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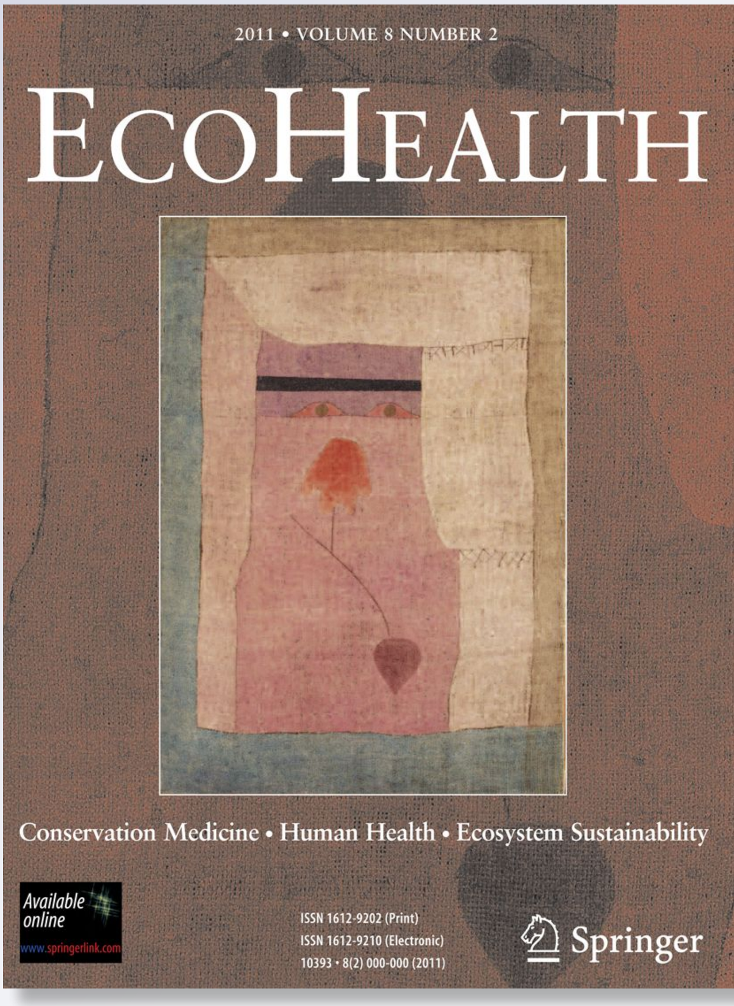

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Original Contribution

Schistosomiasis in Lake Malaŵi Villages

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Abstract: Historically, open shorelines of Lake Malaŵi were free from schistosome, *Schistosoma haematobium*, transmission, but this changed in the mid-1980s, possibly as a result of over-fishing reducing density of molluscivore fishes. Very little information is available on schistosome infections among people in lake-shore communities and therefore we decided to summarise data collected from 1998 to 2007. Detailed knowledge of the transmission patterns is essential to design a holistic approach to schistosomiasis control involving the public health, fisheries and tourism sectors. On Nankumba Peninsula, in the southern part of the lake, inhabitants of villages located along the shores of Lake Malaŵi have higher prevalence of *S. haematobium* infection than those living in inland villages. Overall prevalence (all age classes combined) of urinary schistosomiasis in 1998/1999 ranged from 10.2% to 26.4% in inland villages and from 21.0% to 72.7% in lakeshore villages; for school children prevalence of infection ranged from 15.3% to 57.1% in inland schools and from 56.2% to 94.0% in lakeshore schools. Inhabitants on the islands, Chizumulu and Likoma, also have lower prevalence of infection than those living in lakeshore villages on Nankumba Peninsula. This increased prevalence in lakeshore villages is not necessarily linked to transmission taking place in the lake itself, but could also be due to the presence of more numerous typical inland transmission sites (e.g., streams, ponds) being close to the lake. Temporal data witness of intense transmission in some lakeshore villages with 30–40% of children cleared from infection becoming reinfected 12 months later (also lakeshore village). The level of *S. mansoni* infection is low in the lakeshore communities. Findings are discussed in relation to fishing in the lake.

Keywords: Schistosomiasis, Over-fishing, *S. haematobium*, Lake Malaŵi

INTRODUCTION

From the mid-1980s, a significant increase in schistosomiasis transmission was reported in lakeshore communities in the southern part of Lake Malaŵi (Centers for Disease Control, 1993) particularly on Nankumba Peninsula in Mangochi District (Cetron et al., 1996; Stauffer et al., 1997). Schistosome transmission is now a major concern in the Cape Maclear area of Lake Malaŵi, because the disease poses a great public health problem for local people and reduces revenue from tourism. Transmission occurs along open shorelines of the lake (with *Bulinus nyassanus* as intermediate host) as well as in inland habitats (with

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Bulinus globosus as intermediate host) close to the lakeshore (Madsen et al., 2001, 2004). The establishment of transmission along open shores may be linked to overfishing, reducing density of molluscivorous species, and this in turn allowed populations of schistosome intermediate hosts to increase to higher densities (Stauffer et al., 1997). Although all types of fishing are prohibited within a 100 m zone along the shoreline of the Lake Malaŵi National Park in the southern part of the lake, this clearly is not respected (Stauffer et al., 2007). Seine-net fishing from the shoreline is often observed and gill-nets are often found within this sanctuary zone. Beach seining, however, is the most damaging form of fishing, since nets are often very fine meshed (sometimes lined with mosquito nets) and since the near-shore zone of the lake is where reproduction occurs and where juvenile fishes reside; thus, recruitment of fish populations is seriously impaired. It is evident that densities of some cichlid species, including molluscivorous species, have declined markedly in shallow waters compared to the early 1980s (Stauffer et al., 2006).

Although there are several case reports on visitors to Lake Malaŵi and a study on expatriates or visitors (Cetron et al., 1996), there is little published information on the disease situation among people in lakeshore communities and because the situation in Malawi is so unique, we decided to summarize studies on urinary schistosome (*Schistosoma haematobium*) transmission patterns in Lake Malaŵi based on work conducted between 1999 and 2006, as part of two projects, i.e. (1) "Malaŵi/Danida Bilharzia Control Programme (BCP)" during 1998–2002 (Bloch et al., 2001) and (2) a NIH/NSF funded project that investigated the relationship among snails, fish and schistosomiasis (2003–2007). It was hope that this could assist in developing a holistic programme for control of schistosomiasis involving the public health, fisheries and tourism sectors.

Methods

Study Sites

Lake Malaŵi (Fig. 1), the most southerly lake in the East African Rift valley system, is over 600 km long (Beadle, 1974) and is 75 km wide at its widest point; its total surface area is approximately 29,600 km^2 and it is bordered by Malaŵi, Mozambique and Tanzania. It is also the second deepest lake (760 m) in Africa. The lake harbours more fish species than any other lake on Earth. The climate is generally tropical with a rainy season from about November to April. There is little to no rainfall from May to October. It is hot and humid from September to April along the lake, with average daytime maxima around 27 to 29°C. From June through August (the cold-dry season), the daytime maxima are around 23°C, but night temperatures ranges from 10 to 14°C. During the cold months, the prevailing wind is southerly. Two islands, Likoma and Chizumulu, are inhabited. Both projects concentrated surveys on the Nankumba Peninsula, but some parasitological surveys were done also on the two islands. On Nankumba Peninsula, 5 village areas were studied. These are:

- Chembe (14°01.49S; 034°50.58E) is a fishing village with a population of roughly 8,000–10,000 and is located on an open bay at the northern part of Nankumba Peninsula. It is well protected from the strong winds, which blow in the southern and eastern sections of Lake Malaŵi. People live primarily along an approximately 3000 m stretch of shoreline up to a distance of about 250–300 m from the lake. The shoreline is facing northwest and the inland area is rather low and traversed by a number of streams and rivers, which are potential habitats for *B. globosus*. In the upland areas some agricultural activities take place.
- Chimphamba I (14°04.10S; 034°50.60E) has a population of about 2000 people, is located along an approximately 1200 m shoreline facing southwest. The village area is surrounded by mountains and traversed by few short streams. To the south there is a valley with one major in-flowing stream. The lake bottom outside the village is heavily polluted with debris.
- Chirombo Bay (14°07.73S; 034°55.18E) is located along an approximately 1700 m stretch of sandy shoreline facing east. Most people live along the southern most 1000 m of this shoreline. The upland is flat and the lake bottom slopes gently. Population density is not high. The upland contains a number of streams.
- Malembo (14°13.70S; 034°48.69E) is an important fishing landing site with about 4000 people. Many inland water bodies are found in and around the village, most contain *B. globosus,* and within the lake both *B. globosus* and *B. nyassanus* may be found.
- Nkope (14°11.86S; 034°02.41E) is located along an exposed shoreline on the eastern side of Nankumba Peninsula. It has a population of about 7000 people who are mostly engaged in subsistence farming as well as fishing.

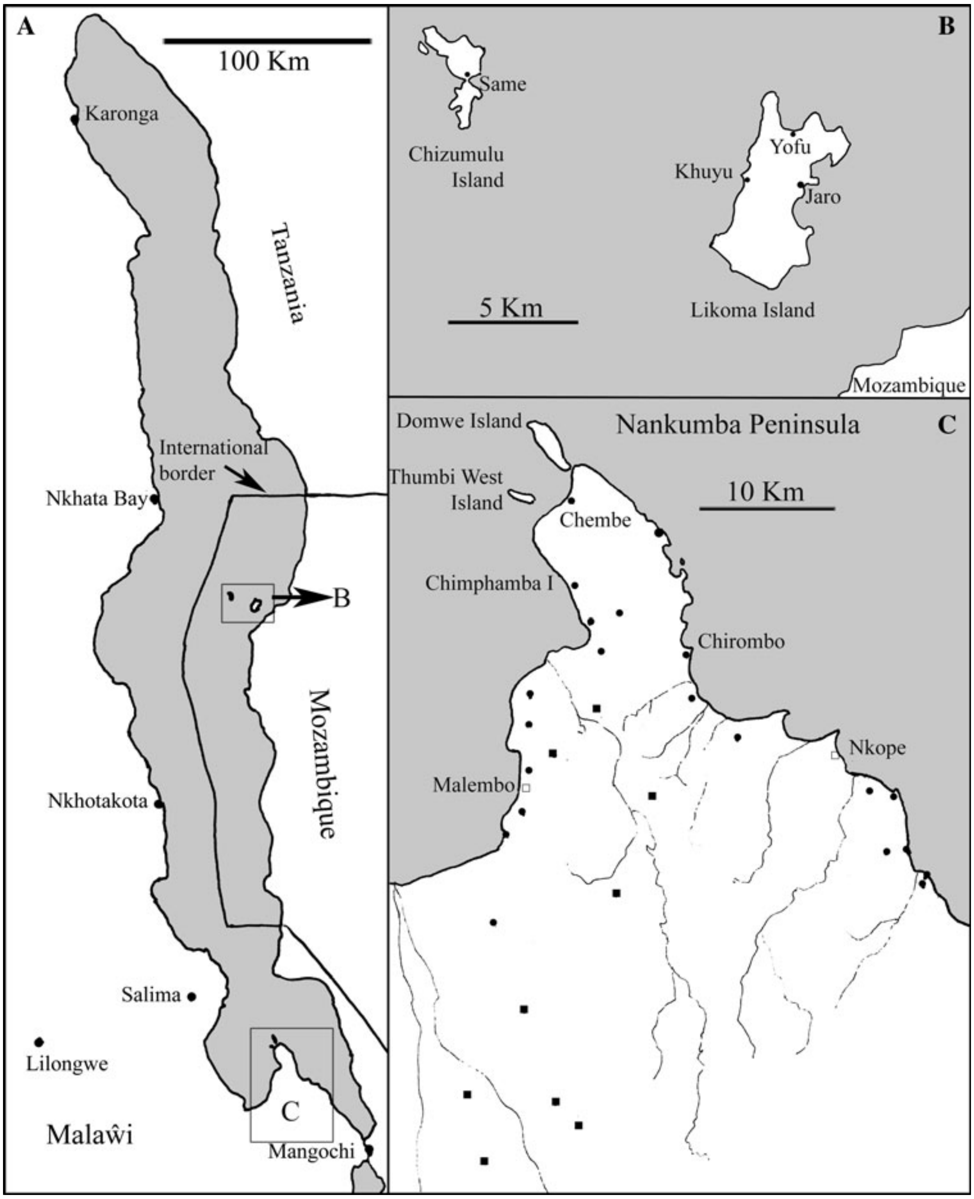

Figure 1. Study villages at Lake Malaŵi. On Nankumba Peninsula (C), *filled squares* indicate inland villages and *filled circles* show lakeshore villages. *Open squares* show the villages where longitudinal snail studies were done.

Parasitological Surveys

The following parasitological surveys were conducted: (1) a cross-sectional study on 29 villages (documented as lakeshore or inland villages) in 1998/1999 (2) a cross-sectional community based survey at Likoma and Chizumulu islands in 2003; (3) annual surveys to determine reinfection among school children in selected classes in three schools on Nankumba Peninsula [Cape Maclear (Chembe village), Namazizi (Chirombo Bay) and Msaka (Chimphamba I village)]; (4) additional cross-sectional surveys in schools on Likoma Island.

The surveys (3) and treatments of children were completed in April/May each year (2003–2007) when transmission was low (and had been low for some months) to ensure maximal clearance of infection in the study individuals. This study also included data on reinfection using Circulating Anodic Antigens (CAA), which is an indicator of active infection (van Lieshout et al., 2000; Doenhoff et al., 2004), as a diagnostic test.

Parasitological Examination

Urine samples, collected from people between 10:00 and 14:00 h, were examined by the filtration technique (Plouvier et al., 1975). All urine samples were checked for presence of blood using dipsticks; urine samples were examined for micro-haematuria (scored with increasing level as 1+, 2+ or 3+) using dipstix; visible signs of haematuria were scored as cloudy yellow, cloudy brown or red. *Schistosoma haematobium* egg counts were expressed as the number per 10 ml of urine. In some surveys, faecal samples were taken as well and they were examined using the Kato-Katz method (Katz et al., 1972). All infected people were offered treatment after examination with Praziquantel at 40 mg per kg body weight. Treatment was supervised by an experienced public health officer.

Immunological Tests

In survey 3, all children who were infected in April 2004 were invited to participate in a 1 year study cohort that would be examined for CAA in blood samples twice, i.e. the first time to confirm parasite clearance after treatment and the second time to determine the reinfection status 1 year later.

Snail Surveys

Surveys for the intermediate host snails included (1) a cross-sectional survey on Nankumba Penninsula in 1998; (2) a longitudinal survey on the intermediate hosts in selected sites at 3 lakeshore villages, Chembe, Nkope and Malembo, with monthly estimation of density and infection levels in these snails from 1999 to 2002. Surveys done on snails from 2003 to 2006 will be reported elsewhere.

Qualitative Snail Sampling

A cross-sectional snail survey was conducted in 1999 around selected villages using different non-quantitative techniques, primarily dredging (see below), scooping or hand-picking. The scoop was made of a kitchen sieve supported by an iron frame and mounted on a 3–4 m long bamboo rod.

Quantitative Sampling

Quantitative snail sampling was done monthly from August 1999 to September 2001 at selected transects (number of transects in parentheses) in the lake at three villages, i.e. Chembe (6), Malembo (3) and Nkope (3). In addition, a number of inland sites were selected. Transects extended from the shore to 50 m offshore and were perpendicular to the shoreline. At each of the following distances from the shore, 2, 4, 6, 8, 10, 15, 20, 25, 40 and 50 m, two samples were taken using a Van Veen grab (KC-Maskiner, Denmark) sampling an area of 0.15 m × 0.15 m and snails were carefully sorted from the sample, identified and measured to the nearest mm class. Counts were converted to number per m^2. Along the shoreline around each transect (except at transects 5 and 6 at Chembe; transect 5 was located on Thumbi island and 6 on Domwe island and the sandy shoreline was of limited size at both), snails were sampled using scooping in ten 25 m stretches (2 people searching for 10 min in each). In inland sites, sampling was done by scooping only (2 people for 10 min). The counts were converted to number per man hour search. Since the actual number of snails collected by the grab samples from the deeper water was relatively small, additional sampling was done using dredging for more reliable estimation of prevalence of schistosome infections. The dredge was made of a metal frame fitted with a nylon mesh and runners to prevent it from descending too deep into soft sediment. The dredge was pulled along the bottom for a distance of 25 m parallel to the shoreline at 10, 25 and 50 m from the shoreline.

Examination of Snails for Cercariae

Bulinus snails were collected during the morning and checked for cercariae shedding on the same day if collected before 1400; if collected after 1400 they were transferred to aquaria and checked the following morning. Snails were transferred individually to small plastic beakers (12.5 ml) with 6 ml of water and exposed to light outside (not in direct sunlight) for 2–3 h before containers were inspected for the presence of schistosome cercariae using a dissecting microscope.

Ethical Clearance

Ethical clearance was obtained from the Ministry of Health's National Health Sciences Research Committee. Permission to conduct the studies was obtained from district authorities, i.e. District Health Officers and the District Education Managers, respectively. At the school level, the study team with help of teachers explained and discussed the study protocol to the targeted pupils and obtained informed consents from parents or guardians prior to commencement of sampling. In Denmark, the research was cleared by the Danish Committee on Scientific Dishonesty, Danish Research Agency, Ministry of Science, Technology and Innovation, prior to commencement. Similarly in USA, the research was approved by The Office for Research Protections (IACUC# 27107), The Pennsylvania State University, PA, USA.

Statistical Analysis

Comparison of prevalence of infection among age groups, village location, or other factors were completed using logistic regression (Hosmer and Lemeshow, 1989) adjusting for clustering within villages. Similarly, egg counts were compared among these factors using count models (Hilbe, 2008) adjusting for clustering within villages. In these analyses, we first used Poisson regression which involves estimation of one parameter, the mean (μ). If the Poisson modelled analysis showed real overdispersion and the variance (V) was greater than μ, we would try to model using negative binomial regression where the variance is modelled as $V = \mu + \alpha \times \mu^2$. The ancillary parameter (α) was estimated using full maximum likelihood estimation as described in Hilbe (2008). The ancillary parameter was then entered into a Generalized Linear Model and model fit was assessed using dispersion statistics to check for over-dispersion and Anscombe residuals to check for outliers (see Hilbe, 2008). The volume of urine examined (usually 10 ml) was used as an offset.

Results

Lakeshore Villages Compared to Inland and Island Villages

Overall prevalence (all age classes combined) of urinary schistosomiasis ranged from 10.2% to 26.4% in inland villages and from 21.0% to 72.7% in lakeshore villages, prevalence of heavy infections (>50 eggs/10 ml urine) ranged from 0% to 6.8% in inland villages and from 3.0% to 28.0% in lakeshore villages. For school children prevalence of infection ranged from 15.3% to 57.1% in inland schools and from 56.2% to 94.0% in lakeshore schools; prevalence of heavy infections ranged from 1.7% to 17.0% in inland schools and from 12.4% to 68.4% in lakeshore schools; and prevalence of blood in urine from 16.9% to 47.3% in inland schools and from 29.7% to 89.2% in lakeshore schools. Lakeshore villages clearly had considerably higher prevalence of infection than inland villages and there was very little overlap between the two groups of villages (Fig. 2). Prevalence of heavy infections showed the same pattern. Although presence of blood in urine clearly was more prevalent in lakeshore villages there was a larger

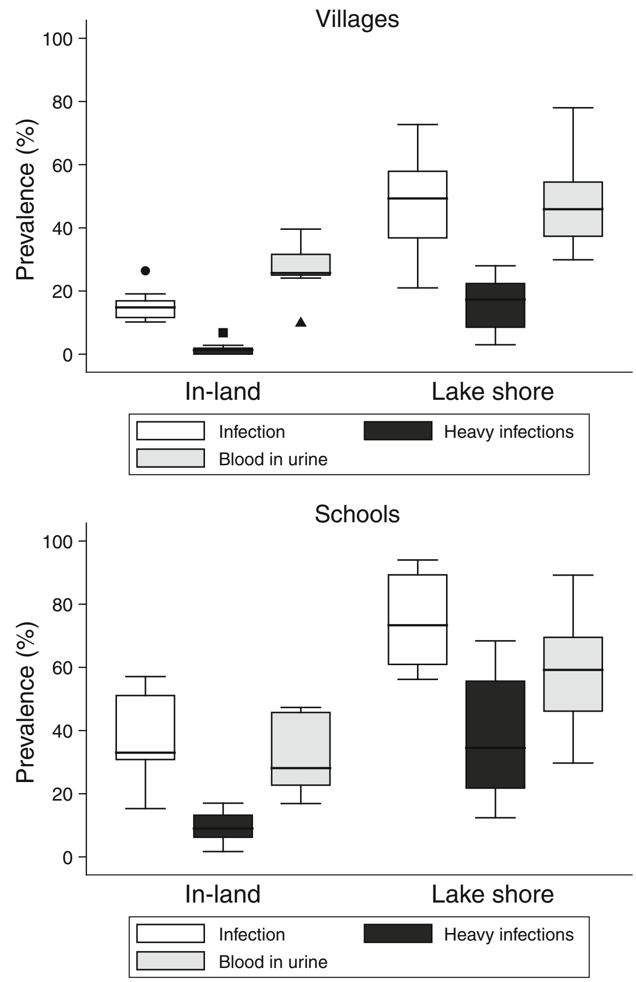

Figure 2. Box plot showing prevalence of *S. haematobium* infection, heavy infections and blood in urine among villages and schools located at the lakeshore or away from the lake (BCP data). The *thick horizontal lines* show medians, the *box* shows the interquartile range and the "whiskers" shows the range of up to 1.5 times the interquartile range above the 75th percentile or below the 25th percentile. *Symbols* indicate values outside this range.

overlap with that recorded from inland villages. Among school children, prevalence of *S. haematobium* infection was much higher than among the total population (age effect). Further, schools in lakeshore villages had considerably higher prevalence of infection/heavy infections than inland villages and there was very little overlap between the two groups. Presence of blood in urine was slightly higher among school children than among the overall population and there was some overlap between schools in inland villages and those in lakeshore villages.

Prevalence of urinary schistosomiasis was very high in lakeshore villagers (Fig. 3) followed by island inhabitants and inland villagers and this pattern was seen in almost in

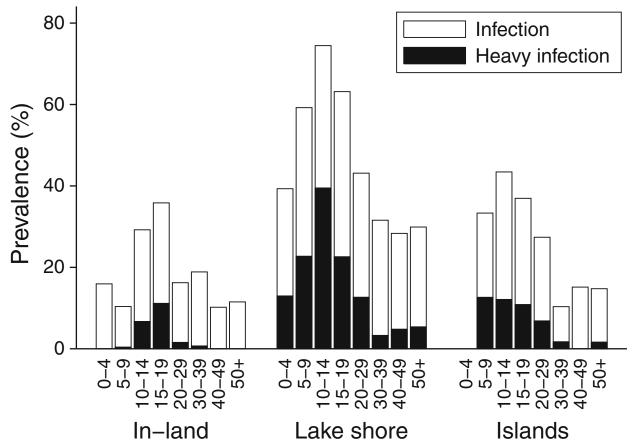

Figure 3. Prevalence of infection and heavy infections by *Schistosoma haematobium* in inland (nine villages combined) and lakeshore (19 villages combined) villages at Nankumba Peninsula (Survey 1 from 1998/1999) and three villages on Chizumulu and Likoma Islands (Survey 2 from 2003).

all age groups. This trend was also observed in the prevalence of heavy infections where heavy infections were relatively low in inland villagers. Logistic regression (Survey 1 only) adjusting for age class and clustering within villages showed that overall the odds of infection in lakeshore villagers was 4.07 greater than that in inland villagers ($P < 0.001$). There was, however, a statistically significant interaction ($P < 0.05$) between the two predictors so the odds ratio for the youngest age class was 3.38, for the age classes 5–9 and 10–14 years combined 4.27 while for people older than 20 years it was 2.79. Similarly, for egg density, when adjusting for clustering within villages there was a significant interaction between age group and location. Egg density was 53.1, 100.7, 75.7, 29.3 and 14.8 times greater in lakeshore inhabitants than in inland villagers for age classes 0–4, 5–9, 10–19, 20–29 and 30+ years, respectively.

Micro-haematuria was a significant predictor of *S. haematobium* infection; the odds of infection for categories 1+, 2+ and 3+, respectively, were 1.46, 1.97 and 2.63 times that of people without signs of micro-haematuria. Similarly, macroscopic characterization of urine was a significant predictor of infection after adjusting for age groups, location and variation between the two factors; the odds of infection was 1.70, 3.07 and 3.13 greater than that among those having normal urine for cloudy yellow, cloudy brown and bloody red, respectively. Egg density was 6.0, 15.6 and 38.0 times greater among people with micro-haematuria levels 1+, 2+ and 3+, respectively, than those who did not have signs of micro-haematuria after adjusting for age class, location and interaction between these two factors. Similarly, for visible signs of haematuria, i.e. cloudy yellow, cloudy brown or red urine samples, egg density was 12.9, 88.2 and 82.9 times higher than that in people with normal looking urine after adjusting for age class, location and interaction between these two factors. The last two values did not differ significantly.

Overall prevalence of *Schistosoma mansoni* infection was 2.9% with egg counts of maximum 21 eggs g^{-1} faeces ($n = 1030$). Prevalence in lakeshore villages was 3.9%, while only inhabitants of one inland village tested positive for *S. mansoni* with prevalence of 6.8% ($n = 44$). Most lakeshore villages in the south-eastern part of the peninsula were positive indicating that transmission might occur in that area. Few infections were found in residents of other villages. Twelve cases were found in the age class 10–14 years and 19 in the age range 15–19 years. Four cases were found in the 20–39 years age class while 1 child <5 years was found infected.

The community surveys at Likoma and Chizumulu islands involved a total of 462 people above the age of 5 from three villages who were examined for infections with *S. haematobium* and 312 people who were examined for intestinal schistosomiasis (*S. mansoni*) and other intestinal worm infections. Prevalence of *S. haematobium* infection peaked at 43.4% among children in the age of 10–14 years (Fig. 3) whereas the level of heavy infection peaked at 11.5% in children aged 5–9 years (Fig. 3). Overall hookworm infection was 12.5% and did not vary among villages, but increased with age class ($P < 0.05$), i.e. 7.95%, 14.7% and 22.2% in people aged 5–9 years, 10–49 years and 50 years and above, respectively. The difference between the two first age classes was not significant when adjusting for village effect. Only one person (50 years old) was found infected with *S. mansoni*.

Longitudinal Study in Three Villages on Nankumba Peninsula

Prevalence, Intensity and Reinfection in School Children

Prevalence of urinary schistosomiasis at Cape Maclear (Chembe) and Msaka (Chimphamba) was high over the 5 project years (average 38.6%), but values for Cape Maclear school in 2005 and 2007 were somewhat lower, 25.9% and 22.8%, respectively (Table 1). Similarly, the prevalence in Msaka in 2005 was lower than during the other years (Table 1). At Namazizi, prevalence was lower than in the other two lakeshore schools (Table 1). When analysed

Table 1. Showing a Summary of the Number of School Children Examined by School During the Five Annual Surveys

School (village)	Msaka (Chimphamba)			Namazizi (Chirombo Bay)			Cape Maclear (Chembe)			*P* value infected	*P* value heavy infections	Total		
	Number examined	Infected (%)	Heavy infections (%)	Number examined	Infected (%)	Heavy infections (%)	Number examined	Infected (%)	Heavy infections (%)			Number examined	Infected (%)	Heavy infections (%)
Year														
2003	133	32.3	9.8	132	10.6	1.5	190	57.4	23.7	< 0.001*	< 0.001*	455	36.5	13.2
2004	213	40.8	19.7	171	14.0	1.2	361	42.9	11.1	< 0.001	< 0.001*	745	35.7	11.3
2005	317	26.5	3.5	235	6.8	0.0	514	25.9	3.7	< 0.001	< 0.05	1066	21.9	2.8
2006	330	37.3	10.0	258	14.0	3.1	616	45.3	9.9	< 0.001*	< 0.01	1204	36.4	8.5
2007	340	36.5	4.7	246	8.1	0.0	514	22.8	2.9	< 0.001*	< 0.01	1100	23.7	2.8
		< 0.01	< 0.001		< 0.05	< 0.01		< 0.001	< 0.001				< 0.001	< 0.001

Prevalence of infection as well as of heavy infections is shown as well.
* Chimphamba and Chembe do not differ significantly in prevalence of infection.

according to age class, prevalence of infection decreased with increasing age, a trend which was also observed for heavy infections. There were no significant differences ($P > 0.05$) both in infection prevalence and heavy infections when data were analysed according to sex of the children. Both prevalence of infection and heavy infections decreased with the increase in standard (class) of the children at the school. As for reinfection, the rates for both infection and heavy infections at Cape Maclear remained constant over the years averaging 40% and 5%, respectively.

Immunodiagnosis

Parasitological and serological examinations of children in the three schools are summarised in Table 2. Half of the children diagnosed as negative using egg counts were positive when using CAA, and 10.6% of the egg positive children were diagnosed as negative using the CAA.

Comparison of Prevalence in School-Aged Children Between Likoma/Chizumulu and Nankumba

Infection level among school-aged children on the islands was comparable to that of school children at Nankumba (Fig. 4) while prevalence of heavy infections was more variable among schools/villages than the variation in total prevalence of infection. Khuyu (Island) and Chembe (Lakeshore Nankumba) villages had the highest prevalence of heavy infections in 2003.

Intermediate Hosts and Transmission

Cross-sectional surveys showed that *B. globosus* was common in inland habitats and it also occurred in the lake, especially at swampy areas or sheltered shorelines, while *B. nyassanus* was common in lake sites. *Biomphalaria pfeifferi*, the intermediate host for *S. mansoni* was found occasionally in inland sites.

At Chembe Village, *B. globosus* was only found on a few occasions in inland sites (not shown in Table 3), while at Malembo and Nkope, this species was found in both lake sites (the lake proper and backwaters) and inland sites such as ponds. Infected *B. globosus* were found at both lake sites and inland sites at Malembo, while infected snails at Nkope were found only in lake sites. *B. nyassanus* was abundant at Chembe especially in sites along the Chembe Village coast and schistosome infected specimens were found at sites 2 and 3, both in snails collected by scooping and in transects.

Table 2. Results of Parasitological and Serological Examination 1 year Post-treatment

School	Parasitology		Serology	
	No. examined	Infected (%)	No. examined	Infected (%)
2004 survey				
Msaka	19	42.1	15	73.3
Namazizi	5	0.0	5	0.0
Cape Maclear	59	37.3	55	76.4
Total	83	36.1	75	70.7
2005 survey				
Msaka	48	25.0	24	41.7
Namazizi	7	14.3	0	0.0
Cape Maclear	64	31.3	31	58.1
Total	119	27.7	55	50.9
Total both years				
Msaka	67	29.9	39	53.8
Cape Maclear	123	34.1	86	69.8
Total	202	31.2	130	62.3

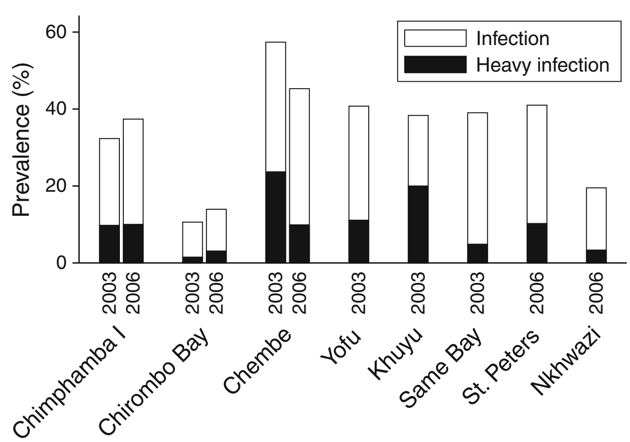

Figure 4. Prevalence of infections by *S. haematobium* in school-aged children in three lakeshore villages on Nankumba Peninsula (Chimphamba, Chirombo Bay and Chembe) and on the Chizumulu (Same Bay) and Likoma islands (Yofu and Khuyu); St. Peters and Nkhwazi schools are located on Likoma island (at Jaro).

At Malembo and Nkope, *B. nyassanus* counts were much lower, but at both villages a single specimen was found infected. The maximum distance from the shore where infected *B. nyassanus* was found was 50 m at a depth of 3.1 m at Chembe village. At Nkope, the infected *B. nyassanus* was found at 25 m from the shore at a depth of 1.25 m.

Bulinus globosus was not commonly found in the lake itself, but occasionally it occurred in high numbers. The species was more abundant in backwaters presumably fed by wave action at these lake sites. *B. globosus* populations in inland sites were rather erratic and they were mainly found after the rainy season. Transmission of *S. haematobium* through *B. globosus* can take place from at least April (after the rainy season) until about November. Scooping in the shallow water showed that *B. nyassanus* numbers increased from about May to peak in August to November (Fig. 5). July to November was the period when infected snails were found. From December/January, *B. nyassanus* counts were very low. The transect sampling showed the same general pattern (Fig. 6).

The distribution pattern varied considerably among villages (Fig. 7) and among individual transects and similarly the pattern by distance from shore varied considerably. Differences could be partly related to the depth profile along these transects; thus at the 4 transects at the Chembe coast water average depth was 2.8 and 4.1 m at 20 and 50 m from the shore line, respectively. At the transects on the islands, these depths were 2.8 and 8.1 m, and at the transects at Malembo and Nkope combined they were 1.5 and 2.0 m, at 20 and 50 m from the shore line, respectively. Young *B. nyassanus* were found only during the cold-dry period and primarily in deeper water (Fig. 8). Egg masses, however, were often observed during scooping during this time of the year.

Discussion

Prevalence of schistosomiasis is higher among lakeshore and island communities than among inland communities.

Table 3. Total Snails Collected During August 1999 to September 2001 Using Different Sampling Procedures

	Chembe		Malembo		Nkope	
	Chembe coast (4)	Islands (2)	Lake (3)	Inland (3)	Lake	Inland
Bulinus globosus						
Total collected			1095	35	270	52
Infected			17	2	1	0
Total backwaters[a]			361		157	
Infected			0		0	
Bulinus nyassanus						
Total transects	485	85	63		28	
Infected	4	0	0		1	
Total scooping	4415	20	67		0	
Infected	13	0	2			
Total dredging	1069	169	191		72	
Infected	1	0	0		1	

[a]Refers to backwaters close to the lakeshore.

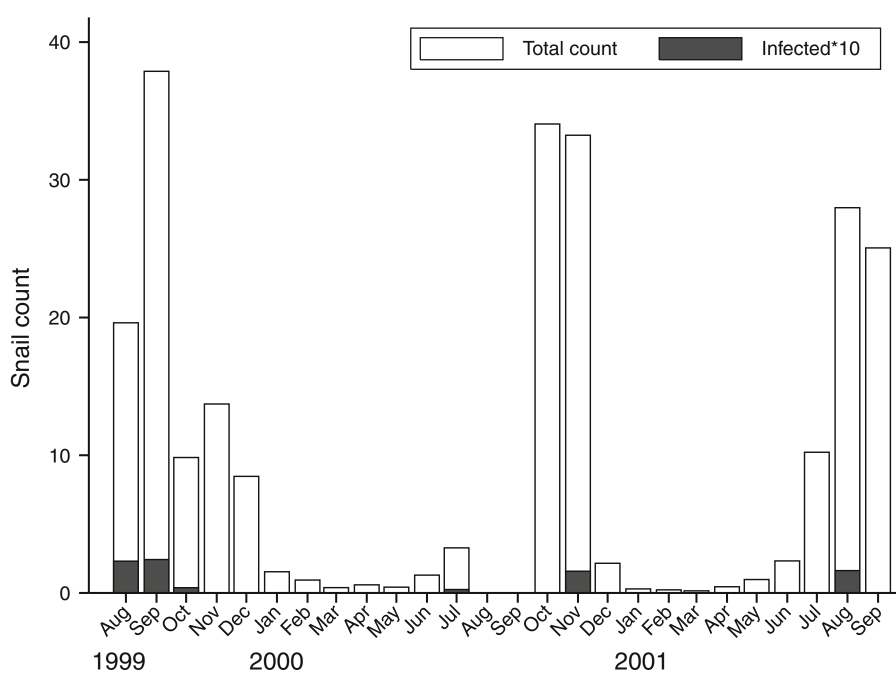

Figure 5. Mean number of *Bulinus nyassanus* collected per man hour search in lake sites at Chembe, Malembo and Nkope.

Within Nankumba Peninsula there are, however, pronounced differences in prevalence of infection and reinfection rates in school children among lakeshore villages, i.e. between Chembe and Chimphamba on one hand and Chirombo on the other hand. This can be attributed to the fact that both Chembe and Chimphamba are enclaved fishing societies where there is over-dependence on the lake while the school in Chirombo draws most of its children from several villages not necessarily along the lakeshore including Monkey Bay town. It has also been observed that while children from Msaka (Chimphamba village) had consistently high prevalence, Cape Maclear's (Chembe village) high prevalence pattern was disturbed by a mass treatment campaign done by Save the Children in 2004 and also the opening of a clinic by Billy Riodan Charity in the village that has been offering various types of treatment including that for schistosomiasis. All in all, transmission in communities along the lakeshore is high as demonstrated by the high reinfection rates both in Cape Maclear (Chembe) and Msaka (Chimphamba) despite treatment

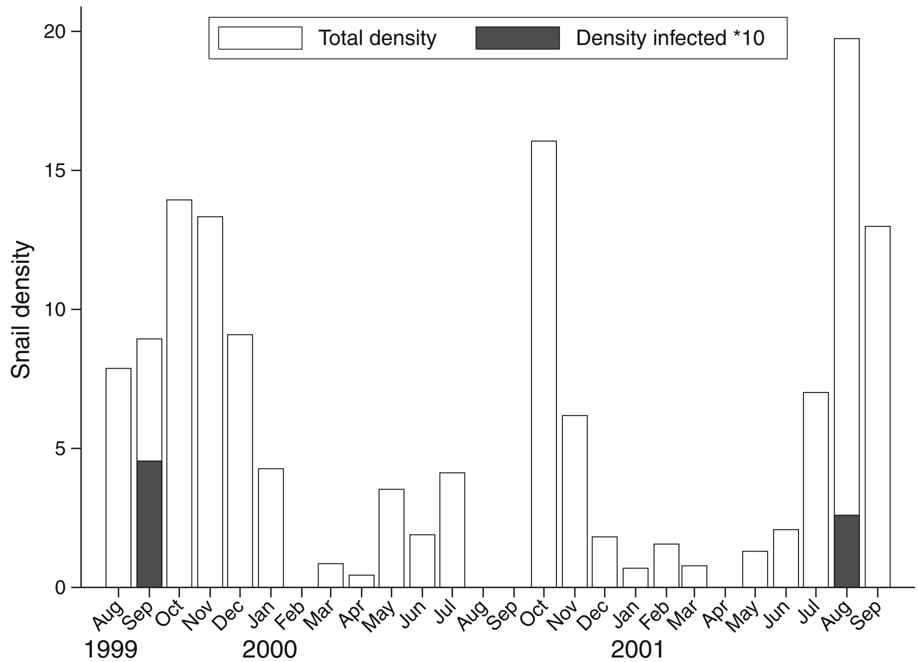

Figure 6. Mean density (no. m^{-2}) of *Bulinus nyassanus* collected in transect sites at Chembe, Malembo and Nkope.

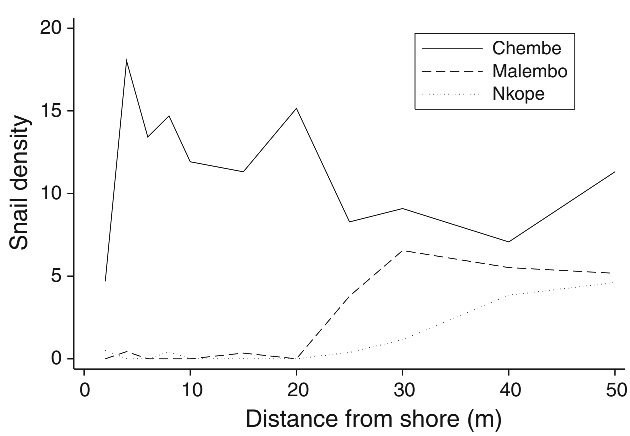

Figure 7. Mean density (no. m^{-2}) of *Bulinus nyassanus* in transect sites at Chembe, Malembo and Nkope (BCP data from 1999 to 2001).

the previous year. This therefore calls for a need to take cognizance of this fact in any plan to control schistosomiasis in the area.

Two snail species are involved in transmission on the Nankumba Peninsula, i.e. *B. globosus* and *B. nyassanus*. *Bulinus globosus* (Morelet 1866) is found in most of the sub-Saharan Africa in various freshwater habitats including streams, rivers, seasonal pools and lakes (Brown, 1994; Mandahl-Barth, 1972; Cantrell, 1981; Madsen et al., 1987; Ndifon and Ukoli, 1989). *Bulinus nyassanus* (Smith, 1877) is a member of the *B. truncatus/tropicus* group and is endemic to Lake Malaŵi; it is found on open sandy areas and has a preference for habitats devoid of vegetation and with substratum consisting of coarse and, to a smaller extent, fine sand, where it is normally found in the upper 2–3 cm of the substratum (Wright et al., 1967; Louda et al., 1983; Phiri et al., 2001; Madsen et al., 2004). Its status as intermediate host was not recognised prior to these studies (Madsen et al., 2001) and an alternative explanation for the changed transmission pattern was that another strain of *S. haematobium*, capable of using *B. nyassanus* as host, had been introduced on Nankumba Peninsula. Molecular data, however, do not suggest existence of two *S. haematobium* strains and *S. haematobium* from Likoma Island can infect *B. nyassanus* from Nankumba (Stauffer et al., 2008).

Transmission takes place both in inland habitats and in the lake proper. Transmission in inland sites (including lake backwaters and sites further inland) is through *B. globosus* and starts towards the end of the rainy season or early dry season in March/April and continues until sites dry out; which could be as early as June/July or 1–2 months later. A few sites may, however, persist for longer but *B. globosus* populations often disappear before sites dry. Usually several inland sites exist in village areas at the lakeshore and these clearly contribute to the higher infection levels in lakeshore communities. Many of the inland water bodies are actually streams that only flow during rains and shortly after, wave action will form a sand barrier isolating "the stream" from

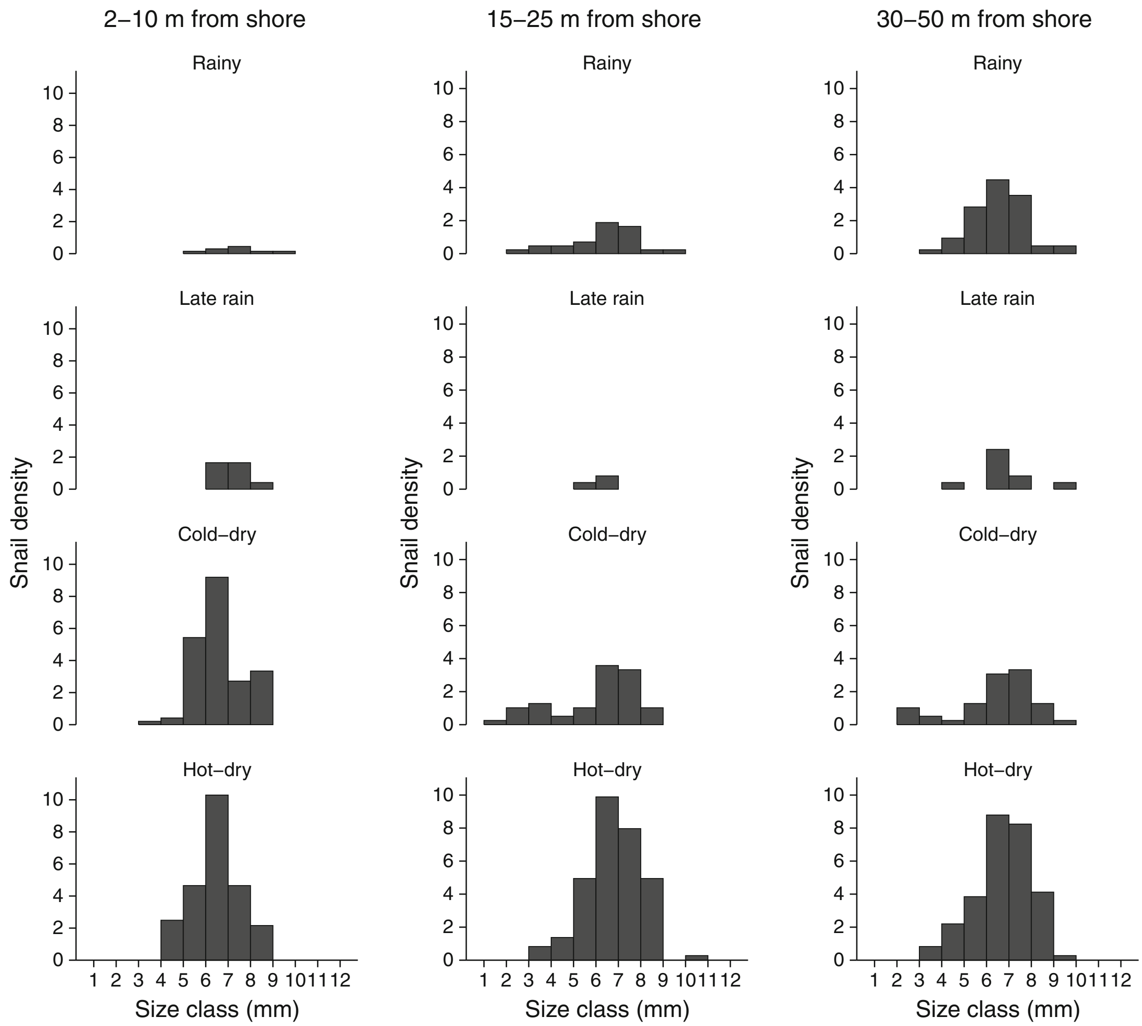

Figure 8. Size distribution of *Bulinus nyassanus* during different seasons and by distance from shore (BCP data from 1999 to 2001).

the lake (Madsen et al., 2004). Transmission in inland habitats can be found all around the lake. Some of the inland sites may support *Biomphalaria pfeifferi* and *S. mansoni* transmission.

Transmission in the lake can be either by *B. globosus* along protected shorelines often with aquatic vegetation or presence of boulders in the water and/or through *B. nyassanus* along open sandy shorelines on the Nankumba Peninsula (Madsen et al., 2004). Transmission by *B. globosus* within the lake or backwaters may commence towards the end of the rainy season or shortly after and may continue up to about October/November which is much longer than transmission in sites further inland. Transmission through *B. nyassanus* will start May/July when populations increase in shallow water and persist into November/December depending on weather conditions; wave action can cause reductions in density of *B. nyassanus* in shallow water. The Chembe shoreline is north-west and during July–August the predominant wind is from the south and the shoreline is well protected, while in November/December the shoreline is exposed to storms coming from a northerly direction.

Schistosoma haematobium transmission through *B. nyassanus* is limited to sites where the snail occurs in shallow water close to the shore. Infected *B. nyassanus* have been found only on Nankumba Peninsula. Density of *B. nyassanus* is generally higher in the southern part, especially in shallow water, of the Lake (Nankumba and Matola) than in the northern part. Density of *B. nyassanus* is partly governed by sediment composition (Genner and Michel, 2003; Madsen and Stauffer, unpublished data) and further there is a negative association between density of *B. nyassanus* and density of *T. placodon* (Madsen and Stauffer, unpublished data).

It is evident that transmission is intense in Lake Malawi along open shorelines at certain villages, especially Chembe, one of the most important tourist resorts, in the southern part of the lake and this is in marked contrast to the situation before the mid-1980s. It has been suggested that this is due to overfishing (Stauffer et al., 1997) but could also be related to other human induced impacts on the lake. A recent detailed review of the fisheries in Lake Malawi has been published by Weyl et al. (2010) and they conclude that there are signs of over exploitation and an increasing fishing effort has resulted in decreased catch rates, depletion of larger, more valuable species in the fishery and species changes, especially in southern Lake Malawi where the concentration of fishing effort is greatest. An industrial trawl fishery which was introduced on Lake Malawi during the 1970s to harvest small cichlids accelerated the decline in stocks of certain species in the lake (Ogutu-Ohwayo et al., 1997).

As human activities in the catchment have increased, so have erosion and consequent sedimentation (Weyl et al., 2010). On settling, the sediment impact negatively on demersal algae and fauna in both the sandy and rocky habitats, sometimes burying completely the photosynthetic algae, stopping primary and secondary demersal productivity and smothering the habitats for the infauna of the algal mats (Weyl et al., 2010). Effectively, the food resources upon which fishes of those habitats depend are lost (Weyl et al., 2010). Nutrient inflow from rivers into the lake, increases productivity and eutrophication and it can be concluded that the lake as a whole, but particularly the southern region and areas around major rivers, is becoming increasingly eutrophic (Weyl et al., 2010).

These effects may have contributed to the changed pattern of schistosome transmission, but more importantly, however, are the activities on a more local scale, i.e. along the actual shoreline where transmission occurs. Transmission within the lake is probably limited to the shorelines in front of certain villages. Beach seining is a common practice at most of these villages, and this reduces fish density in the shallow waters; at greater depths at Chembe, density of *Trematocranus placodon*, the most important snail predator is now roughly comparable to that observed in the early 1980s (Stauffer et al., 2006; Stauffer and Madsen, unpublished data). We have observed in some locations that the intensity of beach-seining fluctuates; at some point the catches becomes too low and beach seining is stopped or moved to other locations and this gives the fishes time to recover. Also due to human domestic activities there is local contamination with organic material and this organic loading could possibly benefit the intermediate host snails and other snails.

Managing the situation not only rely on fisheries management on a lake-wide scale through ecosystem-based approaches where targeted species are part of a complex web of interacting species (Darwall et al., 2010; Kasulo and Perrings, 2006), or at a local level by prohibition of beach seining at shores in front of villages. The lakeshore communities are poor and may not be able to change their practices unless other opportunities for food production or income generating activities are created. It is thus crucial that a holistic approach is adopted in dealing with the situation.

Schistosomiasis control in the area must be spearheaded by regular chemotherapy of infected people, but in order to reduce reinfection rate, some form of transmission control, e.g. safe water supply, sanitation to prevent eggs from reaching the lake, health education and control of the intermediate host snails, should be implemented as well. The most important water contacts in the lake are related to playing and swimming (children and young people) and domestic activities and contamination of the lake by schistosome eggs is not likely to be changed much through provision of sanitary installations. Water contact in relation to fishing is limited to setting off or landing boats, while water contact further offshore most likely does not increase infection risk. The most realistic option for transmission control in the lake, therefore, is control of the intermediate host snails. The only realistic way that this possibly can be achieved is through restoring fish populations in the nearshore area in front of villages. We are convinced that fish populations would be able to recover if beach seining was reduced or stopped completely, because *Trematocranus placodon*, is abundant in deeper waters (>6 m) that are not normally reached by beach seining. If fish populations could be restored, this would most likely only affect transmission through *B. nyassanus*, either because the molluscivores do not feed in the shallow areas where *B. globosus* is found or because the aquatic vegetation or boulders can provide *B. globosus* with some refuge against predation. Surveys have shown that density of *B. nyassanus* is negatively associated with density of *T. placodon* (Madsen and Stauffer, unpublished data). Many of the inland transmission sites are too small and too seasonal to support important fish population and therefore those sites should be dealt with differently, possibly through chemical snail control or drainage. We, however, think that possibilities for converting some of these into aquaculture ponds using species from the catchment area should be further explored.

Conclusion

Schistosome transmission is more intense in lakeshore villages than in inland villages and the reason for this is that inland transmission sites with *B. globosus* as intermediate host are more numerous close to the lake than further inland and for several villages in the southern part of the lake that transmission occurs in the lake along sandy beaches with *B. nyassanus* as intermediate host. Serological examination for circulating anodic antigens of school children treated for schistosomiasis shows that up to about 70% in some villages become reinfected after 1 year.

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