

Microgeographical and tribal variations in water contact and *Schistosoma mansoni* exposure within a Ugandan fishing community

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Summary

OBJECTIVE To explore patterns of water contact and *Schistosoma mansoni* exposure by age, sex, tribe and space within a single village.

METHODS For 10 months, we systematically observed water contacts made by the 800 inhabitants of a small Ugandan fishing village. In order to estimate cercarial exposure, times spent in water were weighted by snail infection levels, time of day and degree of immersion.

RESULTS There were marked differences in water contact patterns between the two main tribes, which inhabited geographically distinct ends of the village resulting in geographically distinct spatial patterns of water contact. The distributions of the intermediate hosts, *Biomphalaria sudanica* and *Biomphalaria stanleyi*, also appeared to differ over small distances. This led to quite different exposure patterns between the two tribes, particularly amongst females.

CONCLUSIONS *Schistosoma mansoni* exposure can vary markedly within a single village. Such non-homogenous patterns of exposure are likely to have wider implications for schistosomiasis control programmes and research studies.

keywords schistosomiasis, *Schistosoma mansoni*, ethnicity, tribe, water contact, spatial distribution, Uganda

Introduction

According to the World Health Organization (WHO), *Schistosoma mansoni* infection is endemic in 54 countries worldwide, with the vast majority of infections occurring in sub-Saharan Africa (Chitsulo *et al.* 2000). A combination of social, cultural, behavioural, geographical, economic, ecological and environmental, as well as genetic and immunological factors may all influence transmission patterns. Testimony to this is the often focal nature of *S. mansoni* infection prevalence and intensity, as observed between communities in Burundi (Gryseels 1991) and in Côte d'Ivoire (Utzing *et al.* 2000, 2003). Focality of associated morbidity has also been observed between communities with uniformly high levels of infection (Fulford *et al.* 1991, Booth *et al.* 2004a).

Only a few studies have focused on the microepidemiology of *S. mansoni* within communities, but it is already clear that the extent of infection clustering depends on location. For example, whereas the spatial distribution of

S. mansoni infection amongst schoolchildren within a single village in Côte d'Ivoire was apparently uniform (Utzing *et al.* 2003), a study conducted in Kenya reported distinct microgeographical variation in *S. mansoni* infection intensity (Booth *et al.* 2004b). These studies point to significant sources of heterogeneity in exposure within and between villages.

An earlier study from Piida village, Uganda, observed that tribe was an important risk factor for infection within the village (Kabatereine *et al.* 2004). Similar conclusions have been reached elsewhere (Robert *et al.* 1989; Sama & Ratard 1994; Ofoezie *et al.* 1997). However, no published studies, to our knowledge, have systematically explored the basis for these tribal differences. In the current analysis, we hypothesize that water contact behaviour, which drives exposure to *S. mansoni*, varies significantly between tribes living in the same village. We use systematic water contact observation data collected during the first year of a 6-year longitudinal reinfection study, and begin by exploring patterns of water contact in relation to age,

sex, tribe and space. We also assess the suitability of direct water contact observations for measuring water contact behaviour amongst fishing communities in rural Africa.

Methods

Study area and population

The current study was conducted in the village of Booma, located along the eastern shore of Lake Albert, in the parish of Butiaba, Masindi district, north-western Uganda. The village is predominantly made up of mud huts; there are few latrines and faeces often pollute the beaches along the lake shore (Kabatereine *et al.* 2004). As conditions are unsuitable for agriculture, the major source of income is from the fishing industry, and, consequently, high levels of water contact are observed at all ages (Kabatereine *et al.* 1999b). The lake is the major source of water for the inhabitants of Booma, and its water is used for domestic and personal needs (Kabatereine *et al.* 2004). During water contact observations, the only alternative sources of water were the river Waki and the river Bubwe, both of which appear free from *Biomphalaria* (Francis Kazibwe, personal observation).

The main indigenous tribe is the Bantu linguistic Bagungu tribe. The second most populous tribe is the Alur tribe, who are immigrant to the area and originate either from the West Nile region in Uganda, or from the Democratic Republic of the Congo (Francis Kazibwe, personal observation). In this study, the large majority of both tribes were born in Booma (90% of Alur and 97% of Bagungu). The two tribes live at geographically distinct ends of the village (see Figure 1) and there are few inter-tribal marriages. At the time of the demographic survey in 1998, there were 97 households with 441 people at the Bagungu end of the village, and 72 households with 363 people at the Alur end.

Water contact observations

Water contact observations followed a similar protocol to that described elsewhere (Fulford *et al.* 1996; Kabatereine *et al.* 1999b) and were made on the whole population of Booma. Local observers, able to identify all members of the community by sight, were recruited and trained to conduct water contact observations. Observations were conducted between mid November 1998 and early September 1999 at 19 different sites, and were balanced with respect to day of the week and site. Observations were conducted in two 6-h shifts, running from 0700 to 1300 h, and from 1200 to 1800 h. The overlap in shifts allowed morning observers to complete

observations started but not completed before noon.

Where possible, successive shifts were undertaken by one male and one female observer. In addition, to avoid inter- and intra-observer bias, the schedules for observers were balanced with respect to time and site. The name of each individual coming into contact with the lake was recorded, along with time of contact, activity (fishing, swimming, playing, collecting water, washing utensils, etc.), duration of water contact to the nearest minute, degree of immersion (1, 2 or 3 parts, or whole body exposed) and any use of soap.

All observations were recorded onto specially designed forms. Completed forms were transcribed onto computer-coded sheets for data entry. Data were entered twice into Excel. Once data were entered, a cross-validation program was run to clean them.

Statistical analysis

All analyses were restricted to individuals from the Alur or Bagungu tribes and performed using Stata 8.0. (Stata Corporation, Texas, USA).

Scoring system. As duration of water contact is not an accurate measure of cercarial exposure, exposure was estimated for each individual by weighting water contact durations by time of day, site and degree of immersion. Overall exposure scores (X_i) were thus assigned to each individual (i) using the following function (Fulford 2000):

$$X_i = \sum_{j=1}^{n_i} \text{site}_{ji} \times \text{hr}_{ji} \times \text{deg}_{ji} \times \text{dur}_{ji},$$

where X_i is the exposure score for the i th individual, observed n_i times, with the j th contact lasting dur_{ji} min. Site_{ji} , hr_{ji} and deg_{ji} are the respective site, time of day and degree of immersion weightings for the j th contact.

Time of day weighting. Data were weighted by time of day (hr_{ji}) to reflect the diurnal rhythms of cercarial shedding. The following bell-curve function describes these shedding patterns (Chandiwana & Woolhouse 1991):

$$H = \exp b_1(t - b_2)^2,$$

where H is the relative number of cercariae emerging at time t ; t is the time of day in minutes past midnight/100, and b_1 and b_2 are two constants. Cercarial shedding data collected as part of a detailed malacological study (Kazibwe 2003) were fitted to this equation using a non-linear least squares method; this gave constants $b_1 = -0.439$ and $b_2 = 7.685$. This function assumes cercariae are immedi-

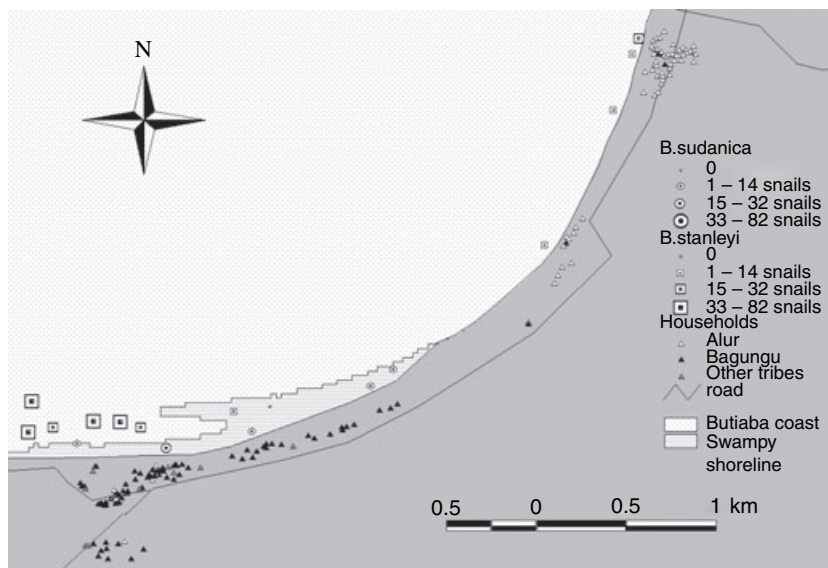


Figure 1 Map of Booma village depicting the spatial distribution of the tribal groups and mean number of *B. stanleyi* (■) and *B. sudanica* (●) between November 1998 and September 1999.

ately dispersed and do not accumulate in the immediate vicinity after they are shed.

Site weighting. Malacological data collected in conjunction with water contact data for a study investigating snail related aspects of *S. mansoni* transmission at Butiaba (Kabatereine *et al.* 1999a; Kabatereine 2000) were used to generate weightings for each site ($site_{ji}$). The average monthly number of *B. sudanica* and *B. stanleyi* shedding human *Schistosoma* cercariae was calculated for each site. These averages were then weighted to reflect the observed lower shedding capacity of *B. sudanica* compared with *B. stanleyi* with respective weights of 0.4 and 0.6.

Our primary aim was to generate an exposure score that reflected an individual's average exposure over the course of the year. Given this, average monthly number of infected snails was used for our site weighting (thus excluding any seasonal influences) so as to smooth out noise from sampling variability.

Degree of immersion weighting. Degree of immersion (deg_{ji}) was weighted as follows: 0.2 = one body part exposed, 0.4 = two body parts exposed, 0.6 = three body parts exposed and 1 = whole body exposed, thus following a weighting system developed previously (Fulford *et al.* 1996; Fulford 2000) where the number of body parts immersed are counted.

Sensitivity analysis and reliability estimates. A sensitivity analysis was conducted in which one factor ($site_{ji}$, hr_{ji} or deg_{ji}) was removed from the exposure weighting in turn and its influence on the shape of age-exposure profiles

examined. To assess the reliability of the water contact data, observations were numbered by site and date. The dataset was then split, with evenly numbered observations forming one group and oddly numbered observations another. Summing observations in each of these groups for each individual gave two estimates of duration or frequency of contact, or exposure. Spearman-Brown split-half coefficients were then calculated, providing an estimate of the reproducibility of our estimates [reviewed in Fulford (2000), Chapter 3]. The Spearman-Brown split-half coefficient (r_{sb}) is given by:

$$r_{sb} = \frac{2r_{xy}}{1 + r_{xy}},$$

where r_{xy} is the correlation coefficient between the two halves.

Data analysis. Water contact and exposure data were positively skewed; therefore, arithmetic means were not appropriate. Instead, geometric mean (GM) total duration, exposure and frequency of contact were used to explore differences in water contact between tribes. Duration of time spent on fishing and non-fishing related activities was explored for males. For this analysis, to compensate for zero values, it was necessary to add 1 min to group-specific total durations before calculating GMs. The non-parametric Wilcoxon rank-sum test was used to test statistical significance. Variation in activities between tribes was explored by merging the 22 observed activities into four categories, namely (i) domestic (fetching water or washing clothes or utensils); (ii) bathing; (iii) recreational (playing, swimming or socializing); (iv)

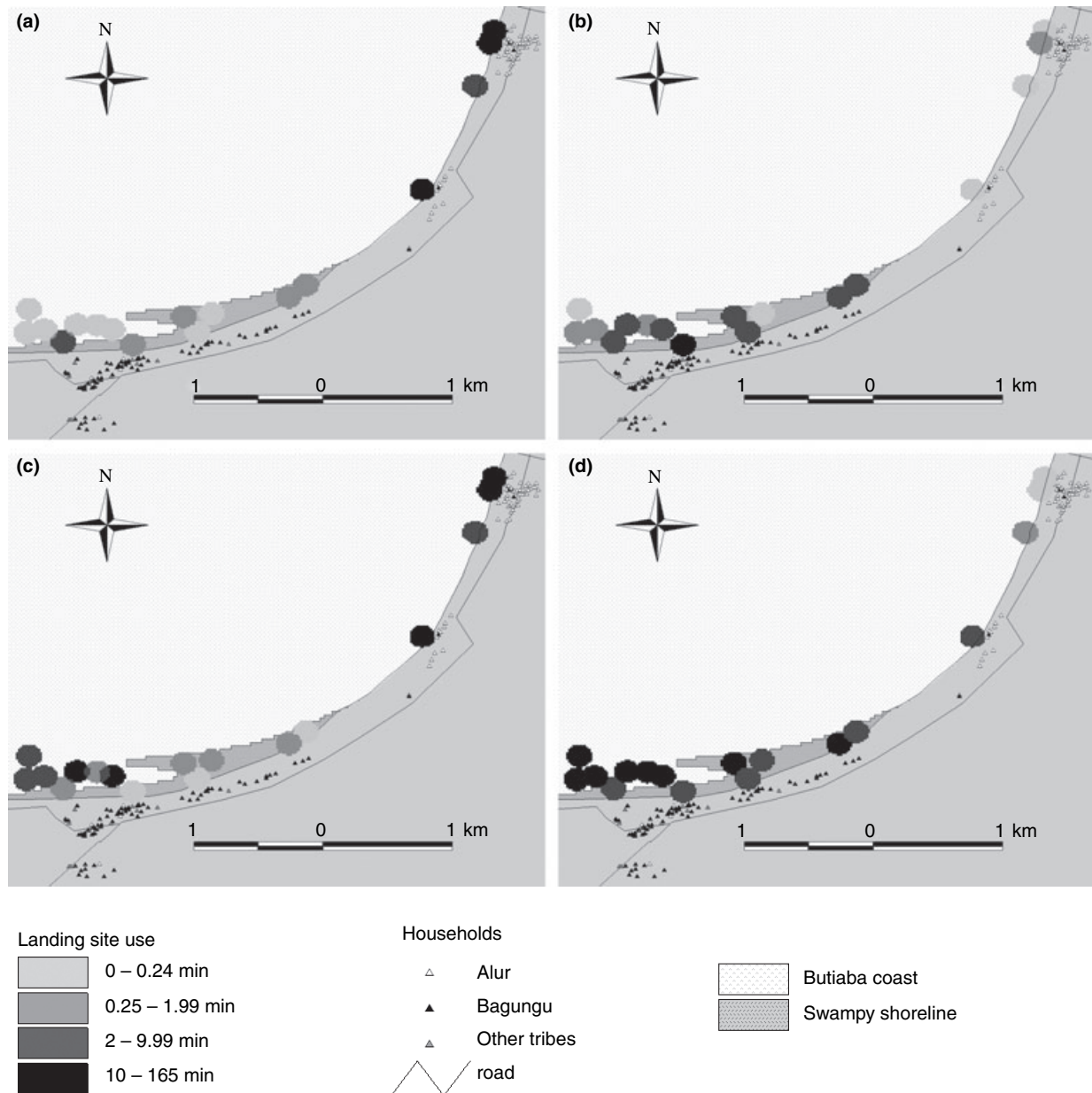


Figure 2 Maps showing the spatial distribution of observed water contacts amongst (a) Alur females; (b) Bagungu females; (c) Alur males and (d) Bagungu males. The arithmetic mean total person minutes spent at each contact site was calculated and a circular neighbourhood measuring 0.1 km in radius was drawn round each contact site. Where neighbourhoods overlapped, the arithmetic mean duration was calculated.

economic (buying fish, cleaning fish, launching boat, fishing on foot or by boat, or other boat-related activities) and (v) other (fording, removing water hyacinth and other). Age-adjusted proportion of time spent conducting the different activities relative to total contact time were

then calculated by tribe and sex. The direct method of standardization was applied, with the total population of Booma as the standard population. Households, water contact sites, roads and other major landmarks in Booma were georeferenced using a global positioning system

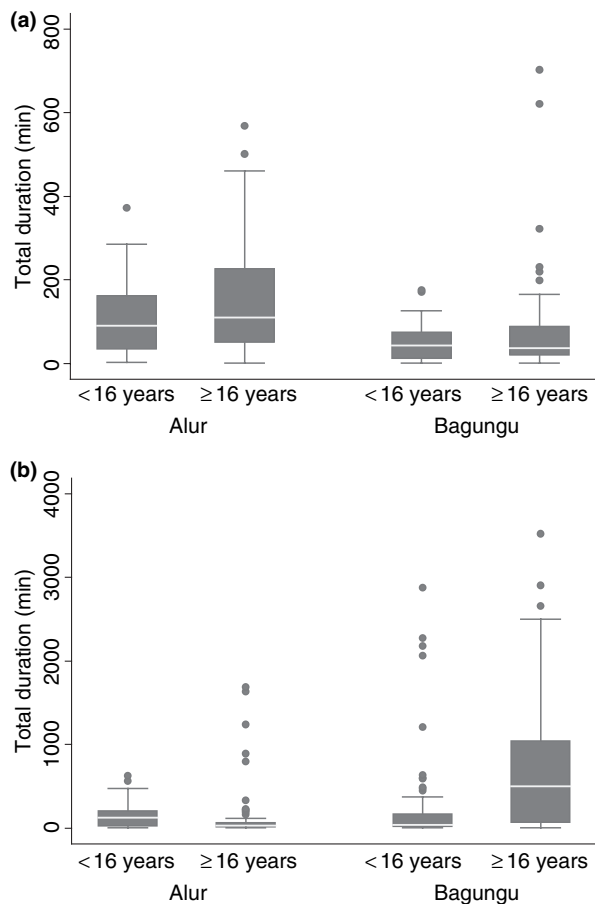


Figure 3 Box plots displaying total duration of water contact between November 1998 and September 1999 by tribe and age group amongst (a) females and (b) males. The dots represent outliers, and the upper and lower lines represent the maximum and minimum values, respectively. The top and bottom horizontal edges to the box indicate the 75th and 25th percentiles, respectively; whereas the line within the box represents the median value. Note the differences in scale.

(GPS) unit (GARMIN eTrexVenture; Kansas City, USA). Maps of the study area and observed water contact were then generated using ArcView GIS 3.2.

Results

A subset from Booma village of 266 individuals lived approximately 2 km away from the lakeshore and had relatively little contact with the water. They were thus excluded from all analysis. A further 214 individuals were not observed during observations; these individuals were also excluded from the analysis as they are likely to have been absent from the village (F. Kazibwe,

personal observation). There was no difference in the proportion of each tribe observed (72% *vs.* 71%, $P = 0.76$).

The remaining 543 individuals shared a total of 19 579 observations (1964 h of contact) over the 220 days of observations conducted between November 1998 and September 1999. Of these contacts, 11 829 (61%) were amongst the Bagungu, and 7 750 (39%) were amongst the Alur. Reliability estimates were high: Spearman-Brown split half reliability coefficients were 0.96, 0.97 and 0.93 for total duration, frequency of contact and total exposure, respectively. Data were highly dispersed: average total duration of contact ranged between 63.8 min amongst Bagungu females and 516.5 min amongst Bagungu males, corresponding standard deviations (SDs) were 92.8 and 731.3 min, respectively.

Water contact observations by tribe, sex, age and space

The geographical distribution of contacts was distinctly different for each tribe: Alur contacts were clustered at sites in the north-eastern end of Booma, whilst Bagungu contacts were focused more at the south-western end (Figure 2).

Duration of contact within tribes. In Figure 3, boxplots display the total duration of observed water contacts by sex, tribe and age group; respective GM total durations are tabulated in Tables 1 and 2. Gender-related differences in water contact were apparent amongst adults (≥ 16 years), but not amongst children (< 16 years); these varied depending on tribe. Amongst the Alur, women spent significantly more time at the lake than the men ($z = 5.0$, $P < 0.001$); amongst the Bagungu, men were observed more at the lake ($z = -6.4$, $P < 0.001$).

Duration of contact between tribes. There were significant differences in water contact between the tribes, depending on sex. Female Alur spent significantly more time in the water than female Bagungu [$z = 6.1$, $P < 0.001$ (all ages combined), Figure 3a and Table 1]. In contrast, although there was no significant difference in duration of contact between Alur boys and Bagungu boys ($z = 1.3$, $P = 0.21$), Bagungu men spent significantly more time in the water than Alur men ($z = -6.0$, $P < 0.001$, Figure 3b and Table 2).

Frequency and duration of each contact. Geometric mean frequency of water contact and duration of each contact are displayed by sex, tribe and age group in Tables 1 and 2. Although the frequency of water contact was similar in magnitude for Alur and Bagungu females, the rank-sum

Table 1 Geometric mean durations, frequency and exposure score (95% confidence interval) by tribe and age group amongst females

	Geometric mean (95% confidence interval)			
	Female Alur		Female Bagungu	
	< 16 years	≥ 16 years	< 16 years	≥ 16 years
Total duration of contact	62.9 (45.8–86.5)	93.6 (71.1–123.2)	28.7 (20.4–40.4)	35.3 (26.4–47.4)
Frequency of contact	11.9 (8.8–16.1)	24.5 (19.3–31.1)	10.7(7.7–14.7)	15.2 (11.7–19.8)
Duration of each contact	3.0 (2.9–3.2)	2.4 (2.3–2.5)	2.1 (2.0–2.2)	2.0 (2.0–2.1)
Weighted water contact duration	2.1 (1.1–3.7)	2.8 (2.0–3.9)	0.003 (0.001–0.008)	0.007 (0.003–0.02)

Table 2 Geometric mean durations, frequency and exposure score (95% confidence interval) by tribe and age group amongst males

	Geometric mean (95% confidence interval)			
	Male Alur		Male Bagungu	
	< 16 years	≥ 16 years	< 16 years	≥ 16 years
Total duration of contact	66.4 (45.2–97.6)	28.7 (18.5–44.5)	56.9 (36.5–88.7)	247.2 (159.5–383.1)
Frequency of contact	13.6 (10.0–18.5)	13.6 (9.7–19.2)	11.6 (8.0–16.7)	39.0 (27.5–55.3)
Duration of each contact	3.2 (3.1–3.4)	2.2 (2.1–2.3)	3.8 (3.7–4.0)	3.8 (3.7–3.9)
Total duration of contact for fishing-related activities	4.1* (2.6–6.5)	3.6* (2.1–6.2)	12.5* (6.3–24.7)	160.4* (91.2–282.2)
Total duration of contact for non-fishing related activities	62.8* (44.5–88.5)	22.1* (16.3–30.1)	18.9* (13.8–26.0)	22.0* (16.4–29.5)
Weighted water contact duration	3.1 (1.7–5.4)	1.5 (0.9–2.7)	0.1 (0.04–0.5)	5.9 (2.4–15.0)

*1 was added to each measurement prior to calculating the results.

test indicated Alur females had significantly more water contacts than Bagungu females ($z = 2.7$, $P = 0.006$). In addition, the average time spent in the water with each contact was longer for Alur females than for Bagungu females ($z = 6.8$, $P < 0.001$). Compared with Alur males, water contacts made by Bagungu males were, on average, both longer ($z = -2.8$, $P = 0.006$) and more frequent ($z = -18.2$, $P < 0.001$).

Water contact observations by type of activity, degree of immersion, sex and tribe

Few fishing-related activities were observed amongst females. Figure 4 displays observed total duration of water contacts for males, stratified by fishing-related and non-fishing related activities; Table 2 displays the corresponding GM durations. Bagungu males spent more time in the water fishing (or conducting fishing-related activities) than Alur males ($z = -7.6$, $P < 0.001$); this was borderline significant among children ($z = -2.4$, $P = 0.02$) and highly significant among adults ($z = -7.4$, $P < 0.001$). Conversely, Alur and Bagungu adult males spent similar durations in the water carrying out non-fishing related activities ($z = -0.04$, $P = 0.96$), and among children, it

was the Alur males who spent more time in the water involved in these activities ($z = 4.9$, $P < 0.001$).

Figure 5a and b displays the age-adjusted proportion of time spent conducting each type of activity, relative to total contact time, by tribe and sex. Lake activities conducted by females were primarily domestic. Bagungu females spent a large proportion of their time fetching water; Alur females spent less time fetching water but more time washing clothes and utensils. So-called 'economic' activities of Bagungu females tended to be boat-related (principally sitting in or paddling boats), whereas Alur females spent little time in boats and more time fishing (predominantly on foot) or processing fish. Alur females also spent more time involved in recreational activities (primarily playing). For males, activities were principally 'economic', specifically, fishing and other boat-related activities (mainly sitting in, paddling and launching boats). Bagungu males spent a far greater proportion of their time involved in these activities than Alur males. However, while Bagungu males were mainly observed fishing from boats, Alur males were observed fishing on foot and from boats in roughly equal amounts. Alur males, like Alur females, were also observed playing and, to a lesser extent, 'socializing', at the lake far more than Bagungu males.

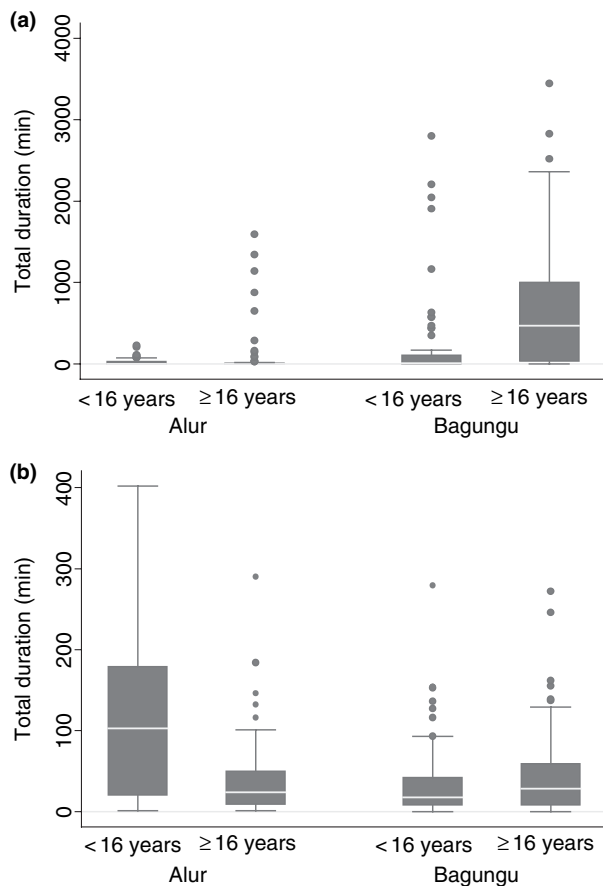
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Figure 4 Box plots displaying total duration of time males spent in the water by tribe and age group for (a) fishing related activities and (b) non-fishing related activities. Note the differences in scale.

Immersion data are shown in Figure 6. Alur children tended to immerse their body more fully in the lake than Alur adults or Bagungu males. Alur females also immersed more fully in the water than Bagungu females, who predominantly only immersed two body parts or less.

Weighted water contact durations

In Figure 7, boxplots depict estimated cercarial exposure by sex, tribe and age-group; corresponding GMs are displayed in Tables 1 and 2. As observed for duration of contact (Figure 3), Bagungu females were exposed to fewer cercariae than Alur females [$z = 11.6$, $P < 0.001$, (all ages combined)], whereas adult Bagungu males were exposed to more cercariae than adult Alur males ($z = -4.3$, $P < 0.001$). Alur boys, experienced greater cercarial exposure than Bagungu boys ($z = 3.2$, $P = 0.001$). The sensitivity analysis indicated site and degree of immersion

had the strongest influence over these results. Bagungu boys experienced greater levels of cercarial exposure than Bagungu girls ($z = -3.8$, $P < 0.001$), and Alur women experienced similar levels of cercarial exposure to Alur men ($z = 1.5$, $P = 0.12$). For both of these findings, only site weighting had a strong influence.

Discussion

We explored patterns of water contact and *S. mansoni* exposure in the village of Booma, located along the eastern shore of Lake Albert in Masindi district, north-west Uganda. Despite the small size of our study area, we discovered a marked geographical variation in water contact behaviour, stemming from the spatial segregation of the two tribes. Tribe influenced the duration and type of water contact conducted, as well as extent of exposure to *S. mansoni*. Although sex, age, type of activity, location, socioeconomic class and religion have all been shown to influence water contact behaviour (Farooq & Mallah 1966; Husting 1983; Kloos *et al.* 1983; Chandiwana 1987; Lima e Costa *et al.* 1987), to our knowledge this is the first published study to demonstrate that tribal background influences water contact behaviour. As water contact behaviour is known to have an impact on the intensity of schistosome infections (Macdonald 1965; Lima e Costa *et al.* 1987; Woolhouse *et al.* 1998), tribal background and residential location should not only be considered when implementing schistosomiasis control programmes, but also as *a priori* confounders in schistosomiasis-related research studies.

We focused on the water contact behaviour of two tribes, the Bantu ethno-linguistic Bagungu and the Nilotic ethno-linguistic Alur. Gender appeared to influence water contact, but to a different extent within each tribe; whereas female Bagungu tended to have a very little contact with the water compared with the male Bagungu, female Alur had more contact with the water than male Alur. It is interesting to note, however, that these possible gender differences only became apparent after adolescence. We also noted much higher levels of water contact at all ages amongst female Alur than female Bagungu. In contrast, observed contact for Bagungu men was considerably longer than that of Alur men.

This latter finding is surprising: anecdotal evidence gathered during studies in the area suggest the Alur spend as much, if not more, time fishing as the Bagungu. This suggests a possible gender bias in the collected water contact data. During water contact studies in the neighbouring village of Piida, it was noticed that many young men were fishing in waters not observable from shore, and thus went unobserved (Kabaterine *et al.* 1999b). Such

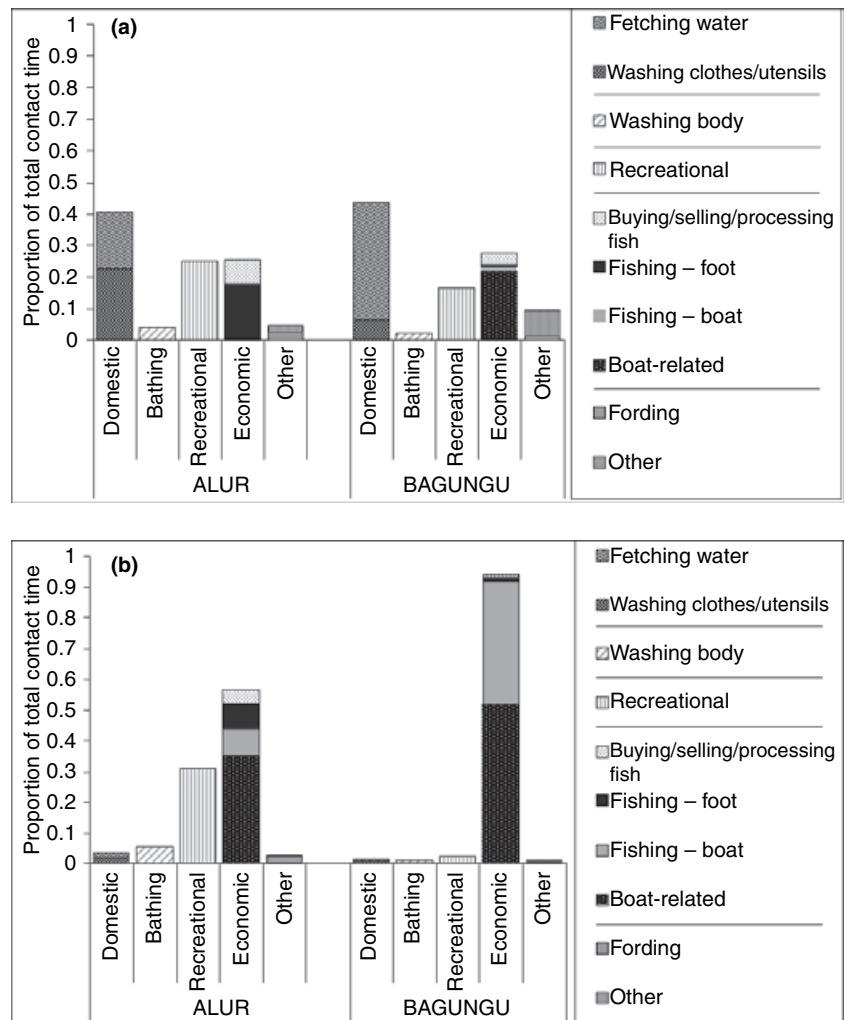


Figure 5 Age-adjusted proportion of time spent conducting the different activities relative to total contact time amongst (a) females and (b) males. Activities were classified as domestic, bathing (washing body), recreational, economic or other. 'Domestic' included fetching water and washing clothes or utensils; 'recreational' consisted primarily of playing, but also of 'social' and, for males only, swimming. Negligible activities, such as hyacinth picking, that did not obviously belong to any other categories were included under 'other'; fording is also grouped amongst other activities.

biases have been noted elsewhere under different settings (Gazzinelli *et al.* 2001; Kloos *et al.* 2006) and may be a problem when water contact sites are widely dispersed (Fulford *et al.* 1996). Like many other studies (Farooq & Mallah 1966; Dalton 1976; Husting 1983; Chandiwana 1987; Watts *et al.* 1998; Gazzinelli *et al.* 2001; Kloos *et al.* 2006), we found gender strongly influenced the type of activities conducted. Females were primarily involved in domestic chores, which were conducted more focally at landing sties. Men, conversely, were predominantly involved with economic activities, notably fishing, which, by its nature, is much dispersed. This suggests many fishing-related contacts may have gone unnoticed in the current study.

Previous attempts to overcome the issue of dispersed water contacts have used a variety of methods. These

include activity diaries (Ross *et al.* 1998), questionnaires (Lima e Costa *et al.* 1987; Barreto 1993; Scott *et al.* 2003), direct observations combined with questionnaires (Bethony *et al.* 2001; Friedman *et al.* 2001; Gazzinelli *et al.* 2001; Kloos *et al.* 2006) direct observations supplemented with regular inquiries into absences (Wilkins *et al.* 1987), and in-depth interviews (Watts *et al.* 1998). The efficiency of the various methods is likely to vary depending on the activity (Gazzinelli *et al.* 2001) and on the nature of contact sites. Use of multiple methods to follow water contact should be considered in study areas where contacts are not focal (Gazzinelli *et al.* 2001; Kloos *et al.* 2006). The wide involvement in fishing activities plus the apparent absence of some villagers suggests a need for supplementary methods under the current setting.

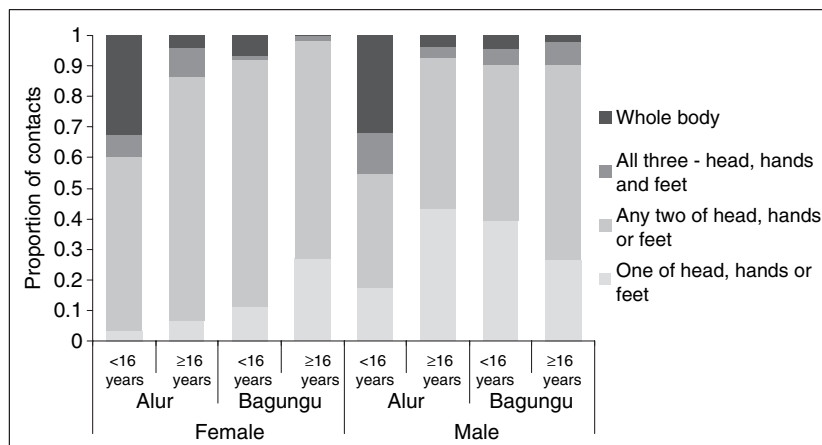


Figure 6 Proportion of contacts involving total immersion, immersion of three body parts, two body parts and one body part by sex, tribe and age group.

Alur children appeared to immerse themselves more fully in the water than Bagungu children, as did Alur women compared with Bagungu women. Activities also differed between the tribes. Alur women spent more time washing clothes and utensils, activities that could have been conducted away from the lake. Alur also spent notably more time involved in recreational activities and bathing than Bagungu. Such patterns suggest a difference in attitude towards the water. Future studies will address the knowledge, attitudes and perceptions of the two tribes, with the aim of understanding the observed practices.

Duration of water contact in itself is not an accurate measure of cercarial exposure; this can only be roughly estimated by weighting water contact durations according to perceived 'risk factors'. Although such methods have been employed to varying degrees elsewhere (Chandiwana 1987; Wilkins *et al.* 1987; Chandiwana & Woolhouse 1991; Chandiwana *et al.* 1991; Etard *et al.* 1995; Fulford *et al.* 1996; Ross *et al.* 1998; Friedman *et al.* 2001; Gazzinelli *et al.* 2001; Scott *et al.* 2003; Bethony *et al.* 2004; Kloos *et al.* 2006), the weightings themselves are often highly subjective and it should be noted that true exposure can only be inferred from water contact data: it is impossible to determine true exposure (Fulford *et al.* 1996). To assess the relative importance of site, degree of immersion and time of day in deriving our weighted durations, we conducted a sensitivity analysis. Site had the strongest influence, followed by degree of immersion. Site is likely to be less subjective than other weightings as malacological data, namely the number of infected snails found at each site, were used to weight durations. However, snail surveys can be inaccurate because of under-collecting, particularly when snails are small.

The potentially pivotal role that water contact site plays in determining cercarial exposure highlights the import-

ance of exploring spatial patterns in water contact and schistosome infections. This has been previously emphasized elsewhere for both *S. mansoni* (Kloos *et al.* 1997, 1998) and *S. haematobium* (Kloos *et al.* 1983; Chandiwana 1987). It is especially important in the current study area where the two tribes live at geographically distinct ends of the village and observe geographically distinct spatial patterns of water contact. In addition, in our study area, different species of *Biomphalaria* appear to dominate different sections of the lake. Previous observations on the ecology of *Biomphalaria* in Lake Albert (Kabatereine *et al.* 1999a; Kazibwe 2003; Kazibwe *et al.* 2006), reported that each species 'occupied slightly different aquatic niches'. Essentially, *B. stanleyi* preferred deeper, sandy water habitats whilst *B. sudanica* preferred shallower, swampy waters. We observed that *B. stanleyi* tended to predominate the 'Alur' shoreline, whilst *B. sudanica* was found mainly along the 'Bagungu' shoreline. Furthermore, prevalence of *S. mansoni* infection was generally greater, and more cercariae were shed per snail, in the *B. stanleyi* populations than in the *B. sudanica* populations (Kabatereine *et al.* 1999a; Kazibwe 2003; Kazibwe *et al.* 2006). Together, these observations may partly explain the apparently higher levels of cercarial exposure of Alur boys compared with Bagungu boys, despite their similarities in water contact, and also the apparent very low levels of cercarial exposure amongst Bagungu females.

The implication of these observations in terms of *S. mansoni* infection and reinfection after praziquantel treatment will be explored in future analyses of data. We have observed non-homogeneous patterns of exposure across Booma village and therefore predict spatial clusters of high intensity reinfection. This is in contrast to a previous study in Côte d'Ivoire where the spatial distribution of *S. mansoni* infection across one village was found to

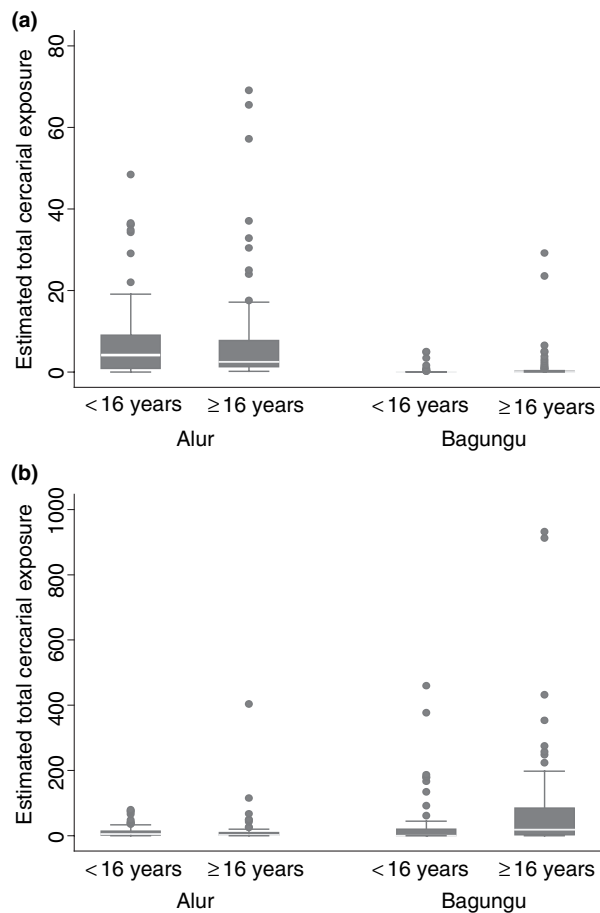


Figure 7 Box plots displaying estimated cercarial exposure by tribe and age group amongst (a) females and (b) males.

be random (Utzinger *et al.* 2003). The authors of that study called for a uniform, community-wide approach to control schistosomiasis (Utzinger *et al.* 2003). In villages like Booma, however, such an approach may not be appropriate. Our results highlight the need to consider tribe and household location as an *a priori* confounder in both the control of schistosomiasis and research programmes: it cannot be assumed that transmission is uniform across a study community. As few populations are likely to be completely homogenous, the question of whether a heterogeneous population influences the effectiveness of control efforts also needs to be investigated.

Ethical Clearance

Informed consent was obtained from all participants and ethical permission was obtained from the Ugandan Ministry of Health.

Conflict of interest

There were no conflicts of interest.

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Variations microgéographiques et tribales dans le contact avec l'eau et pour l'exposition au *Schistosoma mansoni* au sein d'une communauté de pêche ougandaise

OBJECTIF Explorer des profils de contact avec l'eau et de l'exposition au *S. mansoni* selon l'âge, le sexe, la tribu et l'emplacement dans un même village.

MÉTHODES Pendant 10 mois, nous avons systématiquement observé les contacts avec l'eau de 800 habitants d'un petit village de pêche ougandais. Afin d'estimer l'exposition cercariaire, les temps passés dans l'eau ont été pondérés par les taux d'infection d'escargots, l'heure de la journée et le degré d'immersion.

RÉSULTATS Il y avait des différences marquées dans les profils de contact avec l'eau entre les deux tribus principales qui habitaient des extrémités géographiquement distinctes du village, avec pour résultat des profils spatiaux géographiquement distincts pour le contact avec l'eau. Les distributions des hôtes intermédiaires, *Biomphalaria sudanica* et *B. stanleyi* semblaient également différer sur de petites distances. Ceci a mené à des profils d'exposition tout à fait différents entre les deux tribus, surtout chez les femmes.

CONCLUSIONS L'exposition à *S. mansoni* peut varier fortement au sein d'un même village. De tels profils non homogènes d'exposition sont susceptibles d'avoir des implications plus étendues pour les programmes de contrôle de la schistosomiase et pour les études de recherche.

mots clés schistosomiase, *Schistosoma mansoni*, appartenance ethnique, tribu, contact avec l'eau, distribution spatiale, Ouganda

Variaciones microgeográficas y tribales en el contacto con el agua y exposición a *Schistosoma mansoni* dentro de una comunidad de pescadores en Uganda.

OBJETIVO Explorar los patrones de contacto con el agua y exposición a *S. mansoni* por edad, sexo, tribu y espacio dentro de un solo poblado.

MÉTODOS Durante 10 meses, observamos sistemáticamente los contactos con el agua de 800 habitantes de un pequeño poblado de pescadores en Uganda. Con el fin de estimar la exposición a cercarias, los tiempos pasados dentro del agua fueron ajustados por los niveles de infección por caracol, la hora del día y el grado de inmersión.

RESULTADOS Se observaron diferencias marcadas entre los patrones de contacto con el agua de las dos tribus principales, que vivían en extremos del poblado geográficamente diferentes, resultando en patrones espaciales de contacto con el agua geográficamente distintos. Las distribuciones de hospederos intermedios, *Biomphalaria sudanica* y *B. stanleyi*, también parecían diferir a distancias cortas. Esto llevó a patrones de exposición bastante diferentes entre las dos tribus, particularmente entre las mujeres.

CONCLUSIONES La exposición a *S. mansoni* puede tener variaciones marcadas dentro de un mismo poblado. Estos patrones no homogéneos podrían tener una implicación importante para los programas de control de la esquistosomiasis y los estudios de investigación.

palabras clave esquistosomiasis, *Schistosoma mansoni*, etnicidad, tribu, contacto con agua, distribución espacial, Uganda