Intrinsic Vulnerability of Human-Water Contact Sites to Contamination with Schistosoma mansoni Ova in an Endemic Focus in Western Kenya

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Abstract

Human intestinal schistosomiasis caused by *Schistosoma mansoni* occurs in localized foci restricted to specific vector sub population areas. The molluscan vectors, *Biomphalaria spp*, have a widespread distribution within the lake region and elsewhere in Kenya, but the disease is endemic only in areas with certain physical characteristics and risk factors. A comprehensive study was conducted in Budalangi endemic focus of Western Kenya between May 2006 and June 2008 to determine the bionomics of intestinal schistosomiasis transmission with regards to proximity to various contact sites relative to contamination of ova of the worm in the vector breeding habitats with a view of instituting a deworming programme in primary schools. A survey of sanitation relative to presence, distribution and/or absence of latrines was conducted in the whole study area. The main human contact sites were identified and checked for the possibility of contamination with human stool. Distance of the main human water contact site from sampled homesteads without latrines was estimated and recorded within three categories. Vector snails were sampled from four permanent water habitats using standard procedures. Only 30.5% of the homesteads surveyed had pit latrines (χ^2; $p<0.05$) and 70.1% of them were situated less than 100m from various water contact sites. The actual density of vector snails and their mean counts per 10 scoops from the different sites in each type of breeding habitat varied widely (One way ANOVA; Lake Victoria: F = 8.11, df $_{(5, 66)}$, $p<0.05$; Dam: F = 3.65, df$_{(7, 88)}$, $p<0.05$; River Nzoia: F = 0.54, df$_{(2, 33)}$, $p > 0.05$; F = 6.76, df$_{(3, 44)}$, $p<0.05$) showing that their role in harbouring the vector snails and transmission of intestinal schistosomiasis was variable. However the mean vector snail count from all the different habitats showed no significant difference between them being 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$_{(3, 17)}$; $p > 0.051$). The study showed that there was a continuous low level of contamination of *S. mansoni* ova in area among the various other habitats in addition to the lake and that they were equally vulnerable. This information has a bearing on planning and implementing combined mass treatment of people who reside in the study area and vector control programmes in an integrated venture.
Keywords: Vulnerability, Contact sites, Contamination, Schistosoma mansoni ova

1.   Introduction

Over three quarters of the total population in developing countries, which form more than one third of the world's population, are reported to be either without safe water supply or with inadequate sanitation. In the countries represented by this population, Kenya included, up to 80% of all illnesses are water related (WHO, 1984; Khan, 1997). Human intestinal schistosomiasis caused by *Schistosoma mansoni* and transmitted by the pulmonate snails is one such water related vector borne disease.

In Kenya, endemic foci of human intestinal schistosomiasis have been identified as being in Machakos, Kitui, Kirinyaga, Murang'a and Meru districts (Mutinga and Ngoka, 1971; Highton, 1974; Mutahi, 2005); in Taita Taveta at the coast (Thiongo and Ouma, 1987; el Kholy, *et al.,* 1989), around Lake Jibe and Lake Victoria and more so in Bunyala and Samia locations in Busia district (Masaba, 1978). Currently, Bunyala and Samia locations are administratively in Bunyala and Funyula Districts, respectively in Busia County.

The epidemiology of schistosomiasis is known to be influenced by the type of water contact patterns, sewage disposal (Esrey and Habicht, 1986; Esrey, *et al.,* 1985; 1991)), the biology and distribution of potential snail hosts (Vogel, *et al*., 1982) and the role of reservoir hosts (McCullough, *et al.,* 1972). In the studies reported here it was felt that knowledge concerning the epidemiology of human schistosomiasis in relation to contamination of the main contact sites would provide an essential background for the planning and implementation of viable and sustainable control measures or for the prevention of the introduction of the infection into schistosomiasis non-endemic areas. Such knowledge is largely lacking in the Budalangi schistosomiasis endemic focus of the Lake Region of Western Kenya.

For communities living along Lake Victoria, frequent contact with lake water cannot be avoided, let alone being limited. This plays a crucial role in the predisposition of the people to infection and re-infection with schistosomiasis, since the more contacts they made, the higher was the likelihood of hosting more adult worms,

and so was the number of eggs laid by the worms.

The community from which the present study participants were obtained was therefore endemically exposed to schistosomiasis cercariae, due to the relatively prolonged duration of contact with snail infested fresh lake water, the river Nzoia and other related exposure sites. Differences exist in the duration of contact with water among the local people, the time of the day on which contact was made, and individual immunity and general health; given that the area is also endemic to malaria and had high HIV–1 prevalence levels (KDHS, 2003).

The present study was thus designed to provide data that would aid in instituting targeted control strategies in the common human–water contact sites in the flood plains of Budalangi as part of a baseline prototype survey for a planned large scale Primary Schools Deworming Programme (PSDP).

2. Materials and Methods

2.1 Study Area

The present study was conducted between May 2006 and July 2008 in Budalangi Division of the former Busia District (currently fragmented into Busia, Funyula or Samia and Bunyala Districts) in Busia County in the expansive Lake Basin of Western Kenya. The division (latitude $0^035'$, $0^074'$N; longitude $34^009'$, $34^043'$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. It consists of 5 locations namely Bunyala North, Bunyala South, Bunyala East, Bunyala West, Bunyala Central and Khajula locations; and a total of 16 sub locations.

Many parts of the division usually receive long and short rains in April – May and August – October respectively. The dry spell is from December to February. The annual mean maximum temperatures range from 26^0C to 30^0C, while the mean minimum temperatures range between 14^0C and 22^0C (Jaetzold 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 Khajula and Bunyala West locations.

2.2 Survey of Sanitation in the Study Area

An assessment of the distribution of latrines in the whole study area was carried out. Each homestead was checked for the presence or absence of a latrine. The main human contact sites were also checked for the possibility of contamination with humans stool. Distance of the main human water contact site from sampled homesteads without latrines was estimated and recorded within three categories as follows: - 0 - 10 m, 10-20m and over 30m.

2.3 Identification of the Main Human Water Contact Sites

Human – water contact sites were identified partly through discussion with the locals who lived next to them and partly through personal observation using the following characteristics:- the presence of a well-defined footpath and the extent of erosion on the banks.

From the identified contact sites sentinel study points were randomly selected, mapped out and used in the determination of subsequent parameters for further investigation. Each site was examined for evidence of contamination with human stool or urine. Distance was calculated as the shortest overland route between the school or household and the lake shoreline or other water bodies.

2.4 Selection of Vector Breeding Habitats

Four main types of breeding habitats (Table 1) which had been identified earlier were used for these investigations. These 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 1m wide, while zones two and three consisted of the areas from 1 to 2m and from 2 to 3m away from the edge, respectively.

Table1. Details of the vector snail sampling sites

Habitat type	Habitat description	Number of sampling sites (n)	Number of replications
I	Lake Victoria shoreline	6	6
II	Man made dams and drainage channels	8	6
III	River Nzoia dykes and embankments	3	6
IV	Ponds and water reservoirs	4	6

2.5 Sampling of Vector Snails

Sampling of the snails was done according to the procedure developed by Christensen, *et al.* (1987). Data/information collected from each study site included the date of sampling, name of the village and site

number; the type of water (whether clear, turbid or very turbid as measured by Secchi disk visibility). Sticks, stones and man-made objects were removed and the underside of floating leaves of aquatic plants inspected for the presence of snails.

A metal scoop with a fine mesh was used to sample snails from their natural habitats by dragging the mesh steadily through the vegetation. Sampling in each site was carried out twice a month and the sum of totals calculated monthly.

3.   Results

3.1 Survey of Sanitation in the Study Area

The results of the survey on the presence or absence of pit latrines in the Budalangi endemic focus are shown in Table 2. Only 30.5% of the homesteads surveyed had pit latrines.

The level of sanitation as estimated by the number of homesteads with pit latrines was found to be significantly lower (χ^2; $p < 0.05$) in the homesteads without pit latrines than in those with pit latrines. It was further observed that on average more than 70% of the latrines were situated less than 100m from individual contact sites meaning that they were likely to contribute to contamination by surface runoff or seepage.

Table 2. Number of homesteads with respect to presence or absence of pit latrines

	Number of homesteads	% of total	χ^2 test
With pit latrines	175	30.5	
Without pit latrines	398	69.5	$p < 0.05$
Total	573	100.0	

3.2 Relative Proximity of Homesteads to the Main Human Water Contact Sites

The results depicting the relative distances of various homesteads without latrines in the study area are presented in Table 3.

The distribution of the homesteads with respect to distance thresholds from any water body was of the order of 5.3% (<10m), 21.8% (10 – 20m), 43.0% (20 - 30m) and 29.9% (>30m) corresponding to 0.76 – 1.00, 0.51 – 0.75, 0.26 – 0.50 and 0.00 – 0.25 of the extent of vulnerability respectively. Cumulatively this translated to 70.1% of homesteads which contributed to the contamination of the various human water contact sites with ova of *S. mansoni* owing to the fact that they did not have latrines. This implied that the households that were nearest to the snail infested water bodies contributed highest to the contamination with ova of *S. mansoni*.

Table 3. Distance of 398 homesteads from different human water contact sites

Distance (m)	% of households from sites										Total	Deg. Vuln
	I	II	III	IV	I and II	I and III	I and IV	II and III	II and IV	III and IV		
<10	0.0	23.8	0.0	28.6	0.0	0.0	0.0	0.0	47.6	0.0	5.3	0.76 -1.00
10-20	8.0	13.8	11.5	23.0	0.0	0.0	0.0	18.4	25.3	0.0	21.8	0.51– 0.75
20-30	11.7	17.5	9.4	18.1	0.0	0.0	0.0	15.2	13.4	14.6	43.0	0.26 -0.50
>30	12.6	10.1	12.6	16.8	7.6	6.7	7.6	9.2	8.4	8.4	29.9	0.00– 0.25
Total	10.6	14.8	10.3	19.3	2.3	2.0	2.3	13.3	16.3	8.8	100	χ^2(p< .05)

I = Lake, II = Dam, III = River, IV = Pond; Deg Vuln= The degree of vulnerability is a measure of the probability of human stool reaching a water body by seepage and runoff

3.3 Sampling of Vector Snails from Different Breeding Habitats

Data on the numbers of the vector snail, *B. pfeifferi* sampled from different types of breeding habitats from May 2006 to June 2008 is shown in Table 4. 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 was more than two and half times higher than that of *B. pfeifferi* in all the habitats sampled showing their potential role in transmission of urinary schistosomiasis in situations where there was a source of the infection although this vector was not of interest to the present study. The habitual presence of large numbers of the vector, *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 10 scoops from the different sites in each type of breeding habitat varied widely. In all the sites around the lake, the highest count realized was of 8.6 per 10 scoops. 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 the dam, the highest count realized was 8.9 per 10 scoops. In some of the sites investigated, not a single vector snail was obtained. There was a significant difference in the mean counts of snails among the various dam sites that were sampled (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, the highest snail count realized was 6.7 per 10 scoops. There was no significant difference in vector snail count (One way ANOVA; F = 0.54, df $_{(2, 33)}$, $p > 0.05$) among the three breeding habitats situated along the river banks. This showed that there was uniformity in the abundance of the vector snail along the river.

Table 4. Vector snail sampling and relative abundance of Biomphalaria snails from different types of breeding habitats

Habitat type	n[a]	No snails sampled (%)	Mean monthly count ± SE (Range)	Mean count/10 scoops[b] (Range)	p-level
I	6	4381 (30.3)	60.85(32.50 – 103.33)	5.1 (2.9 - 8.6)	P<0.05
II	8	5850 (40.5)	60.94(37.75 - 107.08)	5.1 (3.1 - 8.9)	P<0.05
III	3	2556 (17.7)	71.00(66.25 - 80.08)	5.9 (5.5 - 6.7)	p>0.05
IV	4	1665 (11.5)	34.69(6.75 – 76.42)	2.9 (1.0 - 6.4)	P<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]n is the total number of collection or sampling sites per habitat; [b]To get the mean count per habitat: Total number of snails/[number of sampling visits (24) X number of sampling spots at every site (6) X number of sampling sites per habitat]

In the ponds the highest count realized was 6.4 per 10 scoops. The count in all the four sites was significantly different (One way ANOVA; F = 6.76, df $_{(3, 44)}$, $p<0.05$) indicating that water reservoirs were distinctly variable in nature. The mean count of 5.1, 5.1, 5.9 and 2.9 per 10 scoops from the different sites along Lake Victoria, in the dams, along River Nzoia and in reservoir ponds respectively showed a wide variation from the mean of 4.8 snails. There was no significant difference between them being 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$_{(3, 17)}$; $p > 0.051$).

4.   Discussion and Conclusions

The observation in this study of a significant association between the proximity of households and open water sources was of immense importance because of two reasons. Firstly, pupils who were infected and reported that their homes were far or very far from open water sources indeed attended schools that were less than 1 km from open water sources. This meant that while they may not have engaged in water contact recreational activities close to their homes *per se*, they could still be exposed while travelling to and from school or other places away from their homes. Secondly, the questionnaire method of estimating distance from home to the nearest water source was more subjective and prone to misclassification. Hence it was concluded in this study that the estimate for the effect of household proximity to water source on infection could have been biased.

It was also revealed in this study that an association existed between *S. mansoni* infection and the previous history of intestinal schistosomiasis infection. In their studies Akufongwe, *et al.* (1996) who observed the same kind of scenario explained it on the basis that communities who lived in proximity to contaminated water were more prone to infection. The behavioral factors associated with the water bodies in the study area turned them into potential reservoirs of schistosomiasis cercariae. Fetching water for domestic chores was a regular activity for most of the rural population in Budalangi. Villagers frequenting the water bodies commonly only wore slippers or walked bare foot. This behaviour largely exposed them to vector snail infested waters. Fetching water was often a task of school-aged children. The same water bodies also provided play grounds for the children. In this study it was established that the greater the frequency of contact the greater was the risk of infection. Previous studies have found a variable influence of water contact frequency on schistosomiasis infection and have attributed this to variability in the amount of the body that was exposed to the water (Kloos, *et al.*, 1998).

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's (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.

There was a significant difference in the relative abundance of *B. pfeifferi* snails in all the sites that were sampled on the shores of L. Victoria, dams and ponds but not in the sites on R. Nzoia. The difference 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* spp 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 R. Nzoia varied significantly between the sites sampled along its banks as opposed to that in the dam, pond and in L. 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 (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.

Budalangi division annually experiences flooding when the River Nzoia breaks 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.

Acknowledgement

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