Seasonal patterns in the transmission of "Schistosoma haematobium", "S. mattheei" and "S. mansoni" in the highveld region of Zimbabwe

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Seasonal patterns in the transmission of *Schistosoma haematobium*, *S. mattheei* and *S. mansoni* in the highveld region of Zimbabwe

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Summary

The pattern of fluctuation in the population size of *Bulinus globosus* and *Biomphalaria pfeifferi*, in their infection rates with *Schistosoma haematobium*/*S. mattheei* and *S. mansoni*, respectively, and in the cercarial population size as monitored using hamster immersions, was elucidated in streams in the temperate highveld region of Zimbabwe over a 27-month period during 1982–1984. The results revealed that transmission of *S. mansoni* was erratic and unpredictable without a clearcut seasonal transmission pattern. In contrast, transmission of *S. haematobium* and *S. mattheei* exhibited a marked seasonal pattern, being most intensive during the hot, dry season (September–November) and markedly reduced during the cold, dry season (June–August). During the rainy (December–February) and warm, post-rainy (March–May) seasons transmission was moderate and variable, but occasionally intensive. The results also showed that rodent immersion is to be preferred to measurements of snail population size and snail infection rate in elucidating seasonality of transmission of schistosomiasis.

Key words: *S. haematobium; S. mansoni; S. mattheei; B. globosus; B. pfeifferi;* stream; highveld; Zimbabwe; snail infection rate; hamster immersion; seasonal periods; transmission pattern.

Introduction

The transmission of human schistosomiasis, as well as that of domestic animals, is a complex biological process governed by a range of interacting ecological factors. These factors are determined by local geographical and cli-

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matic conditions and by the behaviour of the definitive hosts. Climatic conditions (primarily rainfall and temperature), by influencing the definitive host water contact patterns, the snail host population density and the rate of the intramolluscan schistosome development, may affect markedly the cercarial population density. Thus, these factors determine the pattern of transmission in terms of its seasonality and overall intensity (see Jordan et al., 1980; Christensen et al., 1983). The schistosomiasis disease picture, being determined by the transmission pattern, may be fairly variable even within well defined geographical areas. Information concerning the local transmission patterns can therefore provide a useful background for the formulation and evaluation of preventive measures and control strategies.

The results of the present study, conducted from March 1982 to May 1984, contribute to available information concerning the epidemiology, particularly the seasonality, of human and bovine schistosomiasis (*Schistosoma mansoni, S. haematobium* and *S. mattheei*) in streams in the temperate highveld region of Zimbabwe.

Materials and Methods

Local conditions of the study area

The study was conducted in Bushu (17° 15′ S; 31° 35′ E) and Chiweshe (17° S; 31° 10′ E) communal areas situated at an altitude of approximately 1500 m above sea level in the temperate highveld region of Zimbabwe. Both areas consist mainly of undulating, sandy savanna grasslands mostly cleared for agricultural use. The human population density is high, animal husbandry is intensive and natural waters (streams) provide the background for all water-related activities. The prevalence of infection with *S. haematobium* and *S. mansoni* in the human population is in the range of 50–60% and 10–20%, respectively, and the prevalence of infection in cattle with *S. mattheei* in the areas is very high (Chandiwana et al., in press).

Monitoring of local climatic conditions revealed a distinct rainy season and a dry season with no or only limited rains (Figs. 1 and 2). Rainfall remained, however, throughout the study period somewhat below "normal" levels. Besides, temperature (air) records revealed high summer and low winter temperatures (Figs. 1 and 2). The climatic features permit the establishment of 4 seasonal periods, namely warm, post rainy (March–May), cool, dry (June–August), hot, dry (September–November) and rainy (December–February) season (see also Shiff et al., 1979).

Twelve intensively used human water contact sites (6 in Bushu and 6 in Chiweshe), all at least to some extent shared by cattle, were selected. Monthly observations were conducted over a 27-month-period (March 1982 to May 1984) on the *Bulinus globosus and Biomphalaria pfeifferi* population sizes, on the *Schistosoma* sp. infection rates in *B. globosus* and *B. pfeifferi* specimens of a shell height/diameter of 6–8 mm, and on the *Schistosoma* cercarial density in water as monitored using the hamster immersion technique (see below). The contact sites were located in narrow, shallow streams generally characterized by a low flow rate, a low turbidity level, a sandy substrate and an abundant aquatic vegetation. Two of the Bushu sites were dry from December 1983 to February 1984, 5 sites (2 in Bushu and 3 in Chiweshe) experienced marked reductions in the water level during parts of the year and 5 sites (2 in Bushu and 3 in Chiweshe) experienced a less marked seasonality in the water flow. However, none of the sites experienced severe flooding conditions during the period of observation. The non-flooding condition is exceptional for this habitat type in the particular area and is attributable to the "below normal" level of rain.

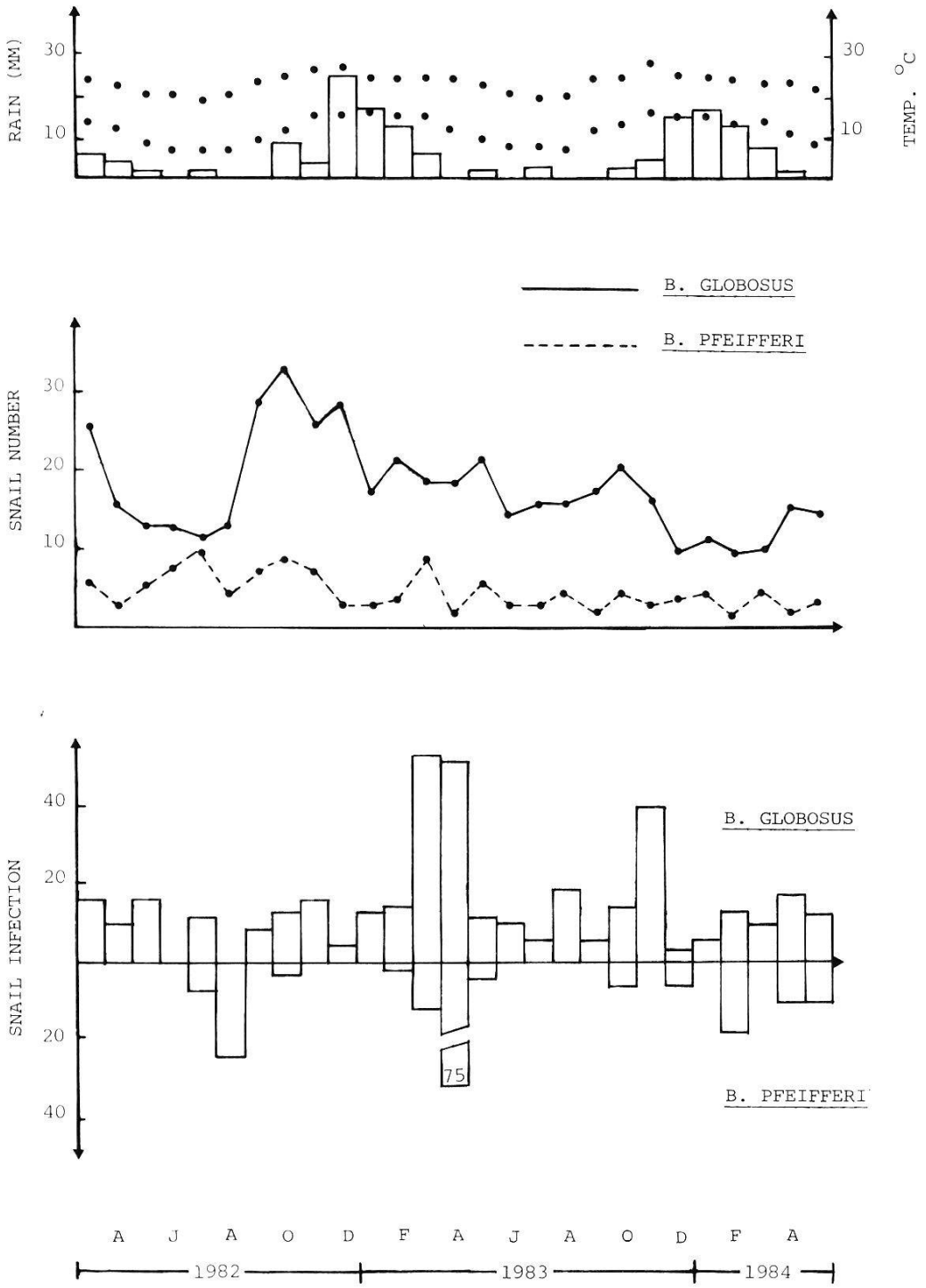

Fig. 1. Seasonal variation in population size (snails per 50 scoops) of *Bulinus globosus* and *Biomphalaria pfeifferi* and in infection rates (prevalence among specimens with shell height/diameter of 6–8 mm, %) with *Schistosoma haematobium/S. mattheei* in *B. globosus* and with *S. mansoni* in *B. pfeifferi* relative to monthly rainfall (mm) and temperature (mean of monthly maximum and minimum temperatures, °C) conditions in streams in Chiweshe communal area. The data represent mean values from 6 human water contact sites.

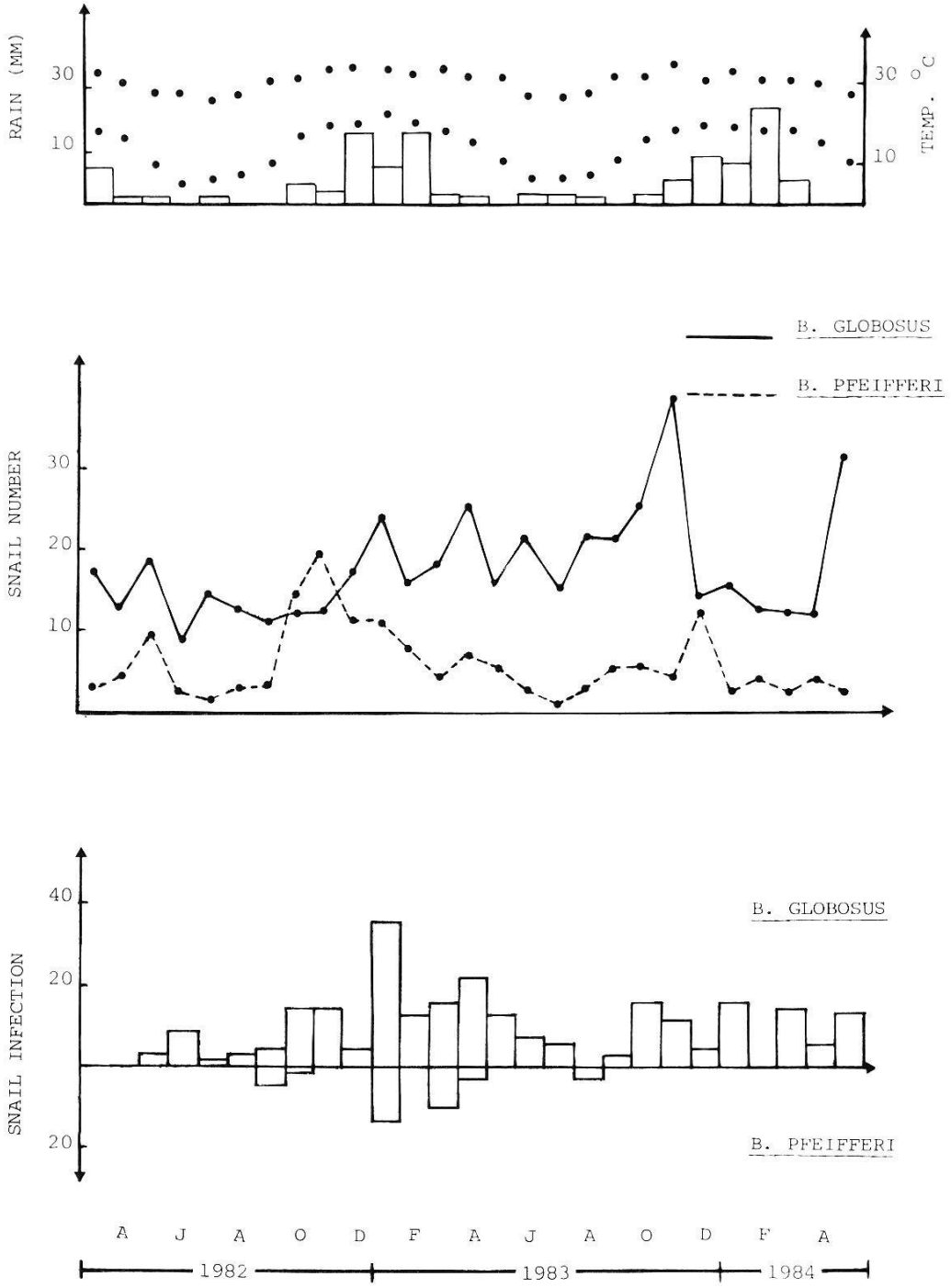

Fig. 2. Seasonal variation in population size (snails per 50 scoops) of *Bulinus globosus* and *Biomphalaria pfeifferi* and in infection rates (prevalence among specimens with shell height/diameter of 6–8 mm, %) with *Schistosoma haematobium/S. mattheei* in *B. globosus* and with *S. mansoni* in *B. pfeifferi* relative to monthly rainfall (mm) and temperature (mean of monthly maximum and minimum temperatures, °C) conditions in streams in Bushu communal area. The data represent mean values from 6 human water contact sites.

Snail density and snail infection rate

Snail sampling was conducted at the 12 sites at monthly intervals over a 27-month-period from March 1982 to May 1984. A fractional scooping method described by Shiff and Clarke (1967) was used and the population size of *B. globosus*, snail host for *S. haematobium* and *S. mattheei*, and of *B. pfeifferi*, snail host for *S. mansoni*, was expressed as number of snails per 50 scoops. Snail specimens of a shell height/diameter of 6–8 mm were examined for trematode infection by being placed individually in small plastic tubes containing 10 ml of "matured" natural water and exposed to light for 1 h during the time period 12.00–14.00 h. Cercariae shed were identified to the *Schistosoma* genus level according to Frandsen and Christensen (1984), and the number of *Schistosoma* cercariae produced per infected snail was recorded. The snails were returned to the locality following examination.

Cercarial density measured using hamster immersion

Hamster (*Mesocricetus auratus*) immersions were, with a few exceptions, conducted at monthly intervals at the 12 sites. Four hamsters were used at each site each month, and each hamster was immersed for 2 h (12.00–14.00 h) on 3 consecutive days, i.e. a total of 6-h immersion per hamster. Fourteen weeks following immersion, i.e. a time period allowing for maturation of any *Schistosoma* species, the hamsters were examined for presence and size (worm burden) of *Schistosoma* infection using the perfusion technique described by Smithers and Terry (1965). Identification of the *Schistosoma* infections to the species level was made on the basis of the morphology of tissue-deposited eggs as observed in squash preparations or, as in the case of single-sex infections, using the starch gel electrophoretic technique described by Mahon and Shiff (1978). A total of 1258 hamsters were immersed and 459 of the 1026 hamsters examined by perfusion had acquired *Schistosoma* infections. A total of 333 of the 459 infected hamsters had their infection(s) identified to the species level, and concurrent infection with several *Schistosoma* species was common. Thus, a total of 418 infections were identified in the 333 infected hamsters.

Data presentation

Statistical treatment of the data (details not presented) revealed no significant correlations between type of contact site and overall malacological/parasitological findings. Monthly results obtained from the 6 sites within each study area were therefore pooled for convenience of presentation and to elucidate the general transmission patterns in the two study areas.

Results

Snail population size and overall transmission intensity

The mean number of *B. globosus* per 50 scoops over the 27-month sampling period ranged, at individual sites, from 10 to 22 in Bushu and from 14 to 22 in Chiweshe. The similar figure for *B. pfeifferi* was generally lower, ranging from 2 to 11 in Bushu and from 3 to 8 in Chiweshe. The population size of both *B. globosus* and *B. pfeifferi* fluctuated markedly during the observation period in both study areas (Figs. 1 and 2). These fluctuations appeared, however, rather irregular and unpredictable. Thus, no clearcut relationship existed between rainfall/temperature conditions and the snail population sizes with the possible exception of *B. pfeifferi* in Bushu repeatedly experiencing a reduced population size in the cold, dry periods. The overall prevalence of infection with *S. haematobium/S. mattheei* in *B. globosus* was 12% (222 of 1851 examined) in Bushu and 15.2% (395 of 2602 examined) in Chiweshe with the figure at individual

sites ranging from 5.7 to 18.1% in Bushu and from 9.2 to 23.0% in Chiweshe. The overall prevalence of infection with *S. mansoni* in *B. pfeifferi* was somewhat lower, being 2.2% (16 of 715 examined) in Bushu and 4.0% (25 of 632 examined) in Chiweshe with the figure at individual sites ranging from 1.1 to 5.3% in Bushu and from 2.0 to 5.5% in Chiweshe.

From the hamster immersions the overall prevalence of *Schistosoma* infection (among animals examined) ranged at individual sites in Bushu from 14.9 to 40.2% (mean 28.1%) and at individual sites in Chiweshe from 45.3 to 84.5% (mean 63.1%). Mean overall number of worms established per perfused hamster ranged at individual sites in Bushu from 0.6 to 2.9 (mean 2.2) and in Chiweshe from 2.8 to 12.9 (mean 7.9). Thus, both snail and hamster data revealed that the overall intensity of transmission was greater at Chiweshe than at Bushu.

The overall female: male adult schistosome ratio in perfused hamsters was 1:1.5 in both study areas, with only limited variation from site to site and from season to season. Besides, the overall ratio of infections with *S. mattheei, S. haematobium* and *S. mansoni* in exposed hamsters was 6:3:1 in both Bushu and Chiweshe.

Seasonal transmission pattern

Observations on the snail infection rates and on the worm populations recovered from the hamsters showed that transmission of *S. mansoni,* in both Bushu and Chiweshe, was limited, unpredictable and rather erratic. However, Bushu and Chiweshe data in combination indicate the apparent possibility for the continuous presence of *S. mansoni*-infected *B. pfeifferi* (Figs. 1 and 2), and *S. mansoni* infections in immersed hamsters were achieved in all seasonal periods (Fig. 4). The overall limited intensity of transmission of *S. mansoni,* however, prevents the definitive demonstration of its seasonal transmission pattern in the study areas. However, the results obtained might indicate that the rate of transmission is reduced during the cold, dry period.

S. haematobium/S. mattheei-infected *B. globosus* were present almost continuously in both study areas during the 27-month observation period with a marked tendency for the infection rates being reduced during the cold, dry periods (Figs. 1 and 2). The overall mean production of *Schistosoma* cercariae was 673 cercariae/day per infected *B. globosus* as compared with a production of only 9 cercariae/day per infected *B. pfeifferi.* The pattern of production of *Schistosoma* cercariae from *B. globosus* was, however, rather irregular, with a tendency for reduced production rates during the cold, dry seasons. Combined observations on snail population sizes and snail infection rates indicate a seasonal transmission pattern with a rate of transmission that is reduced during the cold, dry period.

Data on prevalence and intensity of infection with *Schistosoma* sp. in immersed hamsters revealed that the intensity of transmission in Chiweshe

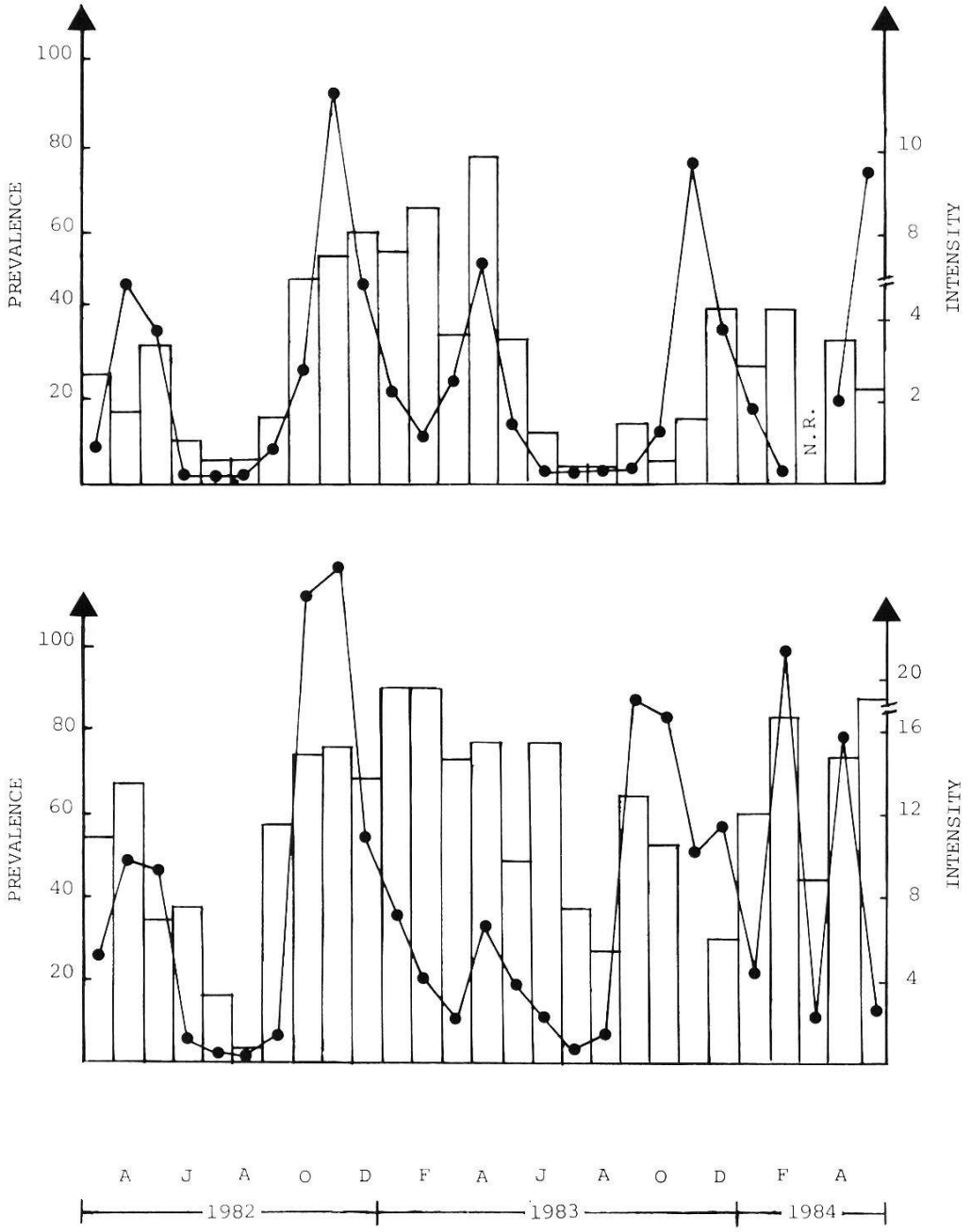

Fig. 3. Seasonal pattern in prevalence (histogramme, % of perfused hamsters infected) and in intensity (graph, worms/perfused animal) of infection with *Schistosoma* sp. in hamsters immersed at human water contact sites in streams in Bushu (top) and Chiweshe (bottom) communal areas. The data represent mean values from 6 sites in each of Bushu and Chiweshe (4 hamsters/month/site with each hamster exposed for 2 h at 3 consecutive days).

exceeded that in Bushu (Fig. 3). This confirms the similar conclusion reached from observations on snail infection rates. Furthermore, the results obtained concerning the infection intensity in immersed hamsters revealed that transmission of *Schistosoma* sp. exhibited a marked seasonal pattern with intensive transmission during the hot, dry season (September–November), with significant reduction in transmission during the cool, dry season (June–August) and with a moderate and variable, but occasionally even high transmission intensity

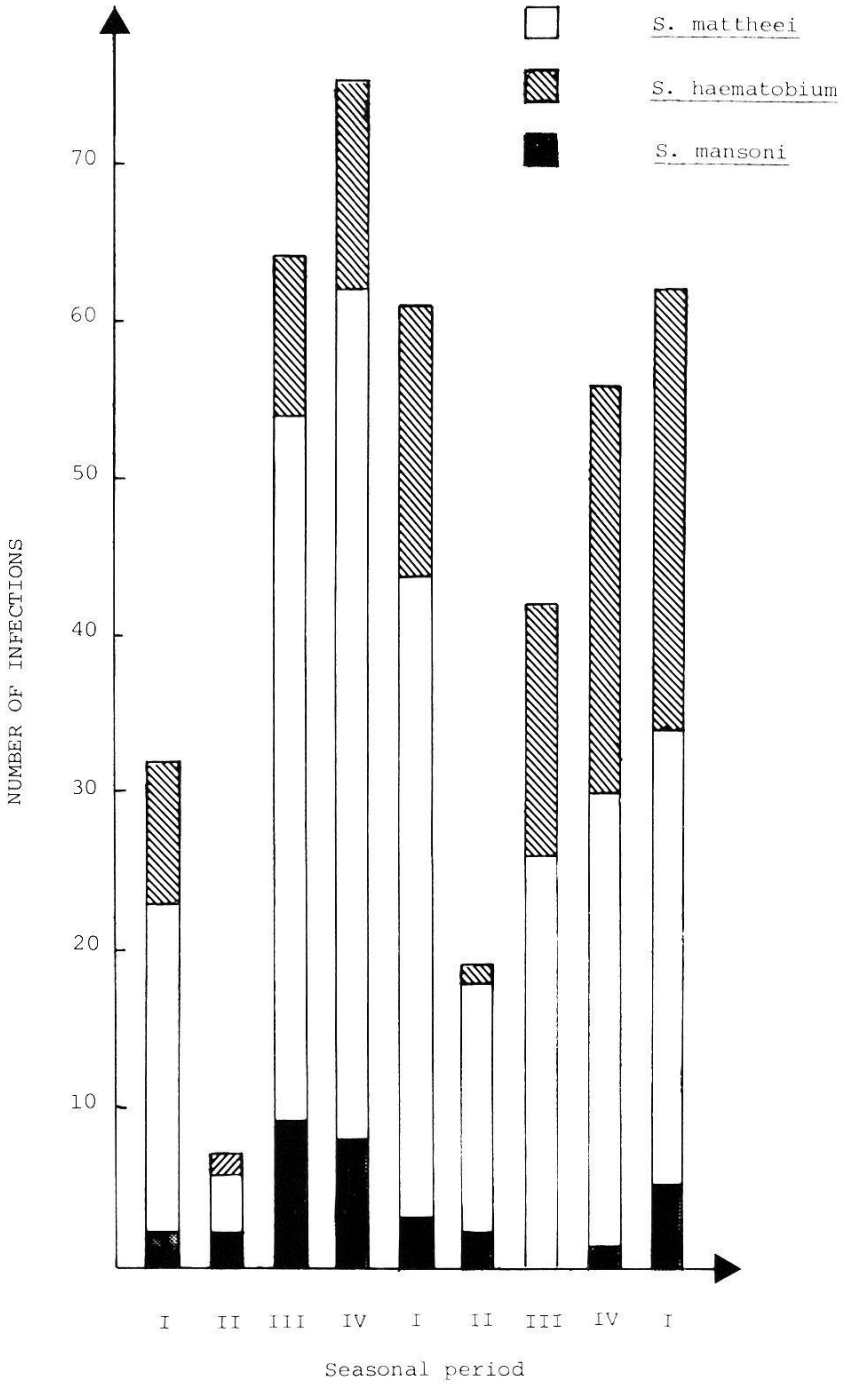

Fig. 4. Number and relative ratio of identified infections with *Schistosoma mansoni, S. haematobium* and *S. mattheei* in hamsters immersed at Bushu and Chiweshe (combined data) in different seasonal periods. I: Post rainy, warm (March–May); II: cool, dry (June–August); III: hot, dry (September–November); IV: rainy (December–February).

during the rainy (December–February) and post-rainy (March–May) seasons (Fig. 3). This seasonal transmission pattern was especially marked in Bushu with the transmission being almost completely blocked during the cold, dry seasons.

The overall ratio of hamster infections with *S. mattheei, S. haematobium* and *S. mansoni* was in the range of 6:3:1 (see above). However, the relative

frequency of the different schistosome species appeared affected by seasonal periods. Thus, the *S. mattheei/S. haematobium* ratio in the dry, cold period of 1983 became markedly increased (Fig. 4), indicating that the reduction in the level of transmission of *S. haematobium* during the cold, dry period was more pronounced than that of *S. mattheei.* From Fig. 4 it may furthermore appear that the overall level of transmission of *S. mattheei* decreased, whereas that of *S. haematobium* increased when comparing the period September 1982 to May 1983 and the period September 1983 to May 1984.

Discussion

The pattern of transmission of schistosomiasis in the temperate highveld region of Zimbabwe, as demonstrated in the present study, with intensive transmission during the hot, dry season (September–November), a marked reduction in the transmission during the cold, dry season (June–August) and with variable, but consistent and even occasionally intensive transmission during the rainy and post-rainy seasons corresponds to the overall transmission pattern demonstrated in other parts of Africa having corresponding climatic conditions (i.e. Hira, 1975; Pfluger, 1976; Pitchford, 1981; Pitchford and Visser, 1962, 1965, 1969; Donnelly and Appleton, 1985; Shattock et al., 1965; Pitchford et al., 1969; Shiff et al., 1975, 1979). The commonly occurring reduction in the snail population sizes in streams during heavy rains (see review by Appleton, 1978) was not observed in the present study, presumably due to only limited flooding. However, it is reasonable to suggest that similar climatic/ecological transmission conditions with more pronounced flooding would result in the overall main transmission being limited to the hot, dry and the warm, post-rainy seasons (see also Shiff et al., 1979).

The marked reduction in transmission during the cold, dry periods is, in the light of the snail populations remaining relatively stable, suggested induced by the well documented (i.e. see Pitchford and Visser, 1965; Shiff et al., 1975) suppressive effect of low temperature conditions on the "biological productivity" of the schistosome infection in the snail host. However, a reduction in the input of schistosome eggs into the snail habitats might also be involved (see below). The level of reduction in the transmission intensity as demonstrated using the hamster immersion technique exceeded markedly the level of reduction indicated from observations on snail infection rates. Water velocity reached the minimum level during the cool, dry period and water temperatures appear favourable for cercarial infection of the rodent definitive host (i.e. see Christensen et al., 1979). This suggests that the lack of correlation between infection rates in hamsters and snails in the cool, dry season is presumably not due to a reduction in the cercarial host-localization capacity (see discussion in Webbe, 1965). It may, however, be suggested that the favourable temperature and lighting conditions during screening for schistosome infections induce a

cercarial emergence which would not take place from snails remaining in the snail habitat. Thus, the cercarial development may be suppressed but may not be blocked completely during the cold, dry period, and the reduction in the transmission intensity may, to some extent at least, be due to a suppression of cercarial shedding during such low temperature conditions. The demonstration by Shiff et al. (1975) in quasi-field experimentation in the highveld region of Zimbabwe of an actual winter dormancy of schistosome sporocyst development may therefore not be a generally occurring phenomenon under field conditions.

The information accumulating thus strongly indicates that observations on snail infection rates only may result in an over-estimation of the actual transmission level during low temperature transmission periods. Thus, an estimation of the actual cercarial density in water is to be conducted for elucidating seasonal transmission patterns in such areas. This may, as in the present and previous studies by Pitchford and Visser (1962, 1965, 1969) and Donnelly and Appleton (1985), be conducted using rodent immersions or alternatively cercarial filtration techniques. However, cercarial filtration techniques neither allow for an elucidation of the cercarial infectivity nor for an identification of the cercarial specimens to the species level. The severe limitations connected with the use of filtration techniques in streams in areas like the present, where 3 or even more schistosome species may be transmitted concurrently, appear on this background easily recognized.

Evidence exists that the hamster is more susceptible to infection with *S. mattheei* than with *S. haematobium* (Chandiwana, unpublished; Preston and James, 1972). Besides, the possible occurrence of hybridization in the hamster between *S. haematobium* and *S. mattheei* would result in the production of eggs morphologically indistinguishable from those of *S. mattheei* (see Wright and Southgate, 1976). From this it follows that the observed relative frequency of *S. mattheei* and *S. haematobium* infections in the immersed hamsters may not be a true reflection of the actual relative rate of transmission of these two schistosome species in the environment. However, the increase in the *S. mattheei/S. haematobium* ratio in the cool, dry season anyway suggests that the level of reduction in transmission of *S. haematobium* exceeded that of *S. mattheei* during this period. A more pronounced reduction in the level of transmission of human than of bovine schistosomiasis during low temperature transmission periods has been demonstrated earlier by Shiff et al. (1979) also working with *S. haematobium* and *S. mattheei* on the highveld of Zimbabwe and by Pitchford and Visser (1962, 1965) working with *S. mansoni* and *S. mattheei* on the Eastern Transvaal lowveld. The more markedly adverse effects of low temperature on the intramolluscan development of *S. haematobium* than of *S. mattheei* (Pitchford and Visser, 1965) might play an important role but it may also be suggested that a relatively more marked reduction in the input of eggs of *S. haematobium* than of *S. mattheei* into the aquatic environment could contribute to the more marked reduction in the transmission of *S. haemato-*

bium than of *S. mattheei.* An accompanying study (Chandiwana, in press) and numerous other studies in schistosomiasis endemic areas have thus demonstrated that a marked reduction occurs in the frequency and duration of human water contacts during the cool season whereas cattle water contacts are less seasonal. The possible effects of such seasonal patterns in the human water contact behaviour on the pattern of transmission of human schistosomiasis should be elucidated in further comprehensive studies. Finally, the demonstration of an overall dominance of male worms in hamster infections in the present study agrees with the results from other field studies, i.e. from studies on *S. mansoni* and *S. mattheei* in Southern Natal (Donnelly and Appleton, 1985), on *S.mansoni* and *S. mattheei* in the Eastern Transvaal lowveld (Pitchford and Visser, 1962), and on *S. mansoni* on St. Lucia, West Indies (Sturrock, 1973).

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