FIELD STUDIES ON SCHISTOSOMIASIS IN ZAMBIA

I Seasonal Fluctuations in the Population Density of *Biomphalaria pfeifferi* and *Bulinus* (physopsis) *globosus* in a Schistosomiasis Endemic Area in Zambia

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ABSTRACT

Previous work done on Schistosomiasis in Zambia was largely concerned with the medical aspects and little had been made on the bionomics of the snail intermediate hosts. This paper records the results of a detailed study carried out over a one year period on the population density of the two species of snails. The ecology of snail habitat is described; and the data on seasonal fluctuation in the population density of the molluscan hosts (*Biomphalaria pfeifferi* and *Bulinus* (physopsis) *globosus*) in Muchinshi area, Chingola district, Copperbelt Province, are presented and discussed. In flowing waters such as Muchinshi stream, the populations of the two snail species are most dense during the cool dry season (July - August) and fall to their lowest during the rainy season (November - March). Schistosomiasis control programme should take advantage of the finding on population parameters by application of a molluscicide when the habitat has been refilled by rainfall to reduce the population before the snail reproductive season begins.

INTRODUCTION

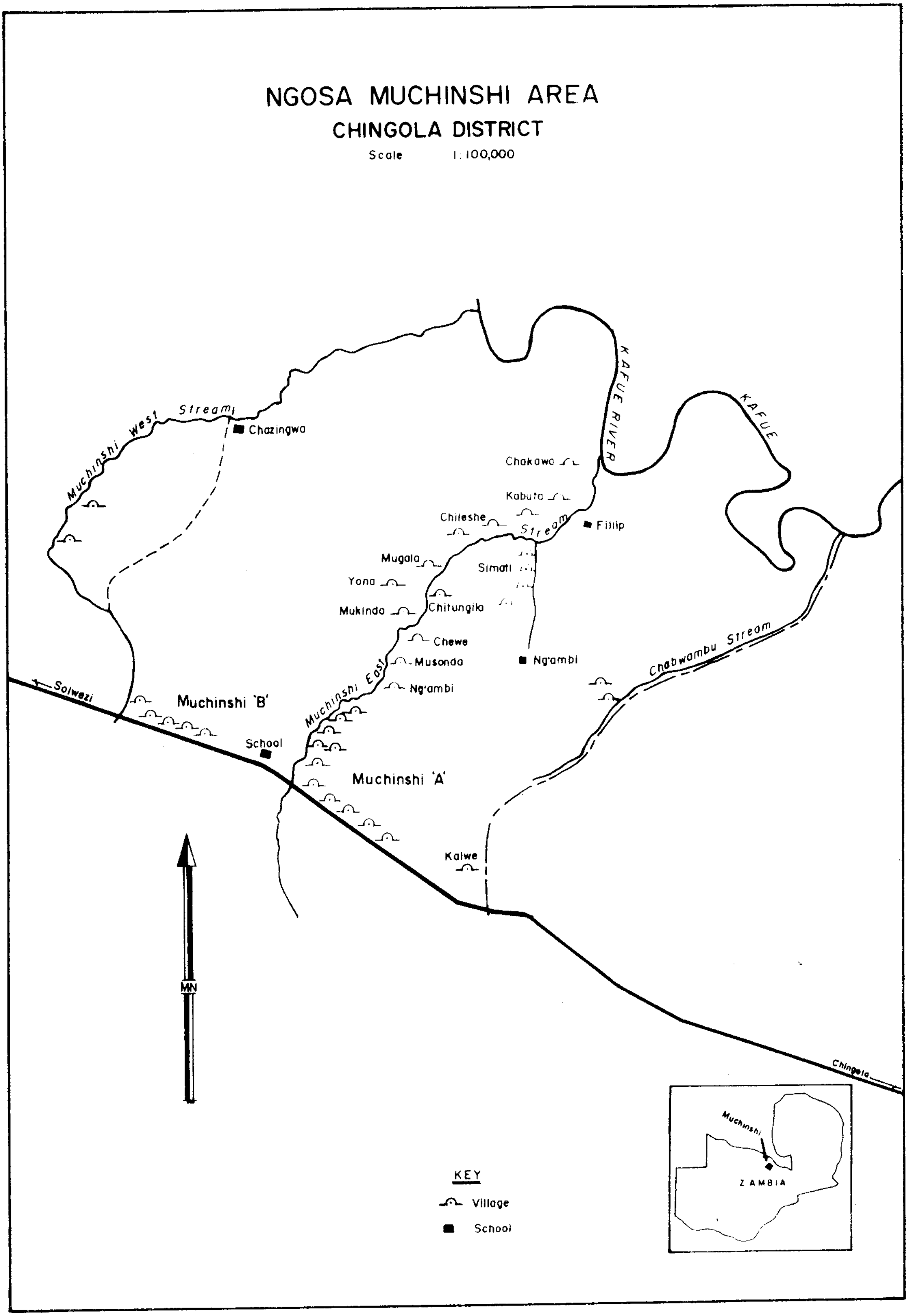
Successful Schistosomiasis control depends largely on a thorough knowledge of the distribution and ecology of snails. Although field studies on Schistosomiasis in Zambia were reported by Goldin and Barclay (*1*), and Hira (*2, 3*), information about the distribution, population dynamics, ecology and biology of the snail hosts of Schistosomiasis in their natural environment is still inadequate, especially in rural Zambia. The present paper records observations on the seasonal fluctuations in snail population densities in an endemic area.

General Considerations

The Study Area

Muchinshi is an area of about 75 Km^2 (Figure 1) and is situated in the west part of Chingola district, about 35 Km on the Chingola/Solwezi Road, near Mutenda Village. It was chosen because of the comparatively high prevalence of Schistosomiasis infections in Mutenda Village (over 60%) which was reported by Boatin (*4*). Three streams pass through Muchinshi. They receive their water from surrounding swamps and flow into the Kafue River. A pilot survey was done in order to choose a suitable stream for the study. The chosen stream should have a good population of intermediate host snails, aquatic vegetations and have spread Schis-

FIGURE 1.


NGOSA MUCHINSHI AREA
CHINGOLA DISTRICT
Scale 1:100,000
Muchinshi West Stream
Chazingwa
KAFUE RIVER
KAFUE
Chakawa
Kabuta
Chileshe
Stream
Fillip
Mugala
Simati
Yona
Mukinda
Chitungila
Chewe
Musonda
Ng'ambi
Ng'ambi
Muchinshi East
Chabwambu Stream
Solwezi
Muchinshi 'B'
School
Muchinshi 'A'
Kalwe
MN
Chingola
KEY
Village
School
Muchinshi
ZAMBIA

tosomiasis to the population resident along the stream in this area. The most important of these streams is the Muchinshi stream which has the highest density of snails, vegetations and about 445 houses are located along this stream with a population of up to approximately 2,500.

Climate and Temperature

In general Zambia has a sub-tropical type of climate with three distinct seasons; the warm wet (November - March), the cool dry (April - August) and the hot dry (September - October). The country generally experiences 4 to 8 dry months per year. The temperature ranges from 2.5°C in the cool dry season to 37°C in the hot dry season and the relative humidity ranges from about 75 to 85 per cent in the warm wet season. The sunshine hours range from about 2600 hours in the South to 3000 hours in the North with up to 10 days of frost (*5*). The rainfall ranges from about 700 mm in the South to 2000 mm in the North.

MATERIALS AND METHODS

The collection site was a stretch of one kilometer of the stream inside the boundary of the study area, where the flow of water is slight and suitable for collecting the snails. The stream in the chosen site is 4 m to 19 m wide, with an average 1.5 m depth of water. The chosen site was not a shaded area, but the banks of the stream were covered with scattered small trees and grass interspersed with aquatic weeds. The surface of the stream contained some green algea and submerged weeds.

In order to obtain accurate quantitive data on the abundance of the snails, the dip-net was employed as a sampling tool (*6*). This instrument is designed to collect all snails in a strip 33 cm wide. The construction and use of the dip net are described by Hairston et al (*7*). The net was made 33 cm wide and covered with wire mesh (7 mesh . cm^{-1}). This wire mesh size was chosen to collect all snails above 2 mm shell height, or diameter.

A sample was taken by making a single pass through the water at right angles to the bank, including emergent vegetation on one side of the stream, or as much of the width of the water course that could be reached. Snail sampling was carried out at 10 stations, 100 meters apart. 30 samples were taken by 30 dip nets along the length of each station. The dip nets were chosen on these occasions by taking an appropriate number of paces along the length of each station. Their location, therefore, varied somewhat between sampling rounds. This avoided the repeated sampling and disturbance of the habitat which might have occured at fixed sampling places. Samples were taken between 12.00 and 14.00 hours on the Wednesday of each week. Four collections were made each month. The procedure was repeated every month throughout 1986. Two trained field assistants were employed to make the weekly collections of snails. At each time of collection the specimens of *Biomphalaria pfeifferi* and *Bulinus* (physopsis) *globosus* snails which transmit *Schistosoma mansoni* and *Schistosoma haematobium*, respectively, were counted and recorded.

Specimens of *Biomphalaria* and *Bulinus* snails were sent at the beginning of the work to Uniformed Services, University of the Health Sciences, Division of Tropical Public Health, Bethesda, Maryland, U.S.A., for identification of the species of snails in the study area. These were later confirmed as *Biomphalaria pfeifferi* and *Bulinus* (physopsis) *globosus* by Dr Edward H. Michelson, Professor of Preventive Medicine/ Biometrics.

RESULTS

In Muchinshi stream the population for both snail species showed a close similar trend over one year of observation. Table I shows the seasonal fluctuation in numbers of the two species of snails over the twelve months covered by the survey. Figure 2 shows the two graphs obtained by plotting the figures for *Biomphalaria pfeifferi* and *Bulinus* (p) *globosus* respectively. The graph for *Biomphalaria pfeifferi* looks like a cone with a peak in July (11, 980 snails), the sides of the cone falling to the lowest points in February (1, 984 snails) and November (2,150 snails).

The graph for *Bulinus* (p.) *globosus* has a shape corresponding to that for *Biomphalaria pfeifferi* except that its top is a plateau with a peak in August (3,236 snails). The graph shows a trough on both sides in January (340 snails) and December (973 snails).

Two facts emerge from the figures plotted in Figure 2: (a) the number of the two species of snails which transmit schistosomiasis show increases during the cool dry season which comprises the months April to August and a great decrease in the warm rainy season, from November to March; (b) The two species show opposite sequences of density, *Biomphalaria pfeifferi* being much more abundant in Muchinshi stream than *Bulinus* (p.) *globosus*. The monthly number of snails collected throughout the year for *B. pfeifferi* was more extensive than for *Bulinus* (p) *globosus*.

Statistical analysis for (b) confirmed that the difference in snail numbers between the two species was highly significant (x^2 = 3903.75 with eleven degrees of freedom. A value of 31.25, or above, indicated that the difference is statistically significant at 0.1% level).

Table I

Population of B. pfeifferi and Bulinus. (p.) globosus Collected Monthly Along Muchinshi Stream

Month	No. of *B. pfeifferi*	No. of *B. (p.) globosus*
January	2,006	340
February	1,984	456
March	3,148	508
April	3,788	901
May	7,672	1,396
June	11,536	2,342
July	11,980	2,793
August	7,476	3,236
September	4,672	2,672
October	4,074	2,885
November	2,150	1,433
December	2,752	973

Table II

Average Temperature, and Total Rainfall Measured for Copperbelt, 1983 - 86

Month	Average Temperature (⁰C)				Total Rainfall (mm)			
	1983	1984	1985	1986	1983	1984	1985	1986
January	21.5	20.9	20.9	20.5	317.5	204.5	307.6	389.3
February	21.8	20.2	20.4	20.7	142.5	259.5	268.9	187.6
March	22.2	21.2	20.9	21.0	136.5	148.5	185.5	201.4
April	21.5	20.8	19.4	20.7	95.1	2.6	65.1	58.2
May	20.0	19.2	18.5	18.5	02.1	0.0	6.2	0.0
June	18.3	17.0	16.0	16.4	0.0	0.0	0	0.2
July	18.0	17.3	16.8	16.3	0.0	0.0	1.5	0.0
August	18.7	18.9	18.7	19.5	0.0	0.0	0.0	0.0
September	22.9	23.3	22.9	22.1	0.0	0.2	0.0	0.0
October	23.9	24.5	23.6	22.9	81.3	38.7	16.3	101.8
November	23.6	22.1	21.6	22.1	111.0	182.8	211.4	44.1
December	20.7	20.5	20.7	21.5	454.5	450.8	191.8	126.2

Table III

Mean Maximum and Minimum Air Temperature for Copperbelt Province During 1986 °C

Month	Mean Maximum	Mean Minimum
January	26.1	16.6
February	27.0	17.1
March	27.7	17.0
April	27.7	15.5
May	27.0	11.0
June	24.5	08.4
July	25.4	07.0
August	28.2	10.2
September	30.5	13.7
October	30.3	16.8
November	29.4	17.1
December	27.3	17.4

DISCUSSION

The results of this study suggest that the possible variable factors which may influence the seasonal fluctuation of these snails in their habitat are rainfall and temperature. In this study area, the record of rainfall and temperature for the period January 1983 to December 1986 has been compiled by the Government Meteorological Department. These figures are summarized in Table II. As shown in Table II the figures for rainfall and temperature for the period between 1983 and 1986 did not deviate much from one year to another. It seems safe, therefore, to use the 1986 rainfall and temperature to interpret the snail populations for the two snail species collected in 1986.

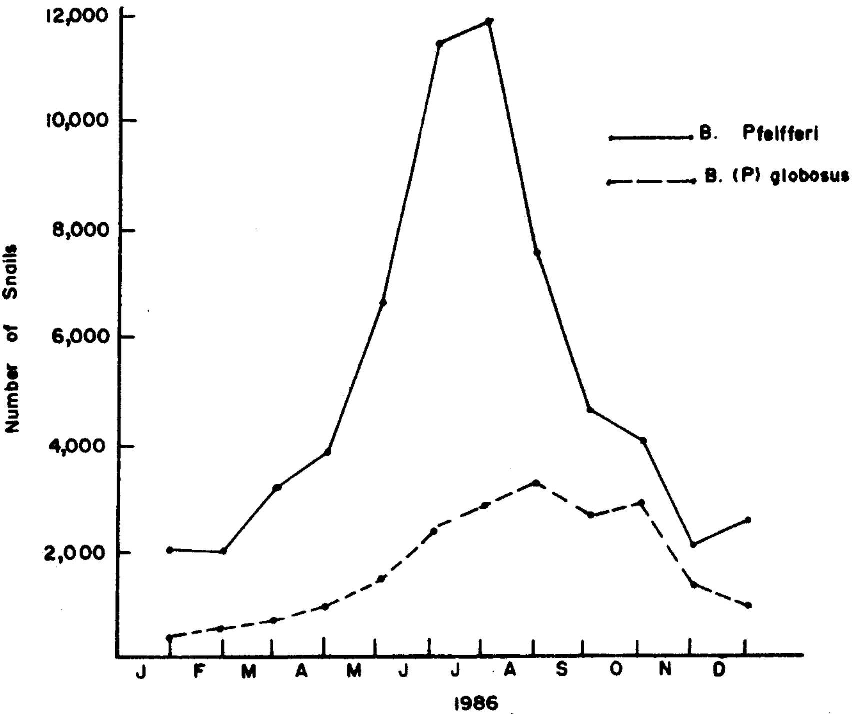


Figure 2. ***Monthly Densities of Biomphalaria pfeifferi and Bulinus (p) globosus in Muchinshi Stream***

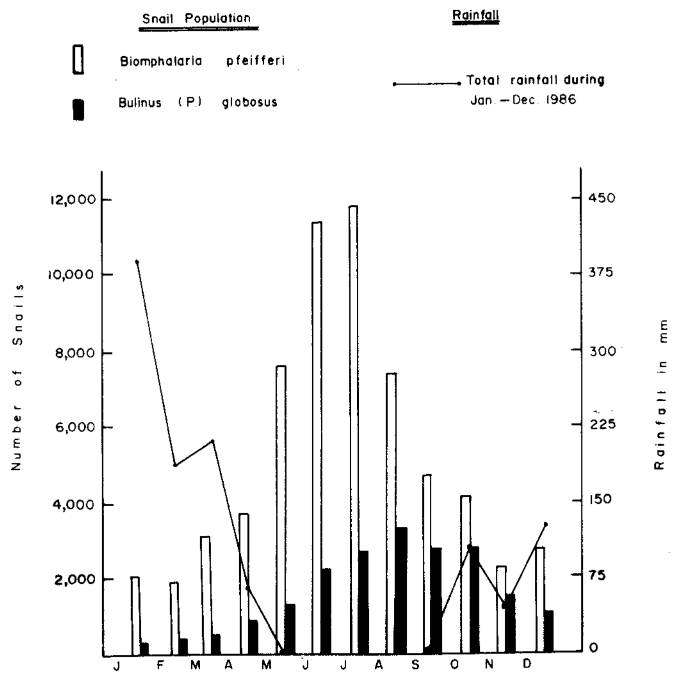


Figure 3. ***Seasonal Fluctuation in the Number of B. pfeifferi and B.*** (p) ***globosus and Monthly Records of Rainfall over one Year***

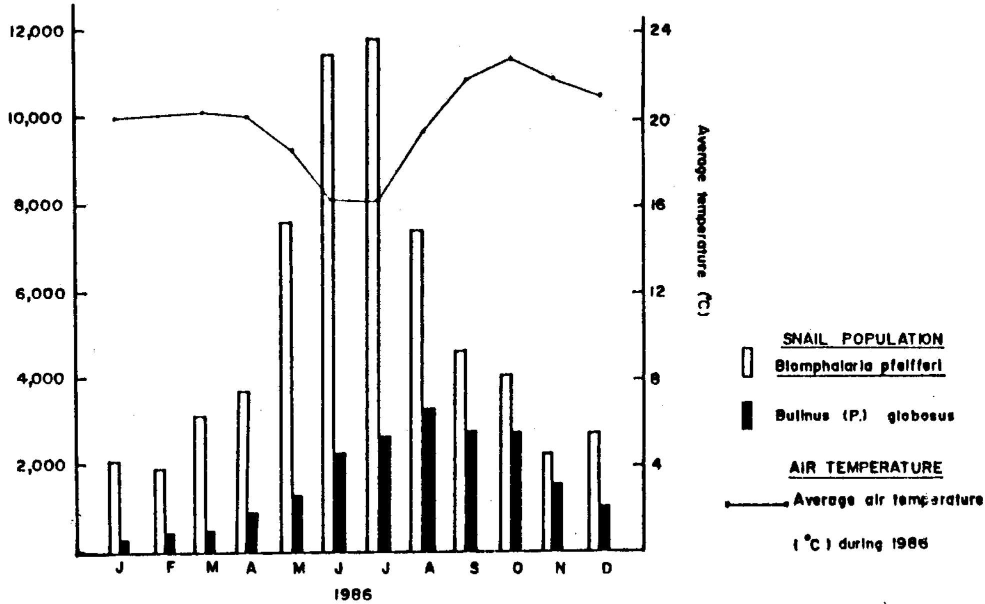


Figure 4. *Seasonal Fluctuation in the Number of B. pfeifferi and Bulinus* (p) *globosus and Monthly Records of Average Temperature over one Year*

The histograms in Figures 3 and 4 represent the population figures of the two species of snails charted with the figure of rainfall and temperature respectively in Muchinshi. The fluctuation in the population density of each snail species relative to rainfall and temperature is clearly seen in these figures.

Figure 3 shows that the population for both snail species decreases in the rainy season (November - April). The lowest figures were found between December and March which was the period of the highest rainfall. But the reverse was the case with the beginning of the dry season (May - September). The greatest number of snails was found in July for *Biomphalaria* and in August for *Bulinus,* roughly at the height of the dry season.

Many instances of fluctuations in abundance related to normal seasonal variations in climate have been reported by McCullough (*8*), Rowan (*9*), Webbe (*10, 11, 12*), Berrie (*13*), Harrison (*14*), Fenwick (*15*), Onabamiro (*16*) and Sturrock (*17*). Onabamiro (*16*) in a similar survey on *B.* (p.) *globosus* in Sierra Leon, found that the greatest number of snails seemed to occur at the beginning of the dry season and very few snails in the rainy season.

Webbe (*10*) reported that a snail population may be adversely affected by rainfall owing to rapid change in water level. Flows greater than one feet per second caused dislodgement of *Biomphalaria glabrata* (*18, 19*). In dry periods, reduced water volume and surface areas might become important for snail population (*20*). Thus it could be suggested that snail populations in Muchinshi stream were only able to build up and thrive in the gentle flows during the dry period of the year.

The other factor apart from rainfall is temperature. Table III gives the mean maximum and minimum air temperature for Muchinshi area in 1986. This table shows that the model air temperature ranges from 24.5°C to 30.5°C (daily maximum) and from 7°C to 17.4°C (daily minimum). Temperature is lowest during the months of June and July (from 7°C to 8.4°C) while highest (30.5°C) between September and October. The greatest daily maximum - minimum temperature fluctuation usually occurs from June to August. Figure 4 shows that the temperature from 16°C and 19°C (the average of daily maximum - minimum temperature fluctuation) appears to be favourable to vector snails. The peak in snail population increases in July for *Biomphalaria* and in August for *Bulinus* (i.e. cool dry season), followed by a rapid decline as temperature continues to rise between September and October (hot dry season). The relatively few snails which survive through the rainy season may breed in March - April (when temperature ranges from 15 - 27°C and seems to be suitable for oviposition and hatching) producing a new generation recognisable by a high density peak in July for *Biomphalaria* and August for *Bulinus*.

It is difficult to assess the influence of temperature on the distribution of snails because little is known about temperature conditions in natural habitats. Since temperature varies within waterbodies mainly in relation to depth and degree of shading, and individual snails are mobile, they presumably have a certain freedom in choosing a favourable microhabitat (*21*). Water temperature on the Rhodesian plateau during the winter can drop to about 11°C (*22*), but winter days are sunny and the surface layer of a stream, or pond is warmed to several degrees above its prevailing temperature (*21*). Shiff (*22*) observed that a greater proportion of the population of *Bulinus globosus, Biomphalaria pfeifferi* and *Lymneae natalensis* was present within 25 cm of the surface in winter than in summer. In Egypt, Dazo et al (*23*) observed that *Bulinus truncatus* and *Biomphalaria alexandrina* suffer high mortality in the hot season while fecundity is greatest in spring and both species are potentially capable of doubling their population within 14 - 16 days. Sturrock (*24*) reported that the optimum temperature for a rapid population expansion of *B. pfeifferi* in Tanzania appeared to be close to 25°C; at 19°C population expansion was much slower, but survival was good, while at 30°C it was poor. He concluded that high temperatures are a major barrier.

Since temperature plays an important part in the life of certain fresh water snails, precise information about geographical and seasonal variations in water temperature is desirable. Constant temperature conditions under which experiments are usually made, are not to be entirely reliable as guides to events in nature, where water temperature usually is highly variable in time and space. Large waterbodies, for example, may provide limited zones of favourable temperature at which snails can move during unfavourable seasons (*21*). Accordingly, temperature is most likely to be a limiting influence in small waterbodies where snails are forced to experience extremes of coldness and warmth.

In view of the density of each snail species in Muchinshi stream, *Biomphalaria pfeifferi* being much more abundant than *Bulinus* (p.) *globosus*, the difference may be due to many factors which affect the suitability of the habitat for each species (*23*). Therefore, *Biomphalaria pfeifferi* finds Muchinshi stream more favourable for reproduction and survival than *Bulinus* (p.) *globosus*. The possible importance of water current, flooding during heavy rainfall and the relationship between snail species and aquatic weeds have been mentioned. It is of considerable interest that *Biomphalaria pfeifferi* is associated with slowly flowing water (*21*). Other factors which conceivably might influence numbers of snails include oxygen concentration (*25*) and food (*26, 27*). One point to be considered is that possibly the difference in the biology between *Biomphalaria pfeifferi* and *Bulinus* (p.) *globosus* plays a part. When conditions are favourable, a rapid growth rate and early sexual maturity allow the individual *Biomphalaria* snail to produce more eggs than *Bulinus* and then a rapid increase in the first species to colonise a newly available habitat. Then, it may be difficult for *Bulinus* to become established and share the resources.

It appears, therefore, that any attempt to control the transmission of Schistosomiasis with molluscicides should be concentrated on eliminating the seasonal stream populations of snails. The most suitable time for an initial mollusciciding programme should be at the end of the rainy season, about the beginning of April when the streams are flowing at a fairly low velocity, the volume of water in the streams is highest and the number of snails has not built up.

CONCLUSION

The two respective vectors of bilharziasis in Zambia are found in the same habitat (Muchinshi stream). Both species are most dense during the dry season and fall to their lowest during the rainy season. *Biomphalaria pfeifferi* is most abundant in Muchinshi stream than *Bulinus* (p.) *globosus*. Control operations should be timed to cuase the maximum damage to a population just before the dry season and so drastically reduce numbers of snails. Therefore, application of a molluscicide to a stream from March to April, at the end of rainy season, would be a very effective control measure against the vectors of bilharziasis.

Summary

(i) Previous work done on Schistosomiasis in Zambia was largely concerned with the medical aspects and little had been made on the bionomics of the snail intermediate hosts.

(ii) For the purpose of this study, Muchinshi Village, which is one of the principle foci of infection with Schistosomiasis in the country, was chosen and a survey was conducted on the seasonal fluctuation in the population of the two snail species which inhabited the area, namely, *Biomphalaria pfeifferi* and *Bulinus* (p.) *globosus*.

(iii) For a period of 12 months (January to December 1986) four collections of snails were taken every month from a stream passing through the centre of the village.

(iv) Rainfall and temperature were found to be the most important factors determining the sequence of fluctuation in population density.

(v) These results are in substantial agreement with those of other workers in East Africa, Nigeria and Ghana.

(vi) The best time to apply molluscicides in this area is between the months of March and April.

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