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CONTROL OF SCHISTOSOMIASIS BY USE OF BIOLOGICAL CONTROL OF SNAIL HOSTS WITH SPECIAL REFERENCE TO COMPETITION

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For a number of decades the control strategy for schistosomiasis and other tropical vector borne parasitic diseases has varied greatly and been subjected to currently available knowledge and capacity, adapted to the actual economical and infrastructural conditions in endemic areas. During the sixties and up to the end of the seventies, control strategy was based primarily on the control of intermediate hosts/vectors. The necessity of eradicating certain species of vectors in order to control the major diseases was advocated by even the highest health authorities, WHO. This strategy failed, simply because of insufficient knowledge of the organisms one sought to combat and because the pesticides/molluscicides used were not specific or effective enough. Not only undesirable ecological side effects resulted, but certain vectors developed a resistance to the substances employed.

As far as schistosomiasis was concerned, the impossibility of eradicating or simply controlling the intermediate snail hosts populations using the existing molluscicides was recognized during the seventies. The availability of new and very effective drugs led to a total change in the aims of control strategy, shifting from a control of the disease in the direction of morbidity control. This strategy is the one that is recommended and used today by WHO. The effective therapeutic drugs can be fitted into an integrated control programme which also includes sanitation, safe water supply, snail control and health education. These elements can easily and with full right, since they are preventive steps, be integrated in primary health care programmes.

One possible way of tackling the problem of tropical parasitic diseases is vaccine strategy as we know it from various viral and bacterial diseases. The possibility of developing a vaccine against schistosomiasis, something which appears to have current interest given the latest conquests in molecular biology, is being discussed constantly and awarded top priority in international research circles.

For almost a generation, the immunological side of schistosomiasis has attracted great interest and appropriated extensive resources, and will undoubtedly continue to do so. While this development naturally has its positive attributes, there are also unseen negative effects, a discrepancy which will be more and more marked in the future. The financial foundation for research in other aspects of schistosomiasis control, and the economic means which are absolutely essential for alternative control programmes to go beyond the stage of wishful thinking and into the active phase, are simply not there.

Naturally the size of the available economic means is a practical matter, but it is our responsibility as researchers and human beings to influence the politicians and to point out the possibilities which exist for controlling schistosomiasis. Here one must distinquish between long-term aspects of control such as vaccine and possible alternative control methods, and the tools which are available today, which when implemented can give good results.

One such alternative control possibility is biological control. Biological control has been the subject of much discussion during the past 30 years, but very little has taken place, primarily because this discipline has failed to capture the interest of the opinion and decision makers. There is very little research material today which is relevant for biological control and schistosomiasis. What exists is often put forward, discussed and rejected. The present research results are anything but unanimous, based on biology as they are, and vary greatly owing to the number of factors involved.

In other areas, for example agricultural and horticultural pest control, much has happened during the past decade. It has been proven that pests can be combatted by other means than poisons and pesticides, namely biological control. These results should absolutely have an encouraging effect on schistosomiasis and other vector borne diseases.

Biological control methods can very easily be fitted into the primary health care system and with great success. At the risk of being provocative, it can be noted that these results with biological control in agriculture/horticulture are just as, or perhaps even more encouraging, than the facts we possess today which can help us develop a vaccine against parasites such as *Plasmodium* spp., *Trypanosoma* spp. and *Schistosoma* spp.

Biological Control

Over the years I have given many lectures on the biological control of schistosomiasis. Unfortunately there is little change in the content of these lectures, since research has made slow progress. At an informal consultation on research on the biological control of snail intermediate hosts held under the auspices of UNDP/World Bank/WHO special programme for research and training in tropical diseases in Geneva in January, 1984, (WHO, 1984) the basis was laid for future years' efforts, but results have not yet been very obvious.

For a better understanding, a short resume of the various candidates for biological control and of the evidence we have concerning special competitors with a positive effect follows below. The list of suggested biological control candidates of intermediate snail hosts ranges from bacteria to birds and basically may be divided into three groups: *parasites/pathogens, predators/parasitoids* and *competitors.*

1. Pathogens

Microbial Pathogens

It is reasonable to assume that snail hosts, like other organisms, may be attacked by a variety of microbial pathogenic organisms. Only a few scattered studies have been undertaken and these most often in the laboratory using only the materials at hand. Investigations of this nature should be carried out exclusively in endemic areas making use of the most recently collected material and in collaboration with microbiologists.

Parasites

Parasites, including schistosomes, reduce the fecundity of snails. The main interested has centered on echinostomes (Lim & Heyneman, 1972; Combes, 1982). Several field trials to prevent transmission of schistosomiasis have failed (Lie et al., 1974).

2. Predators/Parasitoids

Some vertebrate predators, especially fish, can contribute to the suppression of snail host populations in certain specialized situations (e. g. fish ponds), but sound evidence of their efficacy is lacking and needed. Their inability to respond appropriately to rapid changes in prey density may be a major constraint. Birds and turtles have both been suggested as possible control agents. Sciomyzid flies are obligate predators of molluscs and have been used with some success against *Lymnaea* species (Chock et al., 1961; Berg, 1972; Eckblad, 1973).

3. Competitors

In recent years, many authors have published the results of their findings on intermolluscan competition involving either prosobranch or pulmonate species.

The competitors are considered to be the most promising group of snail host antagonists so far identified. Apart from their direct effect on target snail numbers, there is some evidence that their presence may influence the success rate of miracidial penetration by acting as a miracidial sponge or through a "decoy effect". The following have been tried both in the laboratory and under field conditions: *Thiara granifera, Marisa cornuarietis, Pomacea haustrum, Helisoma duryi, Biomphalaria straminea* and *Bulinus tropicus.*

Marisa cornuarietis was first observed in Puerto Rico in 1952 (Oliver-Gonzalez et al., 1956). As far as is known, under tropical African conditions, there has been only one field investigation of *M. cornuarietis.* Following its release into a man-made pond in the northwest of the United Republic of Tanzania, three species of indigenous snails *(Biomphalaria pfeifferi, Bulinus tropicus* and *Lymnaea natalensis)* were apparently eliminated (Nguma et al., 1982).

Thiara (= Tarebia) granifera has also been reported to be an effective antagonist of *Biomphalaria glabrata.* It has been observed to replace a previously thriving population of *B. glabrata* in an extensive habitat on the island of Dominica (West Indies) and may have been responsible for severely restricting the range of the previously widespread *B. straminea* on the island of Grenada (Prentice, 1983). In contrast to these chance observations, *T. granifera* was released in limited areas of the island of St. Lucia in early 1978 (Prentice, 1983). In four separate field trials, *B. glabrata* was apparently eliminated from marshes and streams six to 22 months after the introduction of *T. granifera.* The time at which the target population reached zero was dependent on the number of *T. granifera* introduced.

With regard to *Helisoma duryi,* some successes have been reported from lentic environments. *H. duryi* was first tried in the field, with some success, in Puerto Rico in 1958 (Ferguson, 1978; Frandsen & Madsen, 1979). In St. Lucia, *H. duryi* was shown to compete successfully with *B. glabrata* in simulated field conditions, but when released into the environment it failed to become established (Christie et al., 1981). On the African continent, where it is now widely recorded, preliminary studies were carried out in small ponds in Egypt. At Moshi, United Republic of Tanzania, a field experiment in an irrigation system was started in 1973 and after one year, *H. duryi* exceeded *B. pfeifferi* and constituted more than 95% of the snails collected (Rasmussen, 1974). In 1975, *H. duryi* was seeded in the drains of the irrigation system. A snail survey undertaken in 1981 showed that *H. duryi* was still present in a few drains in which no *B. pfeifferi* snails were found (Madsen, 1983). It should be added that there was also continuous molluscicidng.

Other possible antagonists in field situations suggest that snails may play an important role in the control of intermediate host snails. For example, replacement of *B. glabrata* appears to be correlated with *B. straminea* over a period of probably not more than 10-15 years. Whereas before 1967 *B. glabrata* was widespread, in 1983 it was restricted to only a few habitats; the converse is true of *B. straminea,* which has become widely distributed during the same period (Guyard et al., 1983). In the site of Grand Etang, Guadeloupe, fortuitous colonization by *Ampullaria (= Pomacea) glauca* resulted in the decrease of *B. glabrata* densities, while *S. mansoni* prevalence in rats dropped from 80% to about 5% in five years (Pointier et al., 1983).

Recent field trials on biological control

There is no doubt that snail host population densities in certain kinds of habitat can be drastically reduced, even eliminated, by intermolluscan competition. However, if snail competitors are to be truly successful, they must also contribute significantly to control of the parasite populations which cause disease at levels of socioeconomic significance. With this objective in mind and in relation to the new strategies for schistosomiasis control, which distinguish between schistosomal infection and disease, absolute prevention of transfer of the parasite from snail to definitive host may not be strictly necessary. Unfortunately, snail host population density thresholds, permitting different levels of schistosome transmission (low, moderate, intense), are still unknown. They are likely to be variable, depending on the complex interactions of physical, chemical and biological parameters, but, despite their complexity, a good understanding of them woul ensure a valid interpretation of the efficacy of biological or any other snail control procedures.

In order to demonstrate that there is a continued interest in biological control and that this viewpoint is justified, can be seen in a new example of a field research project dealing with schistosomiasis and biological control. The project has been carried on since 1984 in Sudan as a joint venture between the Blue Nile Health Project and the Danish Bilharziasis Laboratory. The project is supported by the Sudanese who supply funds, personnel, accommodation and transportation and by the Danish International Development Agency (DANIDA) which has stationed DBL staff in the area and financed PhD studies for Sudanese students. Dr. Asim Dafalla and Dr. Khaled Karoum represent the Sudanese and Dr. Henry Madsen and Dr. John Meyer-Lassen primarily have been involved from the Danish side. The project takes place in the outskirts of the large Gezira irrigation scheme and the area was selected in order to avoid inadvertent spreading of the competitors used. It was begun in 1984 and a total of 12 minor canals of approximately two to three kilometers each in length are involved in the experiment. The canals are divided into four groups: one for control, and three other groups with a competitor snail each consisting of *Lanistes carinatus,, Helisoma duryi* and *Marisa cornuarietis.* The snails were set out on a number of occasions and approximately 10,000 snails have been used in the test groups. Collections have taken place regularly during the past three years.

The situation in May, 1987, was as follows:

Some of the introduced snail populations grew well from the start while others took a longer time to become established. The results for *Marisa* are especially promising and will be studied in greater detail. In two of the three canals *Marisa* established itself very well and has now spread to other canals with a population density which is very large. The work was undertaken by J. Meyer-Lassen, K. Karoum and H. Madsen and the results will be published later. Additional articles will be written in connection with Khaled Karoum's PhD studies and thesis.

B. pfeifferi and *B. truncatus* are present in very large numbers in the control canals as well as the experimental canals, while *M. cornuarietis* is only very numerous in a lesser number of localities, although the populations are on the increase. Totalling the number of snails from all collection areas would present, therefore, an incorrect picture.

In September, 1987, approximately 1500 *Marisa* and 300 *B. pfeifferi* were collected in the one experimental canal according to standard collecting procedures; the corresponding figures for March, 1987, were 1000 and 500, respectively. Each canal is divided into a number of collection sites and *M. cornuarietis* was clearly predominant in the experimental canals, in relation to both *B. pfeifferi* and *B. truncatus.* These two species, however, were clearly in the majority at the beginning and end of the canals.

A direct effect of *Marisa's* presence, however, is an almost total lack of vegetation in the canals. For example, in 50% of the *Marisa* sites investigated, there was only a vegetation coverage of 5%, whereas in 50% of the sites without *Marisa*, there was a vegetation coverage of 75%. In other words, *Marisa* is an excellent cleaning agent and there is a clear negative correlation between *Marisa* and the vegetation. The decline in vegetation evidently will also have an effect on other snail species, an effect which future data will hopefully reveal.

In connection with the project, studies were also undertaken to assess the likelihood of *Marisa* surviving aestivation. Canals which had dried out for at least 6-8 weeks were chosen. A lump of material from the bottom was gathered, measured for humidity and dissolved in water. The number of snails which emerged within 48 hours was then registered. The overhead clearly shows that the prosobranchs manage aestivation very well, especially *Marisa.* Spreading to other canals is caused by the fact that now and then the farmers make smaller canals between the minors.

The preliminary results are very positive and it is obvious that the project should continue, also in order to elucidate a possible effect on schistosomiasis transmission.

As is shown, the study is most encouraging, but there are still a number of areas which must be examined before any final conclusions can be reached. One can only hope that this type of experiment will attract greater economic support and foster a positive attitude towards biological control in coming years, since such a means of snail control can be readily adapted to the primary health care system.

Economic development in the developing countries is a slow process, but a gradual improvement of the health situation will undoubtedly occur as additional pit latrines are put into use and as the supply of safe water is improved and extended. Neither must we forget the importance of health education, which must also be extended gradually. Chemotherapy will of course still be important in the most serious cases, but given the economic resources, a long-term control project can naturally be combined with this strategy.

The production of a vaccine would undoubtedly be of great benefit for control programmes, but one must keep in mind related problems that are bound to occur – how much and what sort of coverage, the frequency of injections, etc. Therefore, it is the hope that the possibilities within this little, yes almost microscopic, niche in schistosomiasis research called biological control, and indeed any other alternative control programme, can be extended and to provide a reasonable chance to undertake the necessary research. Perhaps the new molecular biology with its ability to create specific pathogens and mass produce them, will be able to give an impetus to biological control.

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