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Seasonal patterns in the transmission of *Schistosoma haematobium* in Rhodesia, and its control by winter application of molluscicide

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Summary

Surveys of snails occurring at water contact points used by rural people in Rhodesia show that transmission of *Schistosoma haematobium* is very high during the spring and early summer seasons. Although infected snails are found in all seasons, fewest occur in winter and during the heavy rains. It is suggested that the bionomics of this parasite depends on pre-rain transmission because destruction of infected snails during winter reduces the reservoir of infection in the area and also the level of parasitaemia in local schoolchildren.

Introduction

A battery of recent research has demonstrated that the transmission of schistosomiasis is a complex and efficient biological process. WEBER *et al.* (1967) showed that most *Schistosoma haematobium* eggs emerge from an infected person during the period 10.00 to 14.00 hours, the time of the day when micturition into water is most likely to occur. Host location by these miracidia involves complex behaviour patterns as the organisms orientate to external stimuli such as light and temperature (TAKAHASHI *et al.*, 1961; SHIFF, 1974; MASON & FRIPP, 1977) and chemical products of the snail hosts (CHERNIN, 1970; SHIFF & KRIEL, 1970; MACINNIS *et al.*, 1973) to improve the chances of detecting and infecting an appropriate snail. The effect of temperature on the development and production of cercariae is well known (GORDON *et al.*, 1934), but more recently PITCHFORD & VISSER (1969) have shown a pronounced diurnal and seasonal pattern of emergence of cercariae of both *S. haematobium* and *S. mansoni*, while SHIFF *et al.* (1975) have demonstrated, in snails kept in outdoor aquaria, that in neither of these species are cercaria shed during winter (July to August) but that there is a rapid termination of sporocyst inactivity and an almost synchronous appearance of cercariae brought about by the warming weather in September.

This suggests the presence of a heavy cercarial load in natural water systems during spring and early summer, ending perhaps with the flushing effects due to the normal seasonal rains which fall from November to March. After winter, water bodies contract and human contact is concentrated at residual ponds. Thus conditions favour heavy transmission of the parasites. Certainly, at this time, there is evidence of exposure leading to heavy infections, with a high prevalence of the Katayama syndrome in people at risk (CLARKE *et al.*, 1970). The evidence suggests that this season is important in the bionomics of the schistosome.

Here we report an investigation into the seasonal fluctuations in the numbers of infected snails and cercarial load in contact points in a rural area where *S. haematobium* and *S. mattheei* are prevalent, but where *S. mansoni* infections are rare. Furthermore, to determine the importance of the early summer transmission period to the bionomics of the parasite, one blanket treatment of water bodies with molluscicide was carried out each year in part of the area during winter. At this time, although transmission would be low, it was postulated that the reservoir of cercarial production would be accumulating in the snail population. It was further postulated that the systematic removal of this reservoir should lead to a decline in transmission in the area, and a reduction of parasitaemia in the local population.

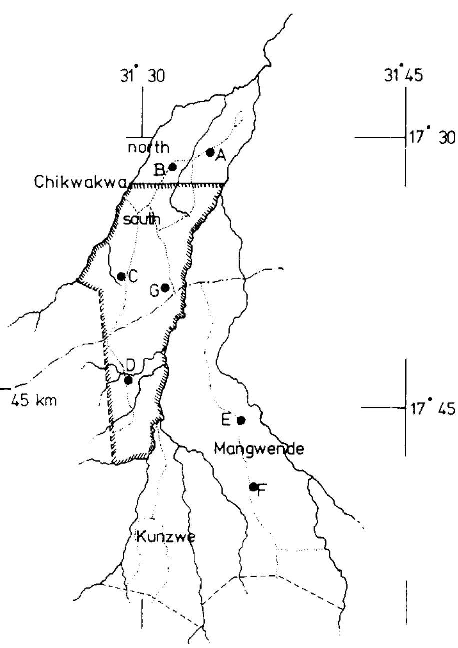

Fig. 1. Map of experimental area showing localities of schools, major rivers (solid lines), roads (dotted lines) and sprayed area (hatched).

Materials and Methods

1. *Locality*

The work was carried out in parts of three contiguous Tribal Trust Lands east of Salisbury (Fig. 1); Chikwakwa, Southern Mangwende and Kunzwe (31°30′E : 17°45′S). The extent of the areas are as follows:

Southern Chikwaka (sprayed area)	146,4 km²
North Chikwakwa (unsprayed)	54,7 km²
South Mangwende (unsprayed)	224,8 km²
Kunzwe (unsprayed)	56,2 km²

The area sprayed with molluscicide and designated as South Chikwakwa is indicated in Fig. 1.

2. *Survey Methods* (Snail)

Before the commencement of the work, all river systems and waterways were examined by one of us (WCC) to detect and map human contact points and to look there for snails. A contact point was broadly defined as a stretch of water body which may or may not carry water throughout the year and where there is obvious evidence of human contact. This contact may be recreational, domestic or agricultural. For the purposes of survey, each contact point was examined by taking 50 scoops both upstream and downstream of the region of contact. The standard scoop has been described (SHIFF & CLARKE, 1967) and in all instances these were used by the same personnel. The number and species of host snails collected was recorded and a maximum of 20 individuals of each species was placed singly in plastic tubes and left in sunlight for approximately one hour. The tubes were then examined and infected snails were removed for transmission to the laboratory and identification of schistosome infection. A few drops of 4% formalin were then added to the tube to fix the cercariae which were also counted in the laboratory. Whereever possible, all snails were returned to their localities after examination. Surveys were carried out at approximately two-month intervals. When more than 20 snails were collected an estimate of the total number of infected snails in the sample was made from the proportion of the sample found to be infected.

Parasitological Surveys

Urine specimen surveys were undertaken from six primary schools in the experimental area at various times between August 1973, the year before the experiment started, and May 1978 when it was terminated. The classes are arranged primarily by age into seven grades. For the purpose of examination 20 to 30 children from each class were provided with screw-capped bottles and asked to produce a urine specimen. This was done between 1000 and 1300 hours. The specimens were returned to the laboratory for examination after sedimentation.

3. *Identication of cercariae*

During the progress of this work it became possible to identify cercariae shed from *Bulinus* (*Physopsis*) *globosus* snails using a system of starch gel electrophoresis (MAHON & SHIFF, 1978). Not all snails brought from the field survived for the infection to be identified, but from September 1975 some infections from each locality were identified for each survey.

4. *Use of molluscicide*

Molluscicide was applied to the entire natural water system in the treated area once each year, during July. In all, 14·5 km of minor streams up to approximately 5m width, and 3·69 km of major

Table I—Showing costs of blanket treatment of all waterways in South Chikwakwa, 146·4 km², using Bayluscide. Costs in U.S. dollars

	1976	1977
Transport	504	650
Supervision	400	315
Spraymen	(8)784	(4)410
Allowances	211	270
Molluscicide	1,439	1,451
Total	3,338	3,096

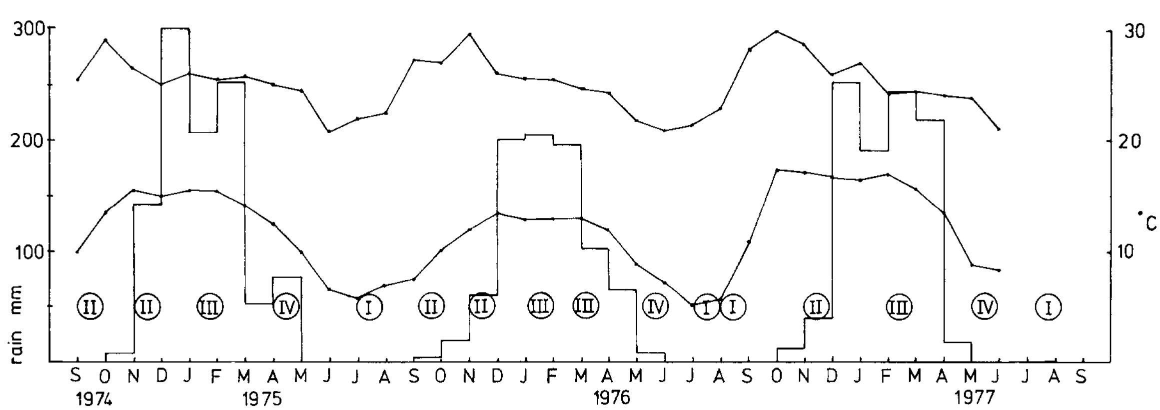

Fig. 2. Graph showing pattern of rainfall and minimum and maximum air temperature recorded in the experimental area. The circles indicate the sample time and the enclosed Roman numerals indicate the classification of that as seasonal periods I to IV (see text).

rivers from 5m to 20m wide were treated. Bayluscide[R] was used for all work and applied in a water suspension of 30 g in 10 litres using hand operated pressure sprayers. Teams of spraymen, working under close supervision, worked along river banks and to the best of their ability blanket-sprayed all the water bodies. Effective coverage rather than economy of chemical was stressed as it was necessary to effect a high degree of snail control. The water system was treated in two to three weeks. The amounts of chemical used were as follows: 1973, 125 kg; 1974, 162 kg; 1975, 113 kg; 1976, 97 kg; 1977, 75 kg.

The decline of the amount used is due to increased familiarity with the area by staff and hence less wastage. In 1974 late rains left rivers swollen and costly to treat.

Costs have escalated in recent years and, for interest, are expressed in Table I, but only for 1976 and 1977.

5. *Seasonal periods*

In any longitudinal field study it is difficult to compare the results of surveys done on similar dates year after year, as seasonal effects do not always follow the calendar. Fig. 2 shows the mean monthly screen minimum and maximum temperatures and the monthly rainfall measured in the area for the duration of the experimental period, from September 1974 until October 1977. Sampling periods are indicated. In order to obviate the problems mentioned above, the seasons have been categorized as follows:

I Cold dry: mean minimum temperature generally below 10°C. Rainfall negligible, usually less than 20 mm.

II Hot period: before and including the early rains. Period of peak seasonal temperature, mean maximum over 25°C, mean minimum 10 to 15°C. Rainfall sufficient to fill ponds, but no flooding. Rainfall approximately 50 mm per month.

III Rainy season: mean maximum fluctuates around 25°C. Rainfall approximately 200 mm per month. Rivers flowing.

IV Warm, post rains: mean maximum temperature between 20 and 25°C. Rainfall less than 100mm per month. No flooding of watercourses.

Each year has been divided according to these seasonal categories and all samplings done within each period for the entire experiment have been combined and averaged. Thus the results expressed in the following sections are the mean of four samplings during period I, six samplings during period II, four in period III and three in period IV.

Results

1. *Snails*

Fig. 3 shows the mean number of *Bulinus globosus* collected per contact point in the sprayed

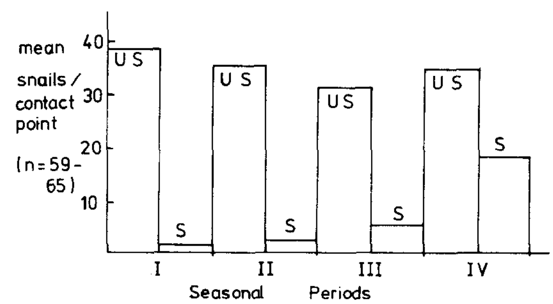

Fig. 3. Showing the mean number of *B. globosus* snails collected per contact point, consolidated into seasonal periods, from the unsprayed area (59 to 65 contact points, marked "US") and the sprayed area (20 to 24 contact points, marked "S").

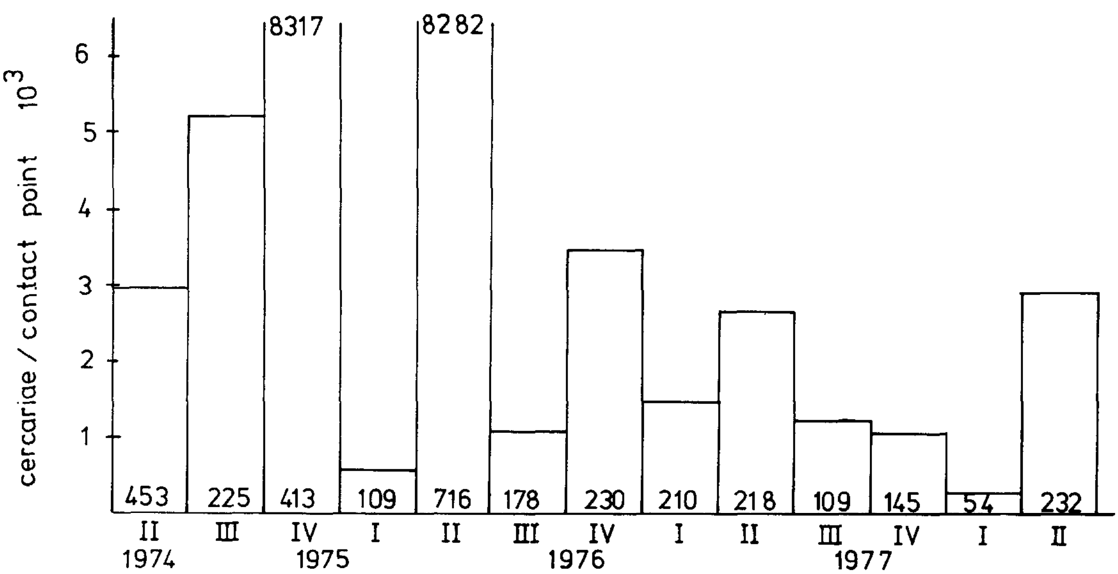

Fig. 4. Unsprayed area. Showing the mean number of cercariae per contact point counted in sequential sampling throughout the experimental period. Numbers along the base line indicate the total infected *B. globosus* collected.

and unsprayed areas. Between 59 and 65 contact points were examined for each survey, depending on the season. As a result of molluscicide treatment each July, the snail population became very low during periods I and II taking almost 12 months to recover. Data from the sprayed area are marked "S" in Fig. 3.

2. *Cercarial density*

Throughout the experiment large numbers of *Biomphalaria pfeifferi* and *Bulinus globosus* were examined for patent infection, but in no instance was a *B. pfeifferi* found to be shedding *S. mansoni* cercariae. *Bulinus globosus* was found to shed both *S. haematobium* and *S. mattheei*. Initially no attempt was made to distinguish between these cercariae but, after September 1975, the technique of MAHON & SHIFF (1978) enabled cercariae to be identified. Thus it was possible to assess the proportion of snails shedding either of these parasites during the various sampling periods.

Cercarial counts from the untreated area (Fig. 4) vary seasonally, with low numbers occurring during period I and high numbers generally during periods II and IV. The pattern is seen more clearly in Fig. 5, showing consolidation of all the samplings into seasonal periods. Here also is expressed the proportion of *S. haematobium* to *S. mattheei* in *B. globosus* snails. The importance of period II in the transmission of *S. haematobium* is quite clear. During periods III and IV approximately 42% of snail infections were with this parasite, but this increased to 63% during the hot, dry period II. Conversely period I appears to be of least importance. In fact, most infections determined at this time were *S. mattheei*.

In the treated area (Fig. 6) very few cercariae were counted and the predominant infection in snails was *S. mattheei*. The effect of the annual July molluscicide treatment on the epidemiologically important seasonal period II, was to reduce the cercarial load on the local population during water contact, not only at that time, but for most of the following year.

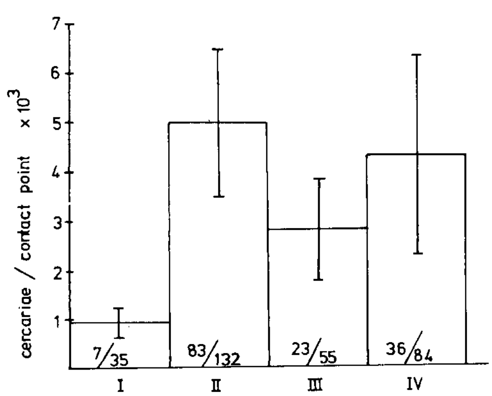

Fig. 5. Unsprayed area. Consolidation of cercarial counts per contact point expressed in seasonal periods I-IV. Numbers are *S. haematobium* infections over total infection identified in *B. globosus* snails. Data combined for entire study period. Standard error of the mean is marked for each seasonal period.

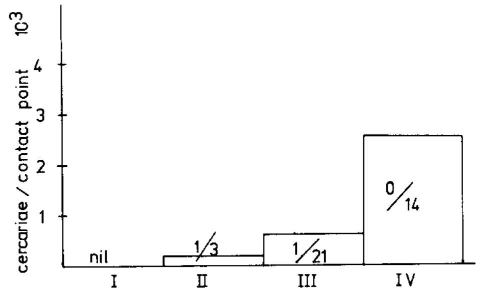

Fig. 6. Sprayed area. Consolidation of cercarial counts per contact point expressed in seasonal periods I-IV. Numbers are *S. haematobium* infections over total infection identified in *B. globosus* snails. Data combined for entire study period.

3. *Epidemiological data*

The prevalence of *S. haematobium* among the residents in both treated and untreated areas was studied by examining local schoolchildren before and during the experimental period. As the surveys have extended over nearly five years, they should reflect the level of schistosome transmission in the areas. The data from six schools are given in Table II and the locality of each school is indicated by an appropriate letter in Fig. 1.

In the sprayed area there was a progressive decrease in prevalence of *S. haematobium* among children at D and C, especially among the younger age group. The prevalence at Mukombani (G) showed a decline in age prevalence between 1973 and 1977, but this trend was not reflected in 1978. This may have been due to the proximity of a large river and heavy water contact by the children during a particularly hot summer period in 1976-77. Large rivers are difficult to treat adequately with molluscicide and pockets of infected snails may well have survived the spraying in the previous July.

In the control areas, prevalence of the disease at Mabika (F) was fairly consistent throughout the five years, while at St. Francis (A) there was a downward trend between 1973 and 1977, followed by an increase between 1977 and 1978. The pattern at Chipangora (B) follows that at St. Francis between 1973 and 1977 but the prevalence in children under 10 dropped dramatically between 1977 and 1978. Inquiries in the area indicate an interest in the use of wells in this particular area. Also, a number of children attending the school came from villages in the treated area. Obviously factors affecting transmission of the parasite are complex and it would be naive to expect clear-cut results from the small number of surveys. The recording of incidence rather than prevalence would have been more accurate, but logistic problems precluded such a study. Still, the trend of reduction of prevalence occurred in the young

Table II—Showing the prevalence of *S. haematobium* infections in schoolchildren living in the sprayed and adjacent unsprayed regions of the experimental area. The locations of the schools are indicated by letters in Fig. 1. Data presented as number infected/number examined

Sprayed Area

	St. Johns (D)		Kadymadare (C)		Mukombani (G)	
Age	6 to 9	10 to 14	6 to 9	10 to 14	6 to 9	10 to 14
Aug. 1973	66/120	106/146	67/121	114/156	70/93	126/147
	55·0%	72·6%	55·4%	73·1%	75·3%	85·7%
March 1977	63/143	44/64	36/120	56/89	36/77	75/120
	44·1%	68·75%	30·0%	62·9%	46·75%	62·5%
Feb. 1978	29/73	74/125	14/65	71/133	32/64	91/136
	39·7%	59·2%	21·5%	53·4%	50·0%	66·9%

Unsprayed Area (Control)

	Mabika (F)		St. Francis (A)		Chipangora (B)	
Age	6 to 9	10 to 14	6 to 9	10 to 14	6 to 9	10 to 14
Aug. 1973	38/69	97/131	57/84	86/104	77/115	97/119
	55·1%	74·0%	67·9%	82·7%	66·9%	81·5%
March 1977	92/142	41/58	49/110	52/89	55/108	74/124
	64·8%	70·7%	44·5%	58·4%	50·9%	59·7%
March-May 1978	80/118	114/141	35/69	84/128	23/75	79/124
	67·8%	80·9%	50·7%	65·6%	30·6%	63·7%

children living within the treated area, while this was not apparent in all the control areas.

Discussion

Our understanding of the bionomics of schistosome populations has developed from a somewhat theoretical start made when HAIRSTON (1965) produced life tables for schistosome populations based on field data from Egypt and the Philippines. These were based on age specific rates of survival and reproduction and were in essence a static interpretation of a dynamic process. WEBBE (1962) studied the transmission of *S. haematobium* in Tanzania and showed a seasonal fluctuation in the infection rate of *Bulinus (P.) nasutus productus* with *S. haematobium*. He suggested that chemical treatment just before the dry season might reduce the number of snails available for aestivation, and that a second treatment after habitats refilled would further reduce the snail population. The approach reported here directed control against the parasite, rather than just the snails, because recent work by SHIFF *et al.* (1975) has shown that the production of cercariae by infected snails is subject to seasonal fluctuations, with a period during winter when *S. haematobium* infections become dormant, followed by rapid sporocyst development and synchronous appearance of cercarial shedding during early summer. This corresponds with the dry season and a decline in the amount of surface water available for human activities and consumption. Clearly this is a period when the population is exposed to heavy cercarial bombardment. It is also a period of considerable importance in the bionomics of the schistosome, because destruction of the reservoir of *S. haematobium* infection by molluscicide treatment in July produces a decline in the prevalence of the parasite in both the human and the snail populations.

The significance of this is that under conditions exemplified by the Rhodesian highveld and middle veld it is likely that one annual application of molluscicide will so affect the *S. haematobium* population that transmission will be reduced to very low levels. Thus, application of a molluscicide on a yearly basis means that expensive chemicals can be used efficiently and personnel already employed by local health authorities could be involved, as the work is so seasonal. This approach, together with discreet use of low-priced schistosomicidal drugs, such as metrifonate, could bring effective control and perhaps the elimination of *S. haematobium* from large regions of Africa well within the realms of possibility.

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