The Study of the Biology of Schistosome Host Snails

BY

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Although the connection between bilharziasis and aquatic snails was established by 1913 in Japan, large scale attempts to control host snails only began in the late 1920's and 1930's. Unfortunately very little success attended early efforts to use biological control or snail-killing substances, molluscicides, although the use of the latter was pursued with much vigour in Egypt and the Middle East. In fact the vast quantities of copper sulphate and sodium petachlorophenate used in Egypt seem to have had little effect on the overall distribution of the host snails and no measurable effect on the incidence of the parasites in the human population.

In recent years, a new series of molluscicides have become available and are proving more effective, notably in Rhodesia, but much more knowledge of snail biology and ecology is required if they are to be used really efficiently. Entomologists have been faced with similar problems; experience with insecticides has shown that these can be applied more intelligently when reliable information is available about the biology and ecology of the insects under control. In fact serious mistakes have been made and control programmes have been badly hampered in the absence of such information.

Of course, studies on water snails have been going on for many years and important work has been done on their systematics and valuable data gathered on their geographical distribution. This all had to be done before a start could be made on studies on snail ecology and biology; pioneer work in this field was largely hampered by the fact that many early workers had little or no experience in hydrobiology, and were forced by circumstances to limit their work to small, short-term projects. What is surprising is not that results were limited but that some valuable facts have emerged.

It is now realised that the study of aquatic snails is a complex hydrobiological problem needing workers trained in hydrobiological methods and ecological principles, with support from comparative physiologists, geneticists, biochemists and others. All these have to be prepared to develop new methods adapted to the peculiar requirements of aquatic snails, and also to make co-ordinated attacks on important problems.

During the last 15 years or so more sophisticated research programmes have been started and useful results have been published. Many of these have been from studies on American and Asian snails but important papers on the biology of African species are now beginning to appear.

In Rhodesia the Research Laboratory of the Rhodesian Ministry of Health has done much valuable work on the effects of molluscicides, using newer preparations, such as Bayluscid and Shell WL8008. Not only have they shown that the use of molluscicides can be successful but they have produced some of the most pertinent information available on this form of snail control. In addition, members of the Research Laboratory team have published the results of important research on the effects of temperature on the biology of host snails and are now working on snail behaviour.

Shiff (1964) and Shiff and Garnet (1966) found that *Bulinus (Physopsis) globosus*, host to *Schistosoma haematobium*, responds more markedly to warmer summer temperatures than does *Biomphalaria pfeifferi*, host to *Schistosoma mansoni*. The snails were cultured under constant controlled conditions, but at different temperatures ranging from 18° to 27°C. Life tables of births and deaths were drawn up over a period of more than six months and used to estimate the "intrinsic rate of natural increase" of the different cultures. The egg-laying rate of *Physopsis*, was much higher in the warmer temperatures and the increase rate, calculated from births and deaths, reached a peak at 25°C. *Biomphalaria* responded to a much lesser degree and there was little difference between the increase rates at 20°, 25° and 27°C. Shiff concludes from this that *Physopsis* is able to take advantage of warm summer temperatures in a way not open to the other species; this would enable it to colonise temporary summer pools and to recover from catastrophes, such as scouring summer floods which sweep most of the population away.

This same property, if possessed by the whole of the subgenus *Physopsis*, could account for its penetration into the cooler parts of Southern Africa such as the highveld near Johannesburg and the Port Elizabeth area. Summer temperatures, even in these regions, often rise above 25°C. and the rapid reproduction at this time of the year would make up for the slow rate during the cooler or cold months.

The University College of Rhodesia and Nyasaland entered the field in the latter half of 1961 when a Snail Ecology Research Unit was established with the financial support of the Rockefeller Foundation of New York. The aim was to carry out research into the ecology of aquatic snails, specially schistosome host snails, and the research programme included the following main projects:

1. The resistance of aquatic snails to the drying up of their habitats.

Many important bilharziasis infection sites in Rhodesia and other parts of Africa are temporary waters which dry up completely at some stage during the dry season. It has been known for some years that schistosome host snails do survive prolonged periods of desiccation and recolonise temporary pools after the onset of rains. C. C. Cridland (manuscripts in preparation) carried out detailed investigations into this problem. He used both field stations and artificial pools on the laboratory roof. As a result of these experiments the picture is fairly clear but only a few main points can be mentioned here. Both *Biomphalaria* and *Physopsis* show remarkable ability to survive for more than three months in dried, sun-baked soil, especially muddy soil, but *Physopsis* proved to be the more resistant of the two. The age group which survived best was that most suited to go into vigorous egg production after the onset of the main rains.

More surprising were Cridland's findings on the survival of these two species on the surface of slightly damp, black, muddy soil in direct sunlight. A significant percentage of larger individuals were still alive after 30 days. These results show the futility of attempts to clear irrigation systems of snails by drying them out for short periods, and also provide important information basic to molluscicIding programmes.

2. The effects of the chemical composition of natural waters on the structure of snail populations and on snail biology.

Natural waters in Southern Africa vary tremendously with regard to their content of dissolved calcium, magnesium, bicarbonate and other ions. These differences are linked to the surface geology and the rainfall. It was realised that this must have some effect on the distribution of snail species as well as on the vigour of snail colonies, but published information was very meagre. It was found that natural waters around Salisbury showed great variation in ionic content and so high priority was given to field work and laboratory studies in this project.

N. V. Williams (manuscript in preparation) investigated snail populations in natural waters within a 50-mile radius of Salisbury. At some stations the water contained very low concentrations of calcium and bicarbonate ions and was classified as "soft", at others the concentrations were high and the water classified as "hard", at yet others the concentrations lay in between and these were classified as "medium". Snail distribution was most interesting. Taking all snail species into account, both schistosome host snails and others, the highest densities were found in the medium waters and the lowest in the really soft waters. *Physopsis* populations were densest in medium waters but the species occurred also in the hard and soft waters. *Biomphalaria* occurred at highest densities in medium waters, was very common in hard waters but was entirely absent from most soft waters.

Williams (manuscripts in preparation) cultured the bilharziasis host snails according to the methods used by Shiff, but he kept the temperature constant at 25°C. and varied the ionic composition of the culture waters. He used a series of calcium concentrations in the range: nil to 50 mg./l calcium as Ca, in which he kept bicarbonate values above 30 mg/l as $CaCO_3$, and a series of bicarbonate concentrations in the range: nil to 800 mg/l as $CaCO_3$ in which he kept the calcium values above 10 mg/l as Ca. He tried to keep other ions as constant as possible or within the ranges found in natural waters.

Life tables were drawn up and the intrinsic rate of natural increase estimated. Both species gave a peak for this parameter in waters with medium concentrations of calcium and bicarbonate, such as Lake McIlwaine water, and values fell off in the harder and softer waters. However, there was a large difference between the response of the two species. *Physopsis* gave a low peak in the medium waters and the range between the highest and lowest values in the whole series was not great. On the other hand the peak for *Biomphalaria* was high and values fell off markedly in the harder and softer waters, especially the latter, and the range between the highest and lowest values in the series was large. Williams points out that this could mean that *Biomphalaria* responds to a greater extent than does *Physopsis* to different levels of calcium and bicarbonate. These results fit in well with the distribution of these two species in the natural waters around Salisbury.

Later work, Harrison and Shiff (in Press), has confirmed Williams' laboratory results. He used a sample from only one field population, but the experiment was repeated using samples of *Biomphalaria* from widely separated districts. When these were cultured the same pattern of results was obtained, with increase rates highest in "medium" water, lower in "hard" water and very low in "soft water". However, a further point emerged, although the samples from the different populations gave the same pattern of results, no two populations gave the same individual results. One population had consistently higher increase rates in all waters, due mainly to higher egg-laying rates, while another took longer to reach egg-laying stage in all test waters.

From this it would appear that we have, in Rhodesia, a number of populations of *Biomphalaria* more or less genetically isolated one from the other; although they all show the general properties of the species each has developed its own particular characteristics. This could be of importance in mollusciciding programmes, especially if various populations or "strains" show different recolonisation rates after mollusciciding, and should there be differing degrees of susceptibility to molluscicides or even molluscicide resistant strains.

3. The effects of the mollusciciding of streams on the snail populations and on the rest of the aquatic fauna.

Wherever large-scale mollusciciding programmes have been embarked on, there have been objections because of the observed or suspected effects on the rest of the aquatic fauna, mainly the fish, but also bottom animals and plankton which form fish food. Other objections have been on the grounds that snail predators might be more sensitive to the molluscicides than the snails themselves, so that snail populations might build up even greater densities once mollusciciding had stopped. There have also been lurking fears about upsetting the "balance of nature."

The University College's molluscicide studies were carried out in close collaboration with the Research Laboratory of the Ministry of Health who applied the molluscicide, mainly Bayluscid.

The first investigation was into the effects of "blanket" treatment of stream catchments, when all tributaries and swamps in the catchment were thoroughly sprayed with molluscicide. Summarised, the main effects were as follows (Harrison, 1966).

1. Aquatic snails were virtually eliminated.

2. All fish were killed. Fish died more rapidly in waters low in dissolved calcium and bicarbonate than in waters with these in higher concentrations.

3. The invertebrate fauna, other than snails, was not seriously affected, notably insects and crabs which prey on snails.

4. Recolonisation by *Physopsis* and *Biomphalaria* was slow, in some cases none was found after 22 months.

5. During the subsequent three months only, there were local increases in insect larvae, including mosquitoes. These changes were linked, probably, with the elimination of fish.

Another study, supported by the World Health Organisation, investigated the results of "surveillance" treatment. Streams were given an initial blanket treatment and subsequently surveyed for snails once every six weeks, spraying with molluscicide was then limited only to sites where snails were found. The streams studied had been under surveillance for more than two years and the main results were as follows (Harrison and Mason, 1966).

1. No schistosome host snails were found in the treated streams until surveillance was discontinued, towards the end of the survey period.

2. The surveillance treatment appeared to have no significant effect on the invertebrate fauna, including snail predators, and no abnormal increases in mosquito larvae were recorded.

3. Fish had not been eliminated in the one stream sampled for them.

4. When surveillance treatment was discontinued, schistosome host snails returned within two or three months. Abnormally high densities of *Physopsis* were encountered in one soft water stream but these fell off during the next five months.

With these and other results becoming available the almost completely blank pages are beginning to be filled in, and we have started to gather relevant knowledge about the biology of African schistosome host snails. Nevertheless this is a mere beginning and the research effort must be kept up and increased to obtain more basic knowledge and to apply this to snail control programmes.

The following lines of research would appear to be necessary, apart from those already in hand:

1. Investigation of the different strains within host snail species resulting from genetic isolation,

methods of identifying them, studies of their different properties in culture, their susceptibility to schistosome infections and their reactions to molluscicides and other forms of control.

2. Population genetics of aquatic snails. Practically nothing is known about this at present; studies in this field would tie in with the above project and would be basic to an undertaking of snail strain differences.

3. Snail-schistosome relationships; for instance the effect of the ionic composition of the water on miracidial viability and snail infection rate. There is also much to be discovered about the viability of infected snails.

4. Snail population studies: for instance the effects of snail densities on reproduction rates, inter-specific competition and snail-predator relationships.

5. Snail parasites and pathogens. These must be playing a major part in controlling natural populations and there is some evidence that, apart from nematode and trematode infections, smaller, unidentified pathogens are active These should be identified and investigated as of possible use in snail control programmes.

Salisbury is an almost ideal centre for implementing this programme. Here we have the active Research Laboratory of the Ministry of Health giving close co-operation to research workers in the Zoology Department and Medical School of the University College. Two, if not three host snails are common in the region and a wide range of natural and artificial water bodies are available for study under varied chemical and climatic conditions. Most important of all, experienced workers, who have already proved themselves, are available.

What is needed is continuing and extended financial support from fund-granting bodies, some of whom have already played a most laudable part in supporting the work already completed.

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