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Focal, seasonal and behavioural patterns of infection and transmission of *Schistosoma haematobium* in a farming village at the Volta lake, Ghana

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Summary

Integrated sampling for human prevalence, intensity, and incidence of *Schistosoma haematobium*, as well as for human water contact and snail distribution and density was carried out in the Volta lake farming village of Agbenoxoe at various times between 1978 and 1980. Nuclepore filters were used for determining egg output. Snail sampling was by the man-time method. A new system of recording human water contact was introduced for the peculiar condition at Agbenoxoe. Results indicated significant focality of infection and transmission in the compact village, concentration in the 5- to 19-year-old age group, and distinct seasonality of transmission. Water contact was frequent but of short duration. Only a few children under the age of 5 entered the water, and age-specific curves for duration of water contact paralleled the curve for geometric mean of egg counts ($\log_{10}$ of eggs + 1) for males and the prevalence curve for females. Water contact for males was of longer duration than for females and included more time playing and wading. These activities probably accounted for the much higher incidence and prevalence rates recorded for males over females in the village. The concentration of infection, transmission, and water contact in the 5- to 19-year-old age groups at Agbenoxoe and villages like it supports a control strategy of treating only this age span with drugs.

Introduction

The formation of the man-made Volta lake from 1964 to 1967 led to a major epidemic of *Schistosoma haematobium* around its 5000 km shoreline in at least 950 lakeside and hinterland communities (Jones 1973). Detailed field studies on the infection at the lake took place between 1971 and 1981, although only one report on the epidemiology has been published (Scott *et al.* 1982). The study area included 26 semi-nomadic fishing and farming villages ranging in size from 50 to 370 people in 1974, along 60 km of contiguous shoreline. As the project was winding down and more became known of the lake as a whole, it remained unclear whether or not conclusions reached on the status of *S. haematobium* and the strategy for its control in the small study area would be valid for other parts of the lake. With WHO sponsorship, Klumpp (1983) studied the epidemiology and transmission of the infection in eight different branches of the Volta lake between 1978 and 1980. Part of this research involved a study of *S. haematobium* in an old, stable Volta lake farming village of over 1000 people, with no tradition of fishing. In many respects, it was similar to other large farming villages and towns around the lake, none of which had ever been studied in depth for schistosomiasis. Thus, the study's objective in this non-fishing village was to collect information on patterns of infection and transmission, and to study the focality and seasonality of transmission from four integrated approaches: prevalence and intensity, incidence, snail sampling, and human water contact.

The work took place at the village of Agbenoxoe (pronounced Ag-ben-och'-way) in the Volta region of Ghana. The purpose of this report is to present the main findings of these studies, and describe how infection and

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transmission in the village was distinctly focal, seasonal, and related to duration of certain water contact activities.

Village description

Agbenoxoe is located at a small inlet on the eastern shore of the Volta lake, 5 km from the regional town of Kpandu and about 220 km north of Ghana's capital, Accra. Mid-day air temperatures near Agbenoxoe range from 22 to 37°C in the main rainy season months of April–October, and from 23 to 40°C in the dry season months of November–March. The average rainfall per year in the area is about 1300 mm. Mid-day surface water temperatures in that part of the Volta lake vary from 25 to 33°C.

In 1979 the village, which is over 200 years old, had a population of 945 living in 95 family compounds ($\bar{x} = 11.1$, s.d. $= 7.8$). All but 43 were indigenous, 'northern' Ewe (Eh'-vay) people. Almost all of the rest were nomadic fisherfolk of the Efutu tribe. In 1980, only 15 long-term residents died or moved away permanently, and the total population grew to 1070. Of the increase, 69 were either new births or returning indigenous villagers, and 71 were newly-arrived Efutus. The overall male to female ratio that year was 1:1.6, and the age pyramid showed the typical broad base and narrow peak.

The indigenous Agbenoxoe people were primarily farmers of yams, cassava, palm nuts, bananas, and plantain. The inundation of the Volta lake between 1964 and 1967 destroyed some low lying houses in the village and forced the relocation of about 100 residents to other parts of the village. The final stabilization of the lake brought the shoreline to a high water range of about 50 to 150 m from all permanent Agbenoxoe compounds (Figure 1).

Between 1978 and 1979, the lake receded to such low levels that the old bridge across the Kple River inlet was above water and could be used again for road traffic to the neighbouring village of Kpandu Dafor. At that time, only two water contact points (WCPs) in the village were in use: WCPs 1 and 2. From July to November 1979, the lake rose 5.1 m, its highest ever seasonal flood, and the inlet filled to a horizontal level about 20 m wider than the level shown in Figure 1. During this period, a seasonal stream on the west side of the village filled up and was used for some water contact, mainly fetching water. It contained no *B. rohlfsi* and was not used after it stopped flowing in November, at which time WCPs 3 and 4 came back into use. From that time, through June 1980, WCP 4 was the most heavily used site, followed by WCPs 1, 3, and 2.

Not included in Figure 1 is the large Christian grotto in the south-western corner of the village. This contains numerous statues and carvings depicting events of the Crucifixion, and is famous throughout Ghana and parts of Togo. Religious groups make frequent pilgrimages to the grotto, and on special occasions, thousands of people flock to the village to see the statues and pray. Nearly all of the indigenous residents are Catholics, baptized at infancy, and since these baptisms are recorded, correct determination of age is easy.

Despite two public lavatories at the grotto, much urination still takes place in the lake. Two bore wells were drilled in the village in the early 1970s, but the hand pumps broke down frequently, and within a few years, the wells were permanently inoperative. In 1973, Jones, surveyed 229 children in the primary and middle schools for *S. haematobium* and recorded an overall prevalence rate of 25.1% (Jones 1973). Soon afterwards, most of the positives were treated once with niridazole by a Ghana health team. Just before the present study began, 56 school children, aged 8 to 14, were examined for *S. haematobium*. The prevalence rate was 76%, indicating that there has been active transmission of the infection since the incomplete chemotherapy.

Agbenoxoe, with its stable population and compact size, had many advantages as a study village: accessibility and close proximity to the lake, medium snail populations along the entire shoreline during much of the year, known ages of the residents, high initial prevalence rates of *S. haematobium* in the school children, and excellent cooperation from the inhabitants. From July 1979 to June 1980, RKK and three field assistants lived in the village for about 2 weeks every month to conduct the research. Before epidemiological sampling began, the

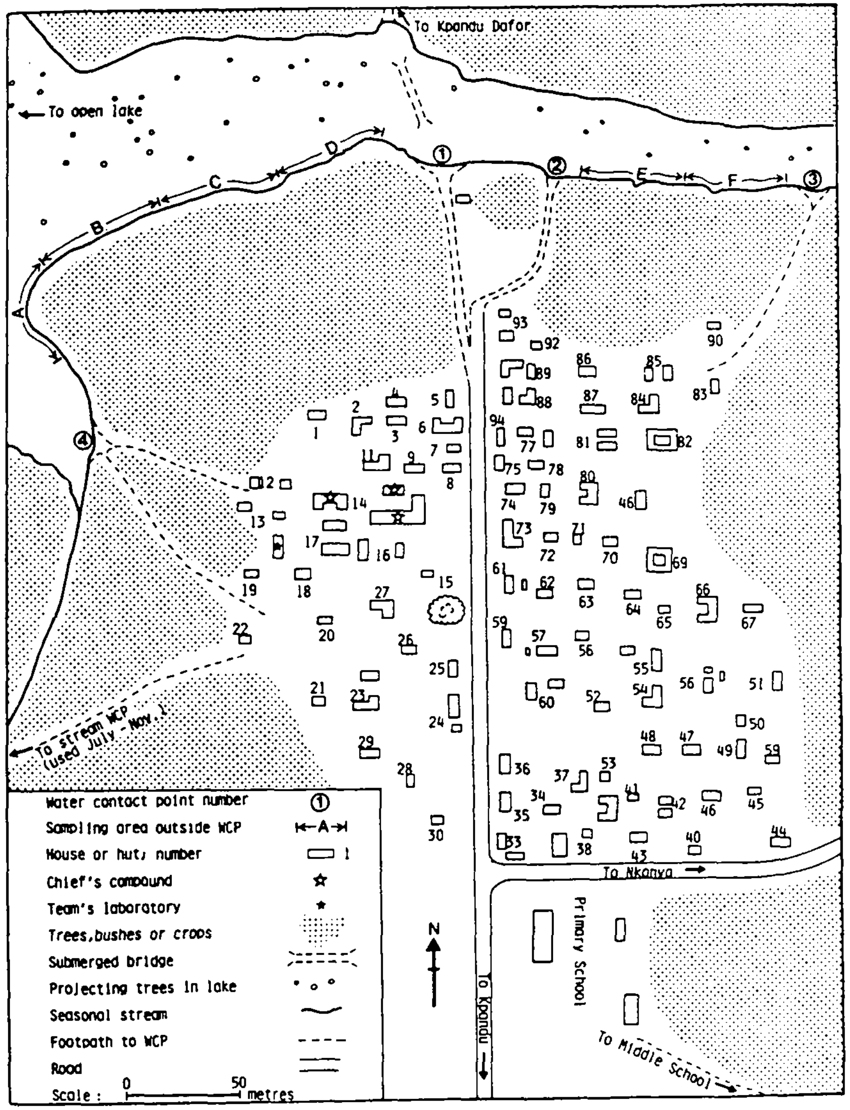

Figure 1. Map of Agbenoxoe showing houses, water contact points and other features.

team built a field laboratory with local participation, mapped all households, conducted a census survey by household, identified and mapped all human water contact points and shoreline areas between them, and intitiated a twice-yearly procedure of household interviews to update the demography and gain information on which water contact points people were using for various activities.

Data collection included: (1) a prevalence and intensity survey of *S. haematobium* in all age groups of people, 1979 and 1980; (2) determination of incidence rates in a cohort of 3 to 14 year-old children; (3) once-a-month snail sampling; (4) additional snail sampling along the entire Agbenoxoe shoreline outside of human WCPs; and (5) frequency and duration of human water contact by all age groups in the most highly infective village transmission point.

At the end of research in May and June 1980, all Agbenoxoe residents were offered a free full course of metrifonate at 10 mg kg^{-1} body weight. Treatment was carried by the Ghana Ministry of Health, which also took over evaluation work in the village. Overall compliance for full treatment was 83.7%.

Materials and methods

COLLECTING AND EXAMINING URINE SAMPLES

Community surveys

Single urine specimens were collected from all age groups of the Agbenoxoe population in June–August 1979, and in May 1980, and examined for the presence and number of *S. haematobium* ova. All samples were collected between 1000 h and 1400 h, from adults and non-school children in individual households, and from pupils at the two schools.

Processing and egg counting followed the method of Peters *et al.* (1976), with the following modifications: Nuclepore filters were of 25 mm diameter and 12 μm pore-size; precision-lined glass graticules were placed over the filters to aid counting. RKK and an assistant performed all of the egg counts at the field laboratory with compound microscopes, normally on the day of collection.

Incidence study

The incidence study was of a cohort of 104 initially negative children. Of these, 71 aged 5 to 14, were screened in August 1979. Three weeks later, the other 35 children, aged 3 and 4, were screened in the same manner. The first follow-up occurred in December 1979; the second and last in June 1980. At each screening, a single urine sample (10 ml to bladder full) was collected from each available subject on each of 3 consecutive days, between 0800 h and 1200 h. The urine was injected by plastic syringe through the same type of Nuclepore filters used in the prevalence-intensity surveys. All processed filters were examined carefully for any *S. haematobium* ova. The calculation of incidence rates followed the method of Farooq and Hairston (1966).

SNAIL SAMPLING

Snail sampling, crushing, and microscopic examination took place once-a-month from September 1978 using the man-time method developed for use in the Volta Lake (Klumpp & Chu 1977). The only modification was that at Agbenoxoe, all sampling took place within a 5 m zone from shore. RKK and three other experienced snail samplers comprised the Agbenoxoe team, and the same men worked together in every site sampled except during January–March 1979 when RKK was away. Apart from the latter period when three men searched for 20 min apiece per site, the standard sampling protocol was for each person to search actively for 15 min per WCP or area to equal 1 man-hour of sampling. *B. rohlfsi* specimens 2.5 mm or greater in shell height were collected.

Earlier testing of this method in the lake revealed that it was sensitive in collecting a high percentage of the total *B. rohlfsi* population in the area being searched (Klumpp 1983).

All water contact points in use at Agbenoxoe were well defined in 1978 and 1979 when the lake was rising or in early drawdown, at which time the entire shoreline was fringed with moderate to dense growths of *Polygonum*, *Paspalum*, *Vossia*, or flooded cassava stalks, and the WCPs were distinct open pockets with the vegetation boundaries. The sites were less well-defined following lake regression in the 'open beach' season each March or April to July, when the shore was relatively free of emergent weed growth. However, even in these periods, water contact was fairly well confined to 15–25 m stretches on each side of the points

where the footpaths leading to the main sites terminated.

The final snail sampling took place in approximate 60 m stretches of the shoreline between WCPs 4 and 3 (designated A–F in Figure 1). This was carried out between January and June 1980, always in the same week that the four main sites were being sampled. Thus, in that 6-month period, it was possible to monitor densities of infected snails in and between the human water contact points along the entire Agbenoxoe shoreline, to obtain more information about the focality of transmission.

WATER CONTACT OBSERVATIONS

The purpose of the study was to record the frequency, duration, and type of water contact of different age groups at WCP 4, and to integrate these data with those from epidemiology and snail sampling. From November 1979 to June 1980, seven observations a month were made, each on a different day of the week. Time of observation was continuous from 0600 h to 1800 h.

Two observers from Agbenoxoe were trained for data collection, and were supervised closely throughout the study. Each knew the names of almost all of the village residents before observations began, and soon became familiar with the names and age groupings of all people using WCP 4 regularly. Their presence did not seem to affect normal water contact behaviour, except perhaps for urination above the water level. Each observer worked for 6 h during the day of data collection, in shifts from 0600 h to 1200 h and 1200 h to 1800 h. Earlier trials with single 12 h shifts by one or two observers proved too tiring. Equipment included a stopwatch, clipboard, filing box with sufficient recording forms, pens, stool, and portable sun shelter of bamboo poles and palm branches, as most of the shoreline was treeless and hot.

WCP 4 was often used by over 100 different people each morning and evening, and it was impossible to keep track of the exact time of each person's entry into the lake. A recording form had to be designed with different intervals which could be ticked-off for each individuals water contact. These were as follows in minutes: 0–1, 1–2, 2–3, 3–4, 4–5 and 5–10. Collecting water was by far the most frequent activity at WCP 4, taking less than 2 min to complete 99% of the time. Other activities were also of short duration, and it was rare for a person to remain continuously in the water for more than 10 min. This was because swimming and playing in the lake was discouraged by the Agbenoxoe chief after a number of villagers had drowned. Moreover, WCP 4 was not used much for bathing or fishing.

When a person approached WCP 4 for entry, the name was written quickly on the recording form along with age grouping: 0–4, 5–9, 10–14, 15–19, 20–29, 30–39, and 40 plus. If age was in doubt, it was filled in later. When water contact took place, any of seven different activity codes could be marked, as appropriate: (1) collecting water; (2) washing (clothes or utensils); (3) wading or playing; (4) bathing; (5) swimming; (6) entering/exiting canoes; and (7) resting legs in water while sitting on a berthed canoe. The time spent in the water for each activity was marked in the appropriate time slot. Repeated entries into the water by an individual were not a problem: there were appropriate cells on the recording form to match time with the corresponding activity. However, new recording forms were used each hour to monitor water contact by time of day. A final cell was available for each individual entry to record obvious urination in to the site.

Because of the great mass of data collected at WCP 4—over 17 000 individual entries—analysis for this report is based on a random selection of two of the seven observation days each month. There was little variation in frequency or duration of water contact by day of week.

Results

PREVALENCE AND INTENSITY SURVEYS

The results of the two surveys for prevalence and egg output of *S. haematobium* are summarized in Figure 2. In 1979, 84.3% of the total population was sampled, and in 1980, 76.7%. In both surveys, participation rates were between 83% and 100% for the 5- to 19-year-old age span, and less than 65% only among 0- to 4-year-olds.

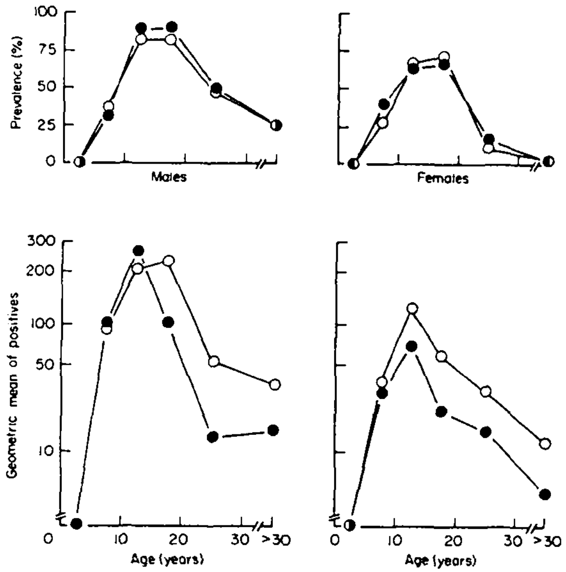

Figure 2. Age- and sex-specific prevalence rates and geometric means of positive egg counts (per single 10 ml sample) in Agbenoxoe, 1979 and 1980. (●) 1979; (○) 1980.

Prevalence results reveal no infections in the 0- to 4-year-old group, a rapid build-up of infection to age 14, the peak between age 15 and 19, and then a rapid decline. There was virtually no difference between the surveys, but in each, prevalence rates were higher in males than in females for almost every age group. Using the Mantel–Haenszel test for age standardization, the overall sex differences were found to be significant ($\chi^2 = 29.1$, $P < 0.001$ in 1979; $\chi^2 = 32.8$, $P < 0.001$ in 1980).

Geometric means of egg output for all infected males and females in 1979 and 1980 showed the expected pattern of a sharp increase from age 5 to about 14 and then a steep decline. In both sexes, levels were higher in 1980, especially among 15- to 19- and 20- to 29-year-olds. The increase in infection intensity in 1980 was probably due to high transmission in the village that year, especially at WCP 4. Within each survey, the geometric means of egg counts were significantly higher in males than females, overall, and among the important 5–9, and 10–14 age groups.

EVIDENCE OF NON-RANDOM DISTRIBUTION OF INFECTION AT AGBENOXOE

Even in this compact village, distribution of infection was clumped. It can be seen in Figure 1 that the main street divided Agbenoxoe into clear east and west sections, partially related to clan differences. After the lake formed, indigenous residents on the west side used site 4 most frequently, except during the 1978–1979 drought, when they used site 1 because the micro-inlet at site 4 dried up. Historically, east side residents used sites 1 and 3 most regularly. The small nomadic Efutu fishing community was scattered throughout the village, but used sites 1 and 2 almost exclusively. Snail sampling in all four Agbenoxoe WCPs between November 1979 and June 1980 showed that the number of infected *B. rohlfsi* at WCP 4 was 3.4 times the number at WCP 3, 4.9 times that at WCP 2, and 9.1 times that at WCP 1.

The 1980 age-specific prevalence rates of all east and west-side inhabitants surveyed are shown in Table 1. Table 2 presents the corresponding geometric means of positives. Both

Table 1. Comparison of 1980 prevalence rates of *S. haematobium* between all people living on the west and east side of Agbenoxoe

Age group	West of road: No. positive/ no. examined	West of road: (%)	East of road: No. positive/ no. examined	East of road: (%)	χ^2* between overall prevalence rates
0–4	0/19	0	0/27	0	
5–9	26/56	46.4	22/91	24.2	
10–14	41/45	91.1	62/92	67.4	
15–19	33/38	86.8	79/107	73.8	
20–29	8/31	25.8	21/69	30.4	
30–39	5/25	20.0	11/49	22.4	
40–49	5/22	22.7	5/48	10.4	
50–59	1/14	7.1	1/30	3.3	
≥60	3/20	15.0	5/38	13.2	
All ages	122/270	45.2	206/551	37.4	12.36 ($P < 0.001$)

*Mantel-Haenszel test.

Table 2. Comparison of geometric means of *S. haematobium* egg counts (per 10 ml) between all infected people living on the west and east side of Agbenoxoe

Age group	West of road	East of road
5–9	95	71
10–14	233	156
15–19	187	129
20–29	76	60
≥30	46	32
all ages	140	102

tables high-light the much higher levels of infection among almost all age groups of the west-side residents.

INCIDENCE STUDY

The main results are shown in Table 3. Only one of the 3- to 4-year-olds converted to positive, in the first follow-up period 92 days after initial screening. This was an Efutu boy who spent much time at WCP 1 with his fisherman father. Among the ages 5–9, there was one conversion to positive after the first 114 days (low transmission season) and nine others after a further 198 days (high transmission season). Of the 10- to 14-year-olds, three converted in the low transmission period and three became positive in the high transmission season. Since other observations in this report will show that water contact was in general extremely low among children less than 5 years old, the best comparison of seasonal incidence rates at Agbenoxoe is among the 5- to 14-year-olds. In this group, the annual incidence rate was 17.9% between August and December 1979, and 36.1% from December to June 1980 (assuming a 2 months' incubation period of worm maturation).

Among 5- to 14-year-olds, 10 of the 25 males in the study converted in either December or June, giving a total annual incidence rate of 46.0%. In the same period, six out of 27 females converted, an annual incidence rate of 19.2%.

Of the 17 children who converted to positive in either December or June, 59% were detected on the first day of examination, 24% on the second day, and 17% on the third day. Six of these had a maximum of 1–5 eggs per 10 ml of urine per examination; two, 6–15 eggs; two, 15–90 eggs; and two, 104–172 eggs. Six children who converted showed eggs on all 3 days; five on 2 days; and three on 1 day. The remaining three positives provided urine on 2 of the 3 days, and showed eggs on 1 day.

Two of the five children that were positive in December were still positive in June; two reverted to negative; and one was absent on all 3

Table 3. Details of children in the cohort converting to positive, and overall incidence rates according to season

Age (years)	Starting number in cohort	Number becoming positive between each of the two periods of examination over total number who were negative at the start of each period (incidence rates in per cent)	
	11/9/1979	September–December (92 days)	December–June (189 days)
3	17	0/13	0/10
4	16	1/14	0/13
3–4	33	(13.9%)	(0%)
	20/8/1979	August–December (114 days)	December–June (189 days)
5	14	1/12	1/10
6	11	0/11	3/10
7	14	0/14	1/12
8–9	10	0/9	4/7
5–9	49	(6.9%)	(39.8%)
10–11	11	1/11	2/10
12–14	11	2/11	1/9
10–14	22	(37.5%)	(28.2%)
5–14	71	(17.9%)	(36.1%)

days. Both of the children who reverted to negative had less than 5 eggs per 10 ml samples in December, showing eggs on only 1 day each.

SNAIL SAMPLING

Results of 21 months of snail sampling in WCPs 1 and 2 showed that transmission in the sites was relatively low and distinctly seasonal. Between September 1978 and June 1979, 17 infected snails (mature *S. haematobium* cercariae) were found in WCP 1, and 11 in WCP 2, giving infection rates of 4.5% and 12.5%. In the same period the second year, seven and 13 infected snails were collected in the respective sites (2.9% and 5.9%). Only one infected snail was found in each site in the flood season of July–October in the 2 years. For seasonality of transmission, 70% of all infected snails came in November to January (early lake drawdown), 24% in February to June (mid to late drawdown), and 6% during the flood period.

After the 5.1 m rise of the lake between July and October 1979 when sites 3 and 4 filled up, snail populations built up slowly in all 4 WCPs, but then rose rapidly to relatively high levels from January to March. Table 4 lists the snail sampling results over 8 months, beginning in November 1979, when the four sites were sampled together. It can be seen that 64 and 19 infected snails came from WCPs 4 and 3 respectively (62% and 18% of total infected snails found in all four sites). Thus, there were much higher transmission potentials in the village in 1980 than in 1979. In 1980, the high transmission season was extended to April. The reason for the high numbers of snails in WCP 4 was that the aquatic weed, *Ceratophyllum demersum*, grew in thick patches there from December to April. The importance of this weed in promoting transmission of *S. haematobium* in the Volta lake is well documented (Klumpp & Chu 1977; 1980). Except for light scattered patches, the weed was absent from the other three sites and all other shoreline areas in the village. Most emergent vegetation grew around sites 2 and 3. At site 1, there was considerable pollution and turbidity caused by extensive fish cleaning and canoe traffic, which may account for the relatively low numbers of total and infected snails found there.

In addition to sampling in the four main WCPs in the village, the entire Agbenoxoe

Table 4. Number of infected *B. rohlfsi* over total number of all *B. rohlfsi* collected in WCPs 1, 2, 3 and 4 November 1979 to June 1980

WCP	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Per cent of infected snails by WCP
1	0/6	0/22	5/58	1/80	0/50	0/11	0/6	1/18	7/251	6.8
2	5/5	0/6	2/44	0/53	0/42	2/37	0/14	4/21	13/222	12.6
3	0/1	4/24	10/86	2/215	3/83	0/10	0	0/8	19/427	18.4
4	0/3	5/48	14/98	11/198	23/123	7/48	1/16	3/17	64/551	62.1

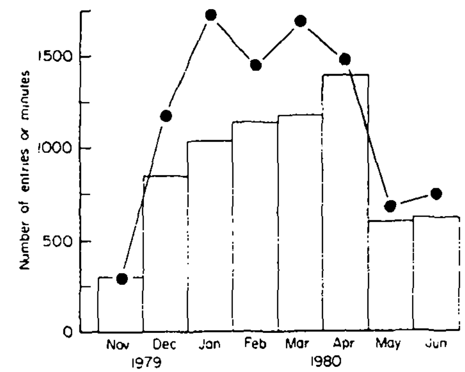

Figure 3. Degree of water contact by month. (□) Total number of entries into lake; (●) total number of minutes in water.

shoreline was sampled for snails and infected specimens during January to June 1980. The areas outside of the main water contact points were designated areas A–F (Figure 1). The data show that the total mean number of all *B. rohlfsi* collected per metre of shoreline sampled was 1.58 in the four main water contact points and 1.21 in the areas between them. Of infected snails, 89 came from within the recognized boundaries of the four WCPs and 56 from the six other shoreline areas. When standardized for numbers per metre of shoreline sampled, the 'densities' of infected snails inside and outside of the WCPs were 0.105 and 0.026 respectively, or four times higher where human water contact was concentrated. The only area outside of a WCP where infected snails were significant was Area A, close to WCP 4. Area A accounted for 26 of the 56 infected snails from areas A–F. These snails were found so close to the recognized side boundary of WCP 4 that they could have been part of the site. The mean density of infected snails per metre of shoreline in areas B–F was eight times lower than in WCPs 1–4.

WATER CONTACT OBSERVATIONS

Variation in water contact each month

There was a clear seasonal trend in the frequency and duration of water contact at WCP 4 (Figure 3). The total number of entries increased each month as the dry season progressed (November to April), and decreased sharply when the main rainy season began (May). The curve for the total time spent in the

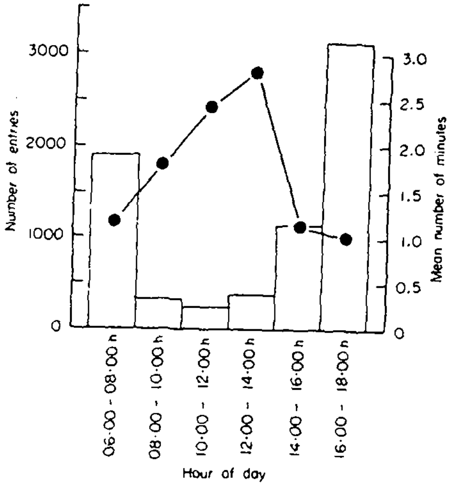

Figure 4. Degree of water contact by hour of day. (□) Total number of entries into lake; (●) total number of minutes in water per entry.

water showed a similar rise and fall, but had an early peak in January, the main transmission month, a small drop-off in February, and a second peak in March.

During the rainy season, about two-thirds of the families frequently collected rain water in 200 litre drums from roof-top drainage. Sixty-five per cent of all main family buildings had aluminium alloy roofs, and one to three drums per house. When the drums were placed below real or makeshift gutters at times of heavy down-pours, each filled up in a matter of minutes.

Variation in water contact by time of day

Results of total frequency and mean duration of water contact for all people using WCP 4 during the study are analysed by hour of day, Figure 4. Greatest frequency of contact occurred in the 0600 to 0800 h and 1600 to 1800 h periods, involving almost entirely children collecting water in buckets for later use in their households. During these peaks, individuals commonly entered the site several times in succession. The curve for mean time spent in the water per entry was inversely proportional to the frequency curve, and mean duration ranged from about 1 min in the morning and evening peaks to 2.75 min between 12 h and 14 h. The midday period coincided with the time of maximum shedding of *S. haematobium* cercariae by *B. rohlfsi* (Chu & Vanderburg 1976).

Degree of water contact by age, sex, and activity

For analysis, all results were standardized by dividing each age- and sex-specific total of frequency and duration of water contact by a fixed 'population at risk'. This denominator represented all of the people at Agbenoxoe who, from household interviews, claimed to use WCP 4 most frequently or exclusively. Small children from these households were also included. These data were fairly 'clean' because WCP 4 was used almost exclusively by indigenous residents on the west side of the village street, and by people in only 13 households east of the village street. The site was seldom used by strangers and the Efutu fisherfolk in the village. The number of males and females at risk was 252 and 210 respectively. By age, the male/female breakdowns were as follows: 0–4, 39/38; 5–9, 39/36; 10–14, 33/33; 15–19, 25/37; 20–29, 41/18; 30–39, 32/9; 40–49, 13/27; and 50+ 30/22.

Figure 5 shows the total frequency of water contact by age and sex per population at risk. For each age group, females had considerably

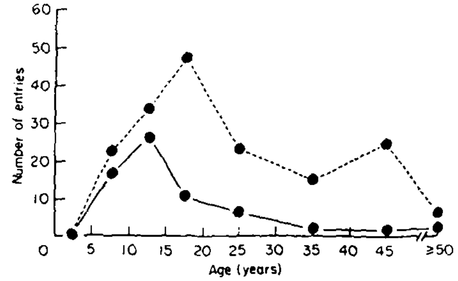

Figure 5. Frequency of water contact (total number of entries into lake/population at risk). (——) Males; (- - - -) females.

more entries into the lake than males, the overall female to male means being 20.3 to 9.9. The greatest frequency of contact for females was in the 15–19-year-old group, following a steady buildup from age 5. There was also a secondary peak among women aged 40–49. Most frequent contact for males was for ages 10–14. After that, lake entry dropped steadily. There were only six recorded entries into WCP 4 by children under age 5.

Collecting water accounted for 97.6% of the 5122 female entries and 81.92% of 2079 male entries. The only other activity of significance for females was washing (101 total entries, or 2.0%). For males, wading or playing in the water accounted for 259 entries (12.4%), and washing clothes 61 entries (2.9%)

The total duration of water contact by age, sex and activity per unit population at risk is presented in Figure 6. The histograms illustrate a number of points. First, the shape of the curve for females is similar to the female prevalence curves in the 1979 and 1980 village surveys: a rise to age 15–19, a rapid drop-off for ages 20–29, and then a slower, more erratic reduction after age 30. The shape for males mirrors the geometric means of infected males in the village: a rapid buildup to age 10–14, and then a very rapid decline to age 30 before levelling off. Second, unlike water contact frequency, there was little overall difference between females and males in duration of contact: 20.4 min and 19.0 min, respectively. This was because males of all age groups averaged between 1.5 min and 2.5 min in the lake per entry compared with an average near 1.0 min for all age groups of females. For the important 5–9 and 10–14 age groups, males spent more time in the water per unit population at risk. Third, while collecting water was the most time-consuming activity for all age groups of females, wading or playing in the water was most time-consuming for males. The mean duration of collecting water per entry was 0.84 min, with little variation by age or sex. The mean duration for wading or playing per entry for males was close to 7.0 min for all ages. There were only 19 total entries for 5- to 14-year-old females wading or playing. Fourth, washing of clothes or utensils was primarily a female activity, and most frequent among girls ages 15 to 19. Mean duration per contact of this activity was 7.1 min for females and 7.5 min for males.

Almost all people at Agbenoxoe used the same method of collecting lake water at the shore. They would wade into the WCP to about mid-thigh depth, carrying an open metal water bucket. Small children also carried a calabash cup. Adults usually filled the bucket directly and placed it on their heads before starting back to their compounds. The children would squat down, with the bucket on their heads, and fill it with the cup. Over 90% of all water collection occurred between 0600 to 0800 h and 1600 to 1800 h. During the morning and evening peaks the water in site 4 was crowded with people and constantly agitated. Thus, the probability of infection of *S. haematobium* cercariae at these times was probably low regardless of season.

By contrast, 74% of recorded wading and playing in the water took place between 1100 h and 1600 h when cercarial densities were at

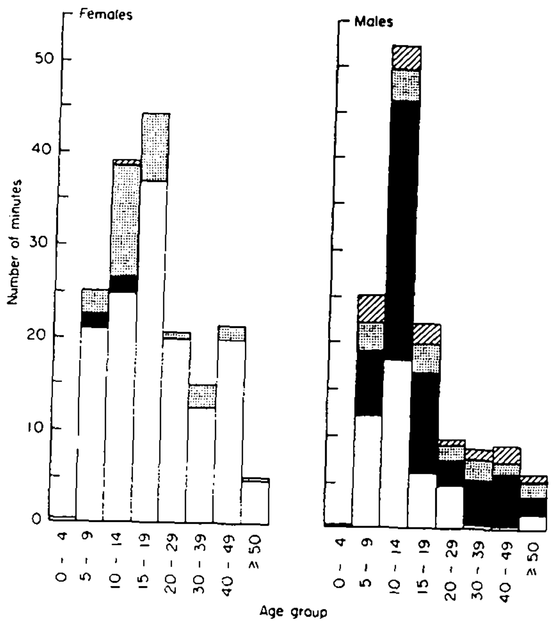

Figure 6. Duration of water contact per person at risk, according to activity. (□) Collecting water; (■) wading or playing; (▥) washing; (▨) other.

their peak. Playing was almost entirely an activity of 8- to 16-year-old boys, while wading was primarily to prepare, inspect and retrieve small fish nets strung in or near WCP 4. In terms of body exposure in the water (thigh to chest level), and most common duration per entry (5 to 10 min), both activities were about the same.

Washing accounted for 14% and 12% of total female and male time in site 4. Females washed household clothes and kitchen utensils while males generally washed their own clothes. Over 90% of all washing was done on shore (in aluminium basins). Time spent in the water for this activity amounted to a series of 1- to 2-min trips to collect water and rinse the soapy items. The main cleaning agent was 'Omo' detergent, along with commercial and locally made bar soap. Approximately 65% of all washing took place between 0800 h and 1100 h when cercarial densities were low, or just building up. The activity was most frequent on Saturdays.

Any effect of the detergent on snails and cercariae in the site could not be ascertained, but was probably negligible because of the high dilution in the lake.

Because few canoes were kept at WCP 4, little canoe-related activity was observed. Bathing and swimming were also uncommon in the site. Few indigenous residents bathed anywhere along the shore, preferring to use water in buckets in bathing stalls at their houses. Almost all bathing in the lake was done in sites 1 and 2, mainly by Efutu males at sunrise and sunset.

Comparison of duration of water contact and geometric means of egg counts of people using site 4

In Figure 7, the geometric means of egg counts ($\log_{10}$ (eggs + 1) per 10 ml) are plotted for the entire population at risk who used or would use WCP 4 as their main point of water contact. Superimposed on this is the water-contact duration curve recorded in the study. For males, the curves show close agreement. Thus,

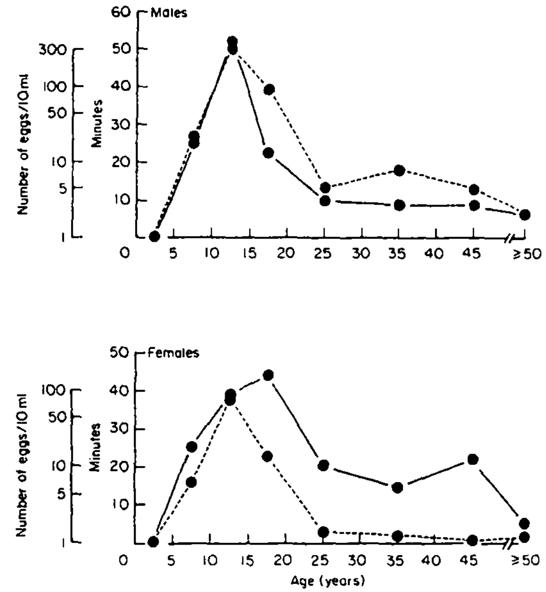

Figure 7. Comparison of age-specific curves of geometric mean of egg counts + 1 per 10 ml among Agbenoxoe residents whose main point of water contact was WCP 4, and mean duration of water contact in WCP 4 by this population. (——) Total minutes in water/population at risk; (– – – –) geometric mean of eggs + 1 ($\log_{10}$ scale).

the acquisition of infection among 5- to 14-year-old boys was proportional to the time they spent in the water. Similarly, the decline in egg output dropped off at the same rate as water contact. Among females, infection and water contact increased at the same rate to age 14, but thereafter, egg output dropped much faster than time spent in the water. The results seem to indicate that along with acquired immunity after age 14, the primary activities of adult females—collecting water and washing—were relatively low risk activities for getting infected. Both were of short duration per contact and occurred mainly when cercarial densities were low. The results for males imply that immunity and a significant reduction in total water contact after age 14 were both important for the reducing egg counts.

Urination in WCP 4

During the 1972 observation hours at site 4, only four different people were seen urinating into the water. One was a boy of 14 who excreted 6964 *S. haematobium* ova per 10 ml urine sample in the 1980 survey. Another was a boy of 8 who produced 320 eggs in the 1980. The final two were 5- to 9-year-old girls who were both negative in 1979 and 1980. Observer presence had an obvious effect on reducing conspicuous urination, and it must be assumed that urination both above and below water was significant in the site.

Discussion

The prevalence rates for all Agbenoxoe residents surveyed in 1979 and 1980 were 38.4% and 40.0%, respectively. These were lower than the overall rates in all but two of 59 Volta lake villages surveyed since 1973 where all age groups could be sampled (UNDP/WHO project-0658 report 1979; Scott *et al.* 1982). The extremely low levels of water contact for young Agbenoxoe children and all adults are the primary reason for the lower rates. Snail populations and numbers of infected snails in the village were comparable to Volta lake fishing villages with overall *S. haematobium* prevalence rates exceeding 70%. Among ages 5 to 19, prevalence rate and geometric mean of positive egg counts was higher at Agbenoxoe than in 14 out of 29 other lakeside villages we surveyed between 1979 and 1980, and higher than in four of five villages with a population of over 1000. Almost all of the large villages around the lake were primarily farming and trading centres, and, as at Agbenoxoe, there was probably much more concentration of water contact and infection in the 5 to 19 age group than would be seen at any fishing village.

Precise determination of age and the significant exposure to infection of Agbenoxoe 5- to 19-year-olds, enabled us to apply a single, two-stage catalytic model to yearly groupings of this age span (1980 prevalence) to predict the rates at which they acquired and lost their infections. For this, the methods of Muench (1959) and Hairston (1965) were followed. The predicted annual incidence rate came to 19.7%, and the predicted natural loss of infection ('outcidence') per year was 2.3%. The annual incidence rate recorded directly from the longitudinal study of all 5- to 14- year-olds came to 30.2%. The two sets of incidence rates correspond well considering the following: (1) sensitivity in detecting positives was greater in the cohort study; (2) true incidence rates probably declined after age 15: and (3) transmission was especially heavy in 1980.

The incidence study at Agbenoxoe confirmed the findings on seasonality of transmission from snail sampling in the village, which in turn, agreed with all earlier long-term snail sampling results in the Volta lake (Klumpp & Chu 1977; 1980): the main transmission season always occurs between November or December and March or April, and transmission is always low and sporadic during the flood season of August to October. An earlier incidence study on *S. haematobium* in Volta lake fishing villages had been conducted by Scott *et al.* (1982). It was somewhat flawed by incorrect calculation of incidence, high absenteeism, inter-village movement, and imprecise determination of age. Nevertheless, the raw data agree closely with the Agbenoxoe incidence results on seasonal variation of infection, and show that despite quantitative differences in incidence between location and time, the basic, seasonal pattern of infection in the lake has remained stable.

Snail sampling along the entire Agbenoxoe shoreline answered a question never seriously addressed in studies at the Volta lake or at any other man-made lake: whether or not transmission potentials are significant outside of the main human water contact points. The present results indicate that in the 'open beach' season of January to June, when human movement along the receding shore was largely unobstructed by vegetation, densities of infected snails per metre of shoreline were four times higher in the recognized water contact points than outside them. In this period, however, nothing more than sporadic water contact was observed in any littoral-zone area outside the four main WCPs: boys playing, men and boys setting fish nets, people growing vegetables along the open shore, and Efutu people bathing. From September to December 1979, a moderate zone of *Paspalum*, mixed with flooded cassava stalks and clumps of *Vossia* formed a fairly solid barrier outside of WCPs 1 and 2, which were then open pockets in the weed zone. This severely restricted human movement in areas A–F during that period, and further concentrated water contact in the main sites. When WCPs 3 and 4 came into regular use again in October and November, they too were pockets within the weed zone.

The findings on human water contact at Agbenoxoe differ in many respects from those of the study by Dalton and Pole (1976) at the small, semi-nomadic fishing village of Fatem, the only other water contact study previously conducted at the Volta lake. At Fatem, frequency and duration of water contact showed no seasonal variation, were significant among 0- to 4-year-olds and adults, highest for 5- to 9-year-olds, and greater for males than for females at all ages. There was also much more swimming, playing, and canoe-related activity.

Despite differences in water contact patterns between Agbenoxoe and Fatem, there were similarities. At Fatem, collecting water and washing accounted for the greatest overall

percentage of water contact frequency, but for a much lower percentage of overall duration. Females engaged in these activities more frequently than males. For males the greatest duration of contact per entry was for swimming, playing, and working on fish nets around canoes. The geometric mean of positive egg counts at Fatem also correlated closely with mean duration of water contact for males and, as at Agbenoxoe, female egg output decreased faster with age than with their reduction in water contact. Their findings led Dalton and Pole (1976) to suggest the installation of piped water at Volta lake villages to reduce the time spent in the lake for activities such as washing and fetching water, thereby effectively controlling the transmission of schistosomiasis. However, evaluation of bore wells in the UNDP/WHO Project showed that they lasted only a few years (Klumpp 1983); and at Agbenoxoe, playing and wading in the lake—not fetching water or washing—were the activities with the greatest risk of infection. Therefore, safe and durable water supplies at the Volta lake may have more value in preventing waterborne infections other than *S. haematobium*.

Long-term focal mollusciciding would not be necessary either at Agbenoxoe or in other Volta lake villages with low to moderate overall transmission. Unpublished evaluation of the UNDP/WHO Volta-lake project between 1979 and 1981 showed that chemotherapy alone could control *S. haematobium* in such villages once focal mollusciciding was stopped.

The strategy for chemotherapy in every village in the UNDP/WHO project was to treat all infected people with metrifonate. While effective, it required considerable manpower and time to examine and treat each infected individual. Because of the high concentration of infection and the transmission potential of the 5- to 19-year-old population at Agbenoxoe, and presumably, other large farming villages like it around the lake, it would seem that at the primary health care level, the single most cost-effective way, initially, to control morbidity and transmission in such a village would be once-a-year drug treatment of the 5- to 19-year-old children only, using either metrifonate or, if reduced in price, praziquantel. First, treatment should not require extensive examination of urine samples, and should take place in primary and middle schools, which usually have enrollments of 60–80% of the 5- to 19-year-olds in rural areas. Treatment of all targeted children could be undertaken if a quick test of positivity in a sensitive indicator sample such as 10 to 14-year-old males was above 60% or so. A good time to treat school children for the infection in Ghana is in October, at the beginning of the dry season, when the peak malaria season is over and just before the start of the main transmission season for schistosomiasis. In Ghana, facilities are lacking for extensive urine testing, but metrifonate is available in the country on a large scale, and a primary health care infrastructure is developing for expanded treatment in rural areas.

To show the importance for transmission of the parasite among the ages 5 to 19 at Agbenoxoe, and index of contamination potential was constructed. It follows similar indices developed in other schistosomiasis projects, in Leyte (Pesigan *et al.* 1958), Egypt (Farooq & Samaan 1967), and St Lucia (Jordan *et al.* 1980). Each included at least three basic age-specific parameters: population structure, prevalence rate, and arithmetic mean of positive egg counts. The product of these three parameters converted into relative percentages to indicate the importance of each group for spreading eggs in the water. For the Agbenoxoe results, a new parameter was added that makes sense for any index of contamination potential: total duration of water contact for each age group. The assumption is that the longer people spend in the water, the more chance they have of contamination. The parameter does not take into account differences in water contact behaviour, activity, and other factors which may influence urination in the water, but, while crude, should improve the sensitivity of the overall index.

The Agbenoxoe data in Table 5 referred to the population at risk whose main point of water contact in the village year after year had been WCP 4 (except for the 1978–1979 drought). This represented 472 people, or 44.1%, of the total population in 1980. The results show that 95.8% of the contamination potential of this

Table 5. Index of transmission potential for people using high transmission WCP at Agbenoxoe, November 1979 to June 1980, including the parameter of total minutes of water contact

Age group	Population structure (1)	Prevalence rate (2)	Arithmetic mean of positive counts (10 ml) (3)	Total minutes in water (4)	Relative index of transmission potential (%) (5)*
0–4	0.108	0.00	0	6	0.0
5–9	0.173	0.39	634	1886	16.0
10–14	0.142	0.88	591	3006	43.8
15–19	0.157	0.85	707	1926	36.0
20–29	0.147	0.35	341	1020	3.5
30–39	0.087	0.19	96	557	0.2
40–49	0.081	0.21	331	434	0.5
≥50	0.106	0.11	72	293	0.0

*Calculated as follows: $[(1) \times (2) \times (3) \times (4)/\Sigma[(1) \times (2) \times (3) \times (4)]] \times 100$.

population came from 5- to 19-year-olds, with ages 10–14 being the most important (43.8%). Without the water contact data in the index, the contamination potential from ages 5 to 19 was 89.5%, and 15- to 19-year-olds were the largest contributors (39.9%).

It was possible to construct the same type of index for the fishing village of Fatem in the Volta lake, from WHO computer printouts of the 1974 precontrol prevalence data, and from 1975–1976 water contact data of Dalton and Pole (1976). Even in this village, where water contact by small children and adults was far greater than at Agbenoxoe, 90.7% of the contamination potential was still caused by ages 5 to 19.

In the schistosomiasis research and control project in Machakos, Kenya, the strategy of treating only school children as the most cost-effective way to achieve community control of *S. mansoni* is being strictly evaluated against two other community-based treatment strategies: treating everyone with egg densities greater than 100 EPG, and treating everyone found positive with the infection (A. E. Butterworth, personal communication). We hope that the results of the present study in Ghana will lead to further evaluation of treating only school children for *S. haematobium*, which may be the simplest and cheapest way to achieve morbidity and transmission control at the community level.

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