus* and their respective eggs were found attached to debris like polythene bags, fishing nets (Figs 4c & 4d) and sacks along the bank of the Weija Lake.

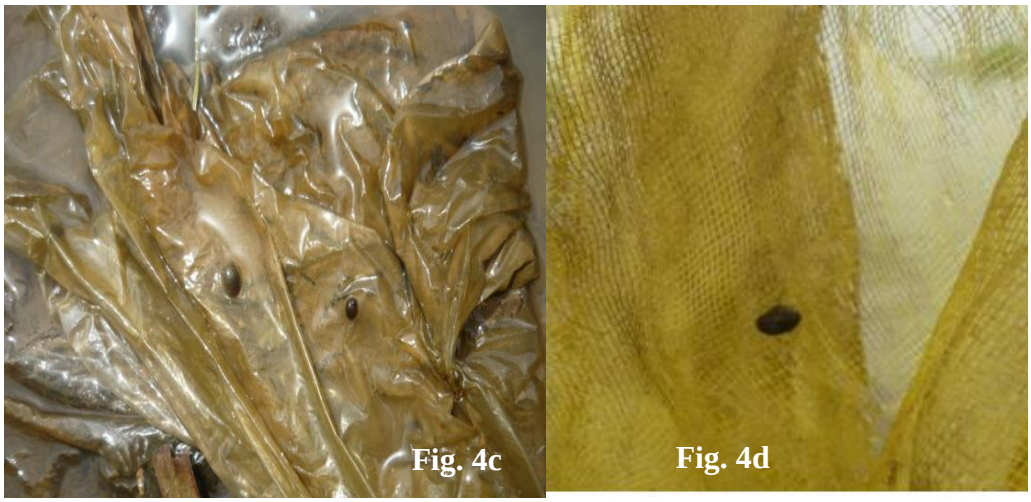

Fig. 4c & 4d. *B. truncatus* and *B.pfeifferi* attached to polythene and fishing net respectively

Discussion

There have been a number of reports on the transmission of schistosomiasis along the Weija Lake (WHO, 1993) and riparian communities including Tomefa with its distribution principally determined by intermediate hosts *Biomphalaria* and *Bulinus* spp. (Abonie, 2013). Studies have suggested that the distribution of intermediate host is influenced by environmental conditions (abiotic and biotic factors) which inadvertently affect disease transmission dynamics (Amsalu, 2010; Marti et al., 1985; Zhou et al., 2008). This study therefore sought to investigate the influence of environmental factors on the seasonal variations of intermediate hosts' abundance in order to contribute knowledge towards the effective control of the disease.

Biomphalaria pfeifferi and *Bulinus truncatus* which are known principal intermediate hosts of *S. mansoni* and *S. haematobium* respectively in Ghana (McCullough, 1959; Yirenya-Tawiah et al., 2011) were the common species collected. An earlier study on concurrent infections of *S. mansoni* and *S. haematobium* in the Tomefa community also reported the two intermediate snail hosts of schistosomiasis occurring in sympatry in the Weija Lake (Abonie, 2013). The presence of *B. truncatus* in the Weija Lake was anticipated since it is a species of perennial man-made habitat (Greer et al., 1990).

In comparison, dead or empty shells of *B. pfeifferi* were more prevalent than those of *B. truncatus*. The observation of higher numbers of live *B. truncatus* compared to *B. pfeifferi*, agreed with an earlier study by Abonie (2013) in the same community. The difference however was not significant.

B. truncatus and *B. pfeifferi* are able to endure broad range of ecological conditions but seasonal variations in their relative abundance have been attributed to variations in abiotic and biotic factors within their habitats (Chingwena, Mukaratirwa, Chimbari, Kristensen, & Madsen, 2004; Hussein et al., 2011; McCullough, 1962; Shati, 2009; Webbe, 1967). In the present study, seasonal variations in the relative abundance of snails as reported by other works (Alebie et al., 2014; Chingwena et al., 2004; Ofoezie, 1999; Wanjala, Battan, & Luoba, 2013) differed between the two species as was observed in a study by Chingwena et al. (2004). Climatic factors such as temperature and rainfall emerge to have significant effect on snail abundance (Amsalu, 2010; Sturrock et al., 2001). In this study, rainfall appeared to affect relative abundance of snail hosts. However, the associations were not significant and therefore might not have influenced snail life cycles and probably accounted for their seasonal variations (Marti et al., 1985; Shati, 2009; Sturrock et al., 2001; Wanjala et al., 2013).

Appleton (1978), Guimarães et al. (2012) as well as Woolhouse and Chandiwana (1989) have reported that heavy rainfall which results in the flooding of the snail habitat negatively influence population density of snail hosts. This perhaps explain the low numbers of live *B. pfeifferi* recorded in the wet season (June and July) which could be attributed to the flushing out of snails due to flooding as a result of the high amount of rainfall recorded in June (Guimarães et al., 2012).

The abundance of live *B. truncatus* was observed to be increasing throughout the wet season while that of live *B. pfeifferi* increased only after the mid-wet season with abundance of both snail species peaking at the end of the wet season where rainfall was relatively minimal. This suggests that the minimal rainfall created a stable and favourable environment for freshwater snails to lodge onto surfaces and not to be washed away by water currents (WHO, 1965). Increase in the rate of development of snails during the period of minimal rainfall is recorded to be an adaptive strategy employed to ensure their survival (Juberg et al., 1987; Mazigo et al., 2012; Paraense, 1972).

Among the physico-chemical variables measured in this study, water temperature appeared to be the key determinant of snail abundance. The positive association between snail abundance and water temperature observed in our study is in agreement with observations that snail distributions are affected by temperatures (Stensgaard et al., 2006).

Water temperature was observed to be positively correlated with abundance of *B. pfeifferi* and live *B. truncatus* which is in agreement with other studies (Chingwena et., 2004; Kazibwe et al., 2006; Wanjala et al., 2013; Opisa et al., 2011). This is indicative of the fact that increase in water temperature to tolerable levels possibly play important roles in the habitat of snail hosts by either ensuring food and aquatic weeds availability (Abdel Malek, 1958; Lydig, 2009) and/or enriching the microhabitat of juvenile snails to ensure their faster growth and development (Wanjala et al., 2013). Also, water temperature positively and significantly correlating with dead *B. pfeifferi* suggests that mortality of *B. pfeifferi* increase with increase in temperature. Woolhouse did not establish a distinct relationship between mortality rate of *B. pfeifferi* and temperature, probably because temperature recorded in his study was within the range of 18-25^{o}C (Woolhouse, 1992).

The number of dead *B. truncatus* on the other hand was negatively correlated with water temperature. This probably implies that *B. truncatus* demonstrate a great level of tolerance to temperature variations in their habitats (Marti et al., 1985; WHO, 1957). Thus, water temperature can be described as a key determinant of the abundance of *B. pfeifferi* as reported by Opisa et al. (2011).

All natural water bodies are described to have some amount of turbidity that could be due to high planktonic density, sediments from soil erosion or flooding (Abdel Malek, 1958; Akande, & Odetola, 2013; Asante et al., 2005). The abundance of live *B. truncatus* and *B. pfeifferi* were all negatively correlated with turbidity which is supported by findings from Akande and Odetola (2013) suggesting that increased levels of turbidity might have a negative influence on the oviposition, development and hatching of the eggs of snail species and therefore the decrease in snail abundance (Appleton, 1978; Wanjala et al., 2013).

Several research works have identified pH values within 5.0-9.3 to be optimum for snail survival (Alves, 1958: Wanjala et al., 2013; WHO, 1957). Hence pH values recorded in this study were within the tolerance limits of snail species. The non-significant relationships observed reflect the fact that pH had little influence on snail abundance and may not be a key determinant of snail abundance as reported (Abdel, 1958; Ofoezie, 1999; Lydig, 2009).

Salinity of aquatic habitats influence the abundance and survival of intermediate snail hosts (Akande, & Odetola, 2013) as pulmonates per se are described to be less tolerant of salinity (Paradise, 2009). Thus, the observed constant salinity measurements indicate favourable condition for snail abundance and survival.

The present study also recorded relatively minimal conductivity values which were within optimum conductivity range suggested for *B. pfeifferi* (Brown, 1980) but lower than values reported for both snails (Lydig, 2009). The negative relationship found between conductivity and abundance of *B. truncatus* (live and dead) and live *B. pfeifferi* was consistent with earlier findings (Salawu, & Odaibo, 2012). Increase in conductivity values probably results in diminution of dissolved oxygen which negatively influences snail abundance (Salawu, & Odaibo, 2012). The number of dead *B. pfeifferi* positively correlating with conductivity also agrees with an earlier study (Ofoezie, 1999). However, the non-significant relationship observed between snail abundance and conductivity suggests that conductivity is not a limiting factor to the abundance of *B. pfeifferi* and *B. truncatus* (Lydig, 2009).

It has been reported that total dissolved solids (TDS) alter water clarity and reduce the passage of light resulting in the rapid heating up of water bodies and increasing their heat retention ability (Environmental Protection Agency, EPA, 2012). High TDS may result in oxygen depletion, a situation that leads to asphyxiation in aquatic habitat and reduction in snail abundance (Salawu, &

Odaibo, 2012). The present study revealed abundance of live *B. truncatus* and *B. pfeifferi* to be significantly correlated with TDS. Even though no significant associations were observed between TDS and dead *B. pfeifferi* and *B. truncatus*, this parameter can be described as an important limiting factor to snail abundance.

Aquatic plants found in the habitats of intermediate snail hosts have been reported to influence snail occurrence and population densities (Lydig, 2009; Odei, 1973; Sturrock et al., 2001; Webbe, 1967). Observation of the five aquatic plants namely *Ceratophyllum* spp., *Nymphae lotus*, *Neptunia oleracea*, *Typha* spp. and *Polygonum senegalense* showed snail species attached to various parts of the plants such as the underside of the broad leaves of *N. lotus*, probably to escape the direct effect of sunlight, feed, oviposit or get access to oxygen (Alebie et al., 2014; Hussein et al., 2014; Lydig, 2009). The stems of *Ceratophyllum* spp., *N. oleracea*, *Typha* spp. and *P. senegalense* also served as important sites for snail species to lay eggs. *Ceratophyllum* spp. was identified as an indicator plant for *B. truncatus* which support earlier reports (Larsson, 1994; Senker et al., 1982). Some snails found attached to materials other than aquatic plants also support earlier reports that occurrence of snail species is not entirely restricted to areas with aquatic vegetation (Barbosa, & Olivier, 1958; IAMAT, 2012; Lydig, 2009). Snails attaching to fishing nets facilitate the introduction of infected snails to non-endemic areas resulting in the continuous spread of the disease through fishing activities.

Conclusion

Intermediate host snails sampled were identified as *B. pfeifferi* and *B. truncatus*. Their relative abundance varied seasonally with increased rate of development observed in the wet season when amount of rainfall was relatively minimal. Total dissolved solids (TDS) and turbidity significantly influenced the abundance of live snail species while only temperature influenced the number of dead *B. pfeifferi*. Rainfall, conductivity, salinity and pH on the other hand did not have significant influence on abundance of snail species. Therefore, TDS, turbidity and temperature can be identified as important limiting environmental factors to intermediate snail hosts abundance. Aquatic plant species present were also identified to influence snail abundance by providing shelter, food and sites for oviposition. The study has provided insight on the usefulness of understanding environmental factors and their influence on snail hosts abundance to inform the best time for effective control of the intermediate host using the appropriate integrated methods.

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Conflicts of Interest

The authors declare the work has no conflicts of interest.

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