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Ecology of *Biomphalaria pfeifferi* in Budalangi Endemic Focus of Western Kenya

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Abstract: Intestinal schistosomiasis occurs in localized foci restricted to specific molluscan vector sub population areas. The molluscan vectors, *Biomphalaria* sp. have a widespread distribution in Kenya. The objective of the present study was to determine the ecology of the molluscan vector with a view of instituting targeted vector control strategies to complement deworming programmes. A study was conducted in Budalangi endemic focus in the lake region of Western Kenya between 2006 and 2008. Vector snails were sampled from four permanent water habitats and used for the ecological studies. The population dynamics and vectorial capacity of the vector snail, *Biomphalaria pfeifferi* were driven by seasonality with rainfall and temperature determining abundance ($R^2 = 0.346$; $p<0.05$). Vector density was influenced by the distance from the permanent habitat ($R^2 = 0.432$; $p<0.05$) and to a lesser extent the depth at the edge of the water bodies ($R^2 = 0.252$, $p<0.05$). Researchers discuss the ecology of the vector in relation to the bionomics of *Schistosoma mansoni* in this study. The results of this study could be used for planning and implementing vector control programmes.

Key words: Ecology, molluscan vector, vectorial capacity, intestinal schistosomiasis, budalangi endemic focus

INTRODUCTION

It has been established that the presence of molluscan intermediate hosts is necessary in the transmission cycle of human schistosomiasis. Being aquatic the molluscan vectors depend predominantly on the presence of natural water bodies to thrive, although certain species are capable of undergoing prolonged aestivation if their habitats dry out (Brown, 1980). Numerous studies in many endemic areas have shown seasonal variations in the snail populations (Jobin, 1970; McCullough, 1972; Sturrock, 1973; Klumpp and Chu, 1977; Sobhon and Upatham, 1990) and found that the interaction of climate and the type of habitat produced seasonal fluctuations in the total snail populations (Jordan *et al*., 1993).

It is essential to carry out snail surveys and detailed population studies because the snail populations possess certain important properties such as density, intrinsic rate of natural increase, dispersion capabilities, age structure, reproduction and survival rates and genetic variability, many of which are usually affected by environmental factors (Sturrock, 1984). Such factors include climatic and seasonal as well ecological ones (Jordan *et al*., 1993). In snail studies it is necessary to measure these factors and assess to what extent they influenced the snail populations (Jordan and Webbe, 1969).

The ecological factors of the habitat in many studies have been reported to include: Physico-chemical factors (temperature, pH, oxygen, conductivity, calcium ion concentration, current velocity and turbidity, the degree of shading and level of pollution with human wastes). The biological factors include the types of vegetation, association with other snails and food preferences and the nature of the substratum (both the chemical and physical nature) (Jordan and Webbe, 1969; Ndifon, 1980).

The biomphalarid snails have been shown to breed well in warm open sunlit pools and ponds (Pfluger, 1980). But water temperature of >27°C still favoured their breeding (Pfluger, 1981). Studies by Jordan and Webbe (1969) showed that the conditions that favoured Biomphalaria in their breeding habitats included temperatures >27°C, water depth of <40 cm, high carbonate concentrations, high water pH and the presence of water lettuce.

In running water, temperatures at or near the maximum are maintained for a period of several hours whereas in shallow still waters, the highest temperatures occurred at the surface and within a few inches below the surface the temperature could be several degrees lower. In such habitats, the extreme effect of high temperature could be avoided by submergence of the vector snails (Nojima *et al*., 1980). In running water, the

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effective mixing ensured that there was no thermal stratification and the maxima recorded at the surface indicated the conditions throughout the bulk of the water (Nojima and Sato, 1981). Temperature affected activity and penetration of miracidia and the discharge of cercariae within a range of 18°-30°C (Madsen, 1985).

While cercarial infection rates were characteristically low in various habitats, they generally increased during the hot Summer months (Madsen, 1985). In impounded water, some *S. haematobium* and *S. mansoni* cercariae have been found during most of the 24 h after shedding. Under field conditions high cercarial densities have a diurnal rhythm with a peak occurring around midday (Prentice and Ouma, 1984). It must be noted that it was during this time of the day when prolonged and frequent human water contact was made and therefore this diurnal rhythm of cercariae was of prime importance in relation to human infection. The viability of cercariae was seriously reduced at temperatures above 35°C (Lawson and Wilson, 1980, 1983).

Turbidity of the water has been reported to have an effect on the vector populations by influencing adult oviposition (Appleton, 1978). Adult Biomphalaria preferred to oviposit on turbid water rather than on clean water. Laboratory studies have also shown that chemo-attractants from decaying organic matter may play a role in the oviposition behaviour of gravid adult Biomphalaria (Brown, 1975). Breeding of the vector snail has also been reported to occur in salty water with a pH of >7.0 (Ndifon, 1980).

Neither colloidal turbidity nor turbidity due to suspended solids could harm juvenile or adult snails (Sturrock and Upatham, 1973) but the deposition of a layer of silt could smother egg masses, impeding reproduction. Silt deposition also limited the growth of aquatic plants, with an indirect effect on snail populations (Babiker *et al*., 1985a). Such turbid conditions may have been associated with the local rainfall regime or with seasonal surges of flood water along a river that served an irrigation scheme (Babiker *et al*., 1985b).

The pressures created by greater water depths in a vector snail breeding habitat adversely affected the snails or their eggs (Nojima and Sato, 1981). In addition, light stimulated cercarial shedding (Brown, 1980). The indirect effect of light has further been supported by the dramatic increase that was usually observed among snail populations in the Sudan when turbidity levels dropped seasonally, allowing the growth of aquatic plants and creating numerous microhabitats suitable for snails (Babiker *et al*., 1985a, b).

On the whole, the factors that mostly determine the conditions of the snail habitats were controlled by the climate with heavy rainfall that produced floods having the effect of washing away snail populations (O'Keefe, 1985a; Sobhon and Upatham, 1990) and sometimes, the vegetation which provided the microenvironments that they preferred, as well as creating turbid conditions which inhibited successful breeding (Babiker *et al*., 1985a). Lack of rainfall causes droughts that were lethal to eggs and young snails. Cloudless conditions with clear water favoured plant growth which increased food supplies and the number of potential snail habitats (Babiker *et al*., 1985a, b). Conversely, prolonged dry sunny periods led to drought conditions that were unfavourable for the snails (O'Keefe, 1985b).

The vector snails of schistosomiasis are essentially browsing animals and feed continuously as they moved (Brown, 1980). Rather than feeding directly on higher plants, they have been reported to ingest decaying plant matter and the micro flora of algae and bacteria that covered it (Klumpp and Chu, 1980). Canopy cover has been observed to be significantly correlated with the emergent plant cover in the various habitats (Brown, 1980). Although, associations and correlations between vector snails and higher plant species have been reported (Sturrock, 1974) it has been argued that their role may merely be one of a suitable physical micro-environment that possibly provided oviposition sites and refuges for the adult snails.

While schistosomiasis tends to have a focal distribution, little was known regarding the dynamics of its transmission both in the human population and in the molluscan vector in the Budalangi endemic focus. In the Lake Victoria region of Kenya, studies by Thiongo and Ouma (1987) found *S. mansoni* infections to be confined to small foci and showed higher prevalence closer to the lake shores in a district neighbouring the selected study district. Therefore, there was reason to suspect that there were important transmission sites other than the lake that played an equally important or complementary role in the transmission of human intestinal schistosomiasis.

MATERIALS AND METHODS

Study area: The study was conducted between May, 2006 and July, 2008 in Budalangi Division in Busia County in the expansive Lake Basin of Western Kenya. The division (latitude 0°35', 0°74'N; longitude 34°09', 34°43'E; altitude 1130-1463 m above sea level) is bordered by Funyula to the North East, Ugenya to the North West and Bondo to the West, Alego-Usonga to the South West and Lake Victoria to the South East. Budalangi division has an approximate area of 1262 km^2 which includes 137 km^2

under a permanent water surface. Most of the division is semi arid with unpredictable rains in the year and therefore most of the land is uncultivated and presently encroached by Lantana camara and Dithornia diversifolia thickets. Marsh and swamps are common features in the low land areas of the division. However, most of them are seasonal. The permanent swamps are found in the administrative location of Bunyala South. Many parts of the division usually receive long and short rains in April to May and August to October, respectively. The dry spell is from December to February. The annual mean maximum temperatures range from 26-30°C while the mean minimum temperatures range between 14-22°C (Ralph and Schmidt, 1982). The River Nzoia roughly divides Budalangi Division into two. It traverses three locations (Bunyala East, Bunyala Central and Bunyala West) ending at the borders of the Khajula and Bunyala West.

Selection of vector breeding habitats and sampling: The four main types of breeding habitats (Table 1) were identified. They included the shoreline of Lake Victoria, dams, ponds and banks of River Nzoia. The breeding habitats were stratified into three zones parallel to their edges with each zone being one metre wide. Zone one was the area bordering the edge up to 1 m wide while zones two and three consisted of the areas from 1-2 and 2-3 m away from the edge, respectively.

In each sampling point, vector snails were sampled using a standard snail scoop according to the procedure developed by Christensen *et al.* (1987). The sampling effort consisted of 10 scoops taken purposely at each collection point. The parameters determined in each breeding site included the depth of the water, its turbidity, temperature, pH, canopy cover, algae, emergent plant cover and debris.

Determination of water parameters in the transmission sites: Throughout the sampling and field infection studies, selected water and environmental parameters of the main human-water contact sites were determined using conventional methods. Characterization of the vector breeding habitats required the following data: For each habitat studied, the water depth was measured using a 1 m stick. Any measurement exceeding 1 m was recorded as >1 m. The distance to the nearest household was measured using tapes. Canopy cover was determined as the percentage cover of the shade cast by the water plants over the habitat. Algal coverage and emergent plants (including both aquatic and immersed terrestrial vegetation) were determined as a percentage of the surface of the habitat covered. Turbidity was measured using Secchi disc visibility.

A Secchi disc was dipped into each habitat and the depth at which the disc ceased to be seen was then estimated. A sample of the water was placed in a clear glass container rested against a white background and graded as clear, low turbidity, medium turbidity or highly turbid. The physico-chemical parameters were measured using a hand held multi parameter field instrument (Multi parameter display system, YSI 650, Yellow Springs, Ohio USA). The instrument automatically recorded pH and temperatures which were the focus of this activity. Data obtained for pH and temperature was then subsequently correlated with field infection rates observed in the various human-water contact sites.

Table 1: Details of the vector snail sampling sites

Habitat types	Habitat description	No. of sampling sites (n)	No. of replications
1	Lake Victoria shoreline	6	6
2	Man made dams and drainage channels	8	6
3	River Nzoia dykes and embankments	3	6
4	Ponds and water reservoirs	4	6

RESULTS

Sampling of vector snails from different breeding habitats: Data for the vector snail, *B. pfeifferi* sampled from different types of breeding habitats from May, 2006 to June, 2008 are shown in Table 2. A total of 14,452 vector snails were sampled from various sites namely: The lake, dam, river and pond. The population of *Bulinus globosus* snails exceeded that of *B. pfeifferi* by >2 and a half times in all the habitats sampled showing their potential role in transmission of urinary schistosomiasis in situations where there was a source of the infection.

The habitual presence of large numbers of the vector snail, *B. pfeifferi* in all the habitats implied that Budalangi was a focal point for *S. mansoni* transmission. The actual density of vector snails and their mean counts per

Table 2: Relative abundance of Biomphalaria snails from different types of breeding habitats

Habitat types	n[a]	No snails sampled (%)	Mean monthly count±SE (Range)	Mean count/10 scoops[b] (Range)	p-level
1	6	4381 (30.3)	60.85 (32.50-103.33)	5.1 (2.9-8.6)	<0.05
2	8	5850 (40.5)	60.94 (37.75-107.08)	5.1 (3.1-8.9)	<0.05
3	3	2556 (17.7)	71.00 (66.25-80.08)	5.9 (5.5-6.7)	>0.05
4	4	1665 (11.5)	34.69 (6.75-76.42)	2.9 (1.0 -6.4)	<0.05
Total	21	14, 452	57.35 (6.75-107.08)	4.8 (1.0-8.9)	
p level			F = 1.32, df (3, 17); p>0.05		

[a]The total No. of collection or sampling sites per habitat; [b]To get the mean count per habitat: Total No. of snails/No. of sampling visits (24) X No. of sampling spots at every site (6) X No. of sampling sites per habitat

Table 3: Physico-chemical parameters of the different habitats in which snails were sampled

Habitat	Temperature (°C)	pH	Canopy cover (%)	Algae (%)	Emergent plant cover (%)	Debris (%)	Turbidity
Pond	24.18±0.48*	7.4±0.13	22.61±4.000	5.71±2.200	4.38±1.100	12.96±2.200	L/M
River	25.12±0.43	6.3±0.14	16.32±2.650	3.89±1.470*	4.17±1.010	20.00±12.94	L/H
Lake	24.56±0.74	6.7±0.43	14.00±6.780	12.00±10.00	0.00±0.000	22.00±8.600	M/H
Dam	24.77±0.77	6.3±0.46	66.60±15.81	16.00±12.00	38.00±22.04	14.32±2.360	L/M

*Correlation is statistically significant ($p<0.05$); L/M = Low to Moderate; L/H = Low to High; M/H = Moderate to High

10 scoops from the different sites in each type of breeding habitat varied widely. The difference in vector abundance among the various sites on the lake was statistically significant (one way ANOVA; F = 8.11, df = 5, 66, $p<0.05$) showing that their role in harbouring the vector snails and transmission of intestinal schistosomiasis was variable.

In some of the sites sampled in the dam, not a single vector snail was obtained. There was significant difference in the mean counts of snails among the various sites in the dam (one way ANOVA: F = 3.65, df = 7, 88, $p<0.05$) typifying the status of variability that existed among the different types of the water reservoirs.

On the banks of River Nzoia, there was no significant differences in vector snail count (one way ANOVA; F = 0.54, df = 2, 33, $p>0.05$) among the three breeding habitats. This showed that there was uniformity in the abundance of the vector snail along the river.

In the ponds, the counts in the four sites were significantly different from one another (one way ANOVA; F = 6.76, df = 3, 44, $p<0.05$) indicating that these water reservoirs were distinctly variable in nature. However, lack of a significant difference in the mean counts from the different sites along Lake Victoria, in the dams, along River Nzoia and in reservoir ponds was suggestive of the fact that the four habitats were equally important for the purposes of vector breeding in the study area (one way ANOVA; F = 1.32, df = 3, 17; $p>0.05$).

Relative density of the vector snail in relation to the depth of water: The relationship between vector density and water depth when analyzed by linear regression revealed a significantly strong negative relationship between the two parameters in the various snail breeding habitats sampled (R^2 = 0.252, F = 21.538, df = 1, 64, $p<0.05$) indicating that the vector snails inhabited the superficial margins of the various habitats sampled.

Relative density of the vector snail in relation to distance from the edge of the breeding habitat: The relationship between vector snail counts and the distance from the edge when analyzed by linear regression provided a strong negative relationship between them. The vector density decreased as the distance from the edge of the breeding habitat increased. This strong inverse relationship was statistically significant (R^2 = 0.432, F = 48.136, df = 1, 64, $p<0.05$) implying that the vector snails could not be found farthest from their breeding habitats but were limited to a few metres away from their edges.

Table 4: Pearson's coefficients of correlation between the various physico-chemical parameters in the different habitats in which snails were sampled

Variables	Temperature (°C)	pH	Canopy cover (%)	Algae (%)	Emergent plant cover (%)	Debris (%)
pH	-0.103	-	-	-	-	-
Canopy cover (%)	-0.142	0.095	-	-	-	-
Algae (%)	0.117	-0.105	-0.042	-	-	-
Emergent plant cover (%)	-0.048	0.031	0.160*	-0.049	-	
Debris (%)	-0.099	-0.060	0.088	-0.015	0.104	-
Biomphalaria snails	0.346*	-0.062	-0.029	0.151	-0.096	-0.088

*Correlation is statistically significant ($p<0.05$)

pH of the water in the vector snail breeding habitats: The pH of the water in the various breeding habitats ranged. The mean pH of the water for the sites sampled along the lake was 6.7 (95% CI: 6.0-7.4), 6.3 both in the dam (95% CI: 5.9-6.6) and along the river (95% CI: 6.2-6.4) and 7.4 (95% CI: 5.4-9.8) in the ponds. The differences in mean water pH in all the habitats were not statistically significant (one way ANOVA: F = 2.483, df = 3, 17; p = 0.094) and implied that the salinity of the water in all the habitats sampled did not fluctuate to adverse limits but remained within a steady range within which the vector snails bred.

Turbidity of the water in the breeding habitats of the vector snail: The turbidity of the water in all the habitats sampled ranged from low, moderate to high among the breeding habitats that were sampled (Table 3). Therefore, the silt and debris that was normally carried by surface runoff which usually carried with it soils and dissolved particles found its way and emptied into the two habitats where turbidity was highest. It was further shown that the dams and ponds relied entirely on water that had filtered through seepage channels from elsewhere carrying less debris.

Correlation of physico-chemical factors of the habitat with abundance of the vector snail: Table 4 presents the coefficients of correlation of the selected

physico-chemical factors that affected the density of *B. pfeifferi* in various breeding habitats. The water salinity, canopy cover, emergent plant cover and the amount of debris were negatively associated with *B. pfeifferi*. The association was not statistically significant ($p>0.05$), hence the vector snail widely tolerated the negative effects of these parameters. Temperature and algae were positively correlated with the abundance of *B. pfeifferi* with the former parameter significantly ($p<0.05$) affecting abundance of the vector snail. Thus, the small habitats experienced wide temperature variations and were more likely to experience fluctuation in the vector snail density than the large habitats.

DISCUSSION

The presence of low numbers of *B. pfeifferi* and the low prevalence of *S. mansoni* was indicative of a low grade of transmission of *S. mansoni* infection in the Budalangi endemic focus. This was in agreement with Pamba (1974) observations in which he found that a particular parasite density must be reached both in the human and vector snail population before a reasonable perpetuation of infection could.

The difference in the relative abundance of *B. pfeifferi* snails in all the sites that were sampled on the shores of Lake Victoria, dams and ponds but not in the sites on River Nzoia could be attributed to the various environmental variables that influenced the development of the vector in each specific site. For example in the sites that were found around reservoir ponds and dam, the presence of floating aquatic plants may have hindered oviposition or inhibited the development of the vector snail due to their mat-like nature of growth. Evidence gathered elsewhere has shown that floating aquatic plants such as *Azolla*, *Lemna* and *Salvinia* sp., interfered with the oviposition of the vector snails, as well as the emergence of their adults (Hosea *et al*., 1998).

The amount of algae in River Nzoia varied significantly between the sites sampled along its banks as opposed to that in the dam, pond and in Lake Victoria. This could have limited the amount of detritus that formed thereby limiting the food for the vector snails in this habitat. Accordingly therefore the vector snail abundance was lower in the river than was expected. In addition, many homesteads that did not have latrines were located closer to ponds and dams than to the river and lake.

Most of the dam and pond sites contained large amounts of discarded plastic and polystyrene materials. These were not necessarily harmful to the vector snail but often added to their available niches, providing surfaces with a thriving microflora to feed the snails and offer numerous oviposition sites. This could probably also explain why the vector snail abundance was higher in the dam than in the river.

The rainfall pattern was found to significantly affect snail life cycles and therefore their population densities. In general, the seasonal vector snail density pattern closely followed the rainfall patterns with peaks occurring during the long and short rainy seasons. An unusually high vector density was observed during the short rains from November to March. Despite the low mean monthly rainfall (36.4 mm SD 28.8) experienced during the study period in this area it still played a significant role in determining the abundance and distribution of the vector by improving existing and creating new vector breeding sites. However due to the permanent and semi permanent nature of the habitats that were sampled in the study area, vector breeding occurred both during the wet and dry seasons. This finding was in agreement with studies carried out by Babiker *et al.* (1985b) in the Gezira irrigation area of Sudan, Chandiwana (1986, 1987) in Zimbabwe and Mutahi and Thiongo (2005) in Central Kenya.

Similar studies on the population dynamics of *B. globosus*, transmitting *S. haematobium* in Eastern Tanzania, in pool and stream habitats by Marti *et al.* (1985) found that the adverse influence of rainfall in both environments was clearly demonstrated by reduced snail densities in relation to fluctuating water levels and changes in water velocity.

In Zimbabwe, the seasonal variations and population dynamics of *B. globosus* and *B. pfeifferi* and the epidemiology of schistosomiasis were studied by Woolhouse and Chandiwana (1989). In addition, Woolhouse (1989) analyzed age-prevalence curves for schistosome infections of host snails and considered that their seasonality was a function of known seasonal variation in the force of infection (contamination) and snail fecundity.

Budalangi division annually experienced flooding when the River Nzoia broke its banks overflowing the low lying villages in the Southern part of the district. It was in this part of the district that rice farming under irrigation from water stored in the dams that were left after flooding or otherwise was utilized. In such habitats, the snail population growth was expected to be delayed until after peak rainfall. However, this was not the case. In the Budalangi endemic focus, flooding was mostly as a result of the relief rains in the Kenya highlands.

It could therefore, be argued that the flooding ensured that there was a continuous breeding of the vector snail since the area experienced two rainy seasons but flood waters came in during the short

rains. The two rainy seasons coupled with the flood waters also acted in concert to drain human stool from nearby thickets to the snail habitats and in part accounted for the observed continuous infection in the vector snail population.

The seasonal variation in vector density was also found to be directly influenced by the temperature pattern. Atmospheric temperature may have had an indirect effect on the vector by influencing the water temperature. Water temperature was undoubtedly one of the most important factors of the physical environment but wide differences in water temperature were usually recorded in the same water collection depending on whether the temperature was measured just below the surface or at the deeper levels.

The optimal temperatures for most vector snails lay in the range of 25±5°C, below which snails could still survive up to 5°C but with reduced breeding (Pfluger, 1980). Above 30°C, fecundity diminished and mortality increased until the thermal death point of prolonged exposure to about 40°C is reached (Pfluger, 1981). In the Budalangi endemic focus, the mean water temperature ranged between 23.70 and 25.55°C in all the habitats but varied significantly in the pond probably due to its small size.

An increase in atmospheric temperature may have directly influenced the water temperature, especially at the edges of the breeding habitats. The high water temperature probably improved the micro habitat of the juvenile snails which ensured a faster growth and development of the vector resulting in their relative increase while a lower temperature only served to prolong their growth and development period (Brown, 1976).

In general, the maximum temperatures recorded in snail habitats have seldom exceeded 35-36°C which was not considered high enough to have any injurious effects on the snails. However, there were a few observations to this exception. In a study on *Biomphalaria pfeifferi* in recorded water temperatures of 40°C in senega paddy fields in the early stages of cultivation, before the rice plants had grown sufficiently to afford shade. Diaw suggested that these maxima may have played a part in restricting the snail to limited parts of the rice field such as the irrigation and drainage outlets where the flow of water reduced the temperature.

In the present study, no vector snails were sampled from the rice fields in the Bunyala South irrigation scheme. However, this finding could not be attributed to the direct effect of the high temperatures in the paddies but to the chemicals that were normally used for soil treatment while preparing the rice fields. The chemicals used could have had molluscidal activity and indeed many shells of dead vector snails were recovered from the rice fields. Perhaps this was a blessing in disguise, so that infections with cercariae of the parasite were curtailed by default. In all the habitats, the relative abundance of the vector snail decreased significantly with the increase of water depth. Vector snails were positively phototactic (Jordan *et al*., 1993) and light stimulated their locomotor activity (Appleton, 1978). Their abundance was therefore negatively associated with water depth. In addition, as the depth of the water in any breeding habitat increased the micro habitat of the vector could be affected by a decrease in water temperature by the presence of predators and by an increase in wave action, especially in Lake Victoria and River Nzoia habitats.

Some of the predators of vector snails included the catfish which suppressed abundance and regulated the rate of vector increase. However, these voracious predatory fishes were confined to deeper and muddy waters beyond which no vector snails were sampled. This could in part explain the absence of vector snails in the waters in the reservoirs of the rice paddies in which the catfish was always abundant especially after flooding of the River Nzoia.

The pH of the water in all the habitats ranged from 5.3-9.3. However, the mean water pH did not differ significantly between the various habitats. The wide tolerance of the vector snails to the pH of the water enabled them to exploit a wide range of habitats and therefore retained a certain steady population density throughout the seasons. This finding was in agreement with studies conducted by Webbe (1982) in which a pH range of 5.0-9.0 was found to be optimum for vector snail habitation of a water body. Extremely low pH could directly be harmful to the snails by causing coagulation of the mucous on exposed surfaces and eroding the shell. But its effects could be modified by diurnal variations in the carbon dioxide content, itself modified by the buffering effect of dissolved ions and the diurnal temperature variations (Klumpp and Chu, 1977; Webbe, 1982). These fluctuations could also have affected the dissolved oxygen concentrations and metabolic oxygen consumption rates by the snails.

The association of the snails with certain aquatic plants such as *Nymphaea* sp., indicated the deliberate selection of microhabitats with higher oxygen tension, lower temperatures and neutral pH than recorded in a particular sampling habitat as a whole. The absence of Biomphalaria snails in some water pockets in the endemic focus could be attributed to the effect of pH caused by high salinity levels.

Turbidity of the water was a favourable factor to the vector snails only up to a certain point, beyond which it became unfavourable. *B. pfeifferi* tolerated a greater degree of turbidity than Bulinus (Sturrock and Upatham, 1973). The level of turbidity was a particularly valuable index of the conditions in the comparatively small water bodies which formed the habitats of many snail vectors in the study area.

Due to the influence of water run-off in the habitats of the vector snail in Budalangi, turbidity of the water bodies was mostly moderate in many sites throughout the study period. However, the turbidity fluctuated from low to moderate in the lake and river habitats as the rainfall patterns changed. In the dam and pond habitats, the vector snails preferred to oviposit on turbid rather than on clean water. In these shallow habitats, a close association was observed between suspended solids in the water and the organic content of the underlying soil which was an important microhabitat of many vector snails.

The organic content of the sub aqueous soil in turn could have had a profound influence on the nature and distribution of the vegetation in and around the habitats. Stagnation of the water was followed by an increasing accumulation of organic trash and could have lowered the oxygen tension, as a result of which the vector snails died. The occurrence of the vector snail in water of low to high turbidity in this study implied that turbidity could not have been a contributory factor to their abundance, thus the vectors in the study area could withstand a certain wide range of turbidity. This partly explained their presence in various habitats throughout the study period. Although, aquatic snails were frequently found in extremely turbid water, their population growth was generally poor, depending on the precise form of the turbidity. However, turbidity associated with seasonal rainfall could ultimately have been beneficial as it replenished the depleted nutrients in the small habitats (O'Keefe, 1985b). This replenishment of nutrients could have contributed to the continuous presence of vector snails even in the dams and ponds in the Budalangi endemic focus because it was prone to annual flooding that emptied into dams and ponds created by dyke embankments on or from the River Nzoia.

CONCLUSION

These studies showed that the local vector snail of intestinal schistosomiasis, *B. pfeifferi*, shared common breeding habitats in the absence of transient habitats. The vector snail density decreased with the increase of the distance from the margin of the habitat in all the habitats studied and their density decreased with an increase in water depth. The vector snail was found to occur at low densities but it was infected throughout the year in all its permanent water habitats which were closer to human habitation. This ensured sustained transmission. The abundance of the vector snail was influenced by seasonality and followed the rainfall and temperature regimes of the Budalangi endemic focus. The snail intermediate host populations were specifically influenced by the temperature, food supply, predators, rainfall and even water composition. Sunlight in the snail habitats, flowering aquatic weeds, abundance of microflora and high dissolved oxygen content also contributed to the abundance of the freshwater snails. The present study therefore did determine the vector snail density, abundance and infection rates in the snail intermediate hosts and thereby provided information that could be utilized in designing a suitable programme for effective control of schistosomiasis.

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