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ECOLOGICAL STUDIES ON THE INTERMEDIATE HOST SNAILS AND THE RELEVANCE TO SCHISTOSOMIASIS CONTROL

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A detailed knowledge of distribution patterns of schistosome intermediate hosts and their population dynamics and factors affecting these patterns will provide useful information about the possibilities and desirability of conducting snail control measures in various transmission situations. On the basis of various case studies the association between the occurrence of human water contacts and the presence of schistosome intermediate hosts or infections in the intermediate hosts is illustrated. Other parameters affecting snail distribution patterns and density fluctuations are discussed. It is concluded that ecological studies on the intermediate hosts are extremely relevant, either to optimally apply existing control measures or to develop alternative measures of snail control, such as ecological or biological control.

Key words: schistosomiasis control – intermediate host snails – ecological studies

The present strategy of schistosomiasis control is based on morbidity control within the framework of the primary health care system (Mott, 1984). Morbidity reduction achieved through chemotherapy can best be maintained through parallel preventive measures reducing the exposure to cercariae-infested water (Wilkins, 1989). Water supply and sanitation programmes as well as health education are important measures in an integrated approach to schistosomiasis morbidity control. However, such control measures may have little impact on water contacts of a recreational nature among the younger segment of the human population or on occupational water contacts (Jordan, 1977). Snail control, therefore, is an important control measure to reduce exposure to cercariae infested water, especially in areas where transmission patterns are simple and focal and where the amount of water is relatively small.

Detailed studies on distribution patterns of schistosome intermediate hosts and their population dynamics and dynamics of schistosome infections in the host snails and factors affecting these patterns, will provide useful information about the possibilities and desirability of conducting snail control measures in various transmission situations. Patterns of snail distribution and seasonal density fluctuations vary greatly not only from one region to the other, but also within a limited area in the same habitat and from one year to the other. Such information is obviously essential for optimizing a strategy for the control of schistosome intermediate snail hosts, i.e. which are the most important transmission sites and seasons and which indicators should be used to identify transmission sites and determine whether to do snail control in an identified site at a given time. At present, focal molluscicide application implemented seasonally according to the transmission pattern, is the most realistic approach to snail control (Klumpp & Chu, 1987).

Furthermore, a detailed understanding of factors responsible for observed distribution patterns and fluctuations in density may help in the development of alternative snail control procedures such as environmental or biological measures, either directed against the snails or aimed at destroying or modifying key elements in the snail habitat, such as for example aquatic macrophytes.

The variability of snail distribution patterns is illustrated below on the basis of previously published case studies of two irrigation schemes, i.e. Office du Niger in Mali (Madsen et al., 1987) and the Gezira Agricultural Scheme in the Sudan (Madsen et al., 1988).

"OFFICE DU NIGER", MALI

This extensive irrigation scheme was established in the late 1930s and is one of the most important areas for schistosomiasis transmission in Mali. The prevalence of schistosome infections varies greatly among villages. Data summarized in Doumenge et al. (1987) show *Schistosoma haematobium* prevalences in the range of 10.5-97.0% and *S. mansoni* prevalences in the range of 2.7-83.7%, i.e. areas of Ké-Macina and Niono. The main wet-season crop is rice, while vegetables are grown during the dry season. Irrigation for rice production starts around June and the rice is harvested in December-January. The scheme is fed from the River Niger at Markala. Shortly after the off-take, the canal divides into the two main canals, which lead water into two lakes, situated in ancient branches of the River Niger. Principal canals are taken off at various points from the lakes. The principal canals may be 20-30 m wide and feed other large canals called 'distributeurs'. From these canals (principal or distributary) secondary and tertiary canals lead water to the fields.

The only intermediate hosts of human schistosomes found in the "Office du Niger" were *Biomphalaria pfeifferi* and *Bulinus truncatus* (Madsen et al., 1987). Both species were very common in the two lakes, in large (principal and distributary) canals as well as in smaller canals, but they rarely occurred in the field ditches. *B. truncatus* was found at low density in ditches in the periphery of a rice field, but rice fields were generally dry during the surveys (Madsen et al., 1987). Some human water contact sites (WCS) in the lakes and large canals contained very high snail densities and schistosome infections were normally recorded in these sites. *B. truncatus* commonly occurred in other habitats, whereas *B. pfeifferi* seemed to be restricted to the lakes and canal system (Madsen et al., 1987).

The lakes contain a dense growth of submerged vegetation reaching no more than 20-30 cm from the bottom. This vegetation was especially common where the bottom slope was low and at depths greater than 0.5 m. Both *B. pfeifferi* and *B. truncatus* were abundant in this type of vegetation. WCS where this type of vegetation occurs may be snail-free up to 5-10 m from the shore (depending on the bottom slope) if no marginal vegetation is present.

The principal canals are probably the most important sites for human water contact as most villages are located close to such canals. For each village there may be several WCS of varying importance. The aquatic vegetation varied considerably among canals and along each canal and this was related to a great variability in abundance of the intermediate host snails (Madsen et al., 1987).

Snail distribution, especially in large canals, appeared to some extent to be focal in this scheme and high snail densities appeared to be associated with human water contact activities, which apparently create favourable microhabitats for the snails. This is probably due to an alteration of the vegetation and an increase of the trophic status of the site by contamination with food remnants and other debris. Infected snails are found almost only in well-defined human water contact sites. Local infection rates with schistosomes were often high (i.e. up to 27% in *B. pfeifferi*). Generally, *B. pfeifferi* and *Bulinus truncatus* were associated with submerged aquatic macrophytes or emergent hydrophytes and were absent from areas without aquatic macrophytes. This absence of schistosome intermediate hosts from barren surfaces might be partly explained as the result of fish predation.

No conclusion could be reached about transmission in rice fields because these surveys were done during the dry season, i.e. after rice harvesting. However, there is evidence from other areas that transmission takes place primarily in canals necessary for field irrigation rather than in the fields themselves. Thus, rice fields seem not to constitute a favourable habitat for the schistosome intermediate hosts as temperatures may be very high (Wibaux-Charlois et al., 1982). Species like *Bulinus forskalii* and *B. senegalensis,* however, seem to be able to maintain populations within rice fields. Thus, *B. senegalensis* was found to live in rice-fields in Senegal (Vercryusse et al., 1985) and in Vallée de Kou, Burkina Faso (Madsen unpublished). Although *B. senegalensis* is an intermediate host of *S. haematobium* in some areas and common in Mali, though not reported from the "Office du Niger", schistosome transmission in rice fields is likely to be of minor importance, because human water contact is scattered and not very intense.

On the basis of the observed distribution patterns of the intermediate hosts, a programme of focal snail control using niclosamide in these well-defined and quite limited human water contact sites was evaluated (Madsen et al., 1986). In addition to the snail distribution pattern, financial constraints in buying niclosamide and the fact that these canals and lakes play a very important role for fish populations was taken into consideration, in order to to minimize the environmental impact of the treatment.

Niclosamide was applied in two different ways depending on snail distribution within the sites. When snails were found in marginal vegetation, 2-3 ppm was applied along the shore from 10-40 m upstream from the WCS to 10 m downstream. In case snails were found in low submerged vegetation, the chemical was applied at 2-4 g (a.i.)/m^2 directly between the plants. The results indicate that a satisfactory snail-kill can be achieved in the target area by this method of niclosamide application. However, the method requires a thorough surveillance for snails and supervision of the application. The time spacing of applications should be 4-6 weeks, but special situations may necessitate more frequent applications.

There is one report on the evaluation of this snail control strategy which indicates that operational use of the procedure is not particularly effective (Werler, 1989). This was judged from parasitological data from an area under focal snail control compared to an area without snail control operations (Werler, 1989). Unfortunately, no longitudinal snail surveys have been done in the area, and it is not known whether habitats other than large canals and lakes play a role in the transmission of schistosomes.

GEZIRA-MANAGIL AGRICULTURAL SCHEME (GMAS)

The Gezira irrigation scheme started in 1924 and the Managil extension opened in 1963 (Madsen et al., 1988). Together, they comprise approximately 840,000 hectares. The scheme is irrigated from the Sennar Dam on the Blue Nile through two main canals, i.e. one for the Gezira and one for the Managil. The open earth-lined and gravity-fed irrigation canals are designed to distribute water sequentially from the main canal as follows: branch, major, minor, 'abu eshreen', 'abu sitta' and finally field ditches. Minor canals are 1.42 km apart and taken off in pairs from major canals at off-takes 2.84 km apart. Each field has one field canal (abu eshreen) that takes water from the minor through a 30 cm pipe which can be sealed when not needed. Abu eshreens are taken off at each 300 m on the minor canal and run at right angles to the minor canals. The fields are divided into 4 ha holdings by abu sitta canals that run 300 m across the field from the abu eshreen.

The prevalence of intestinal schistosomiasis is high in the Gezira Agricultural Scheme, while that of urinary schistosomiasis is variable but generally low (Gaddal, 1985). *B. pfeifferi* and *B. truncatus* are very abundant and all types of canals in these irrigation schemes may harbour populations of the intermediate hosts of schistosomes (Madsen et al., 1988). In the main canal, fairly high densities of both *Biomphalaria pfeifferi* and *Bulinis truncatus* may occur just upstream of sluice gates, where water is relatively calm close to the shore. Minor canals are probably the most important transmission sites as snail densities are generally high and most of the human water contact takes place in these canals. The distribution of both snail species varies greatly in the area and from one year to the other as illustrated in Figs 1, 2. This variation can to some extent be related to the specific conditions in the minor canal, such as distance from the offtake, the function of the canal, physical and chemical characteristics of the canal water and biological factors in the site.

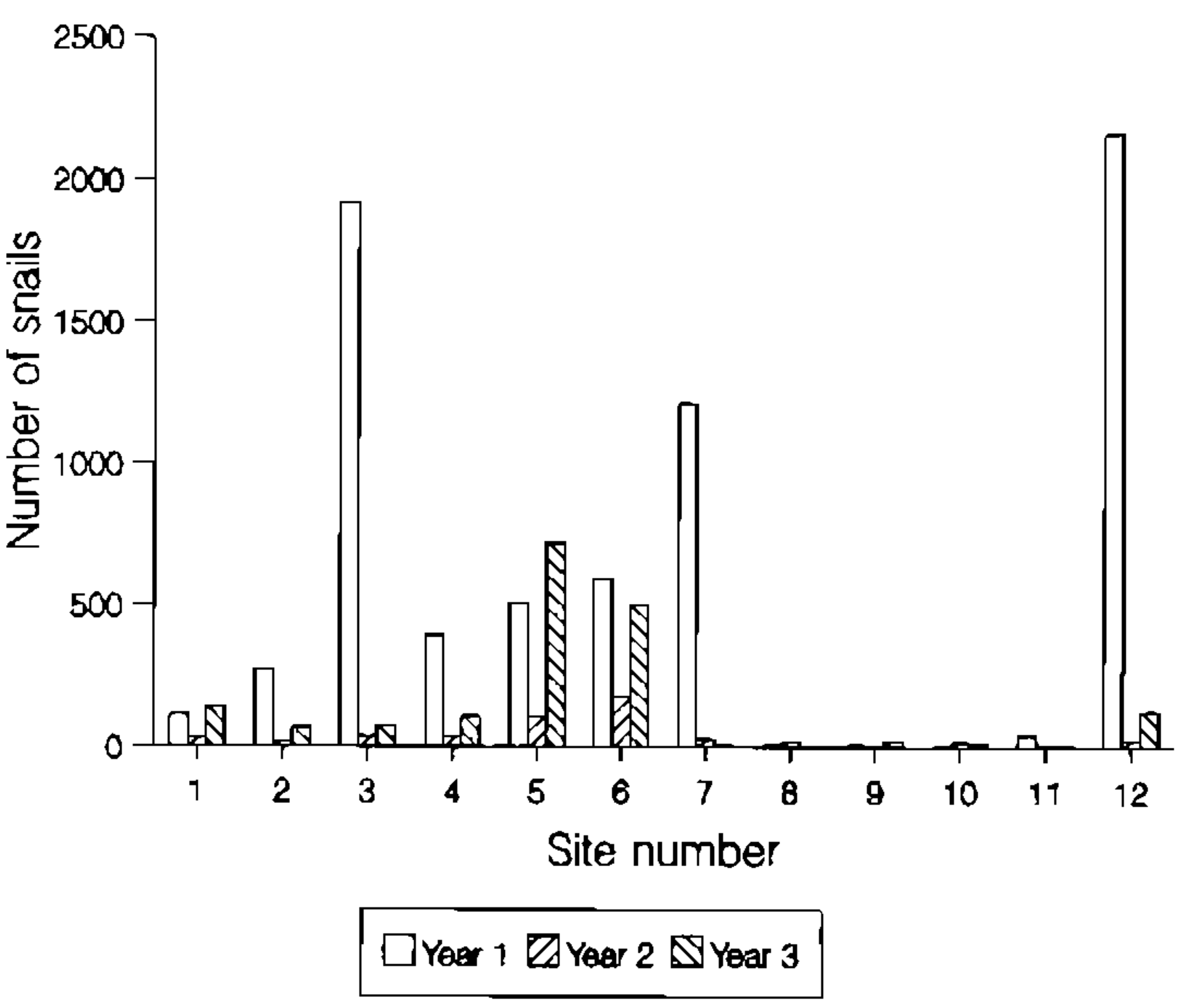

Fig. 1: total number of *Biomphalaria pfeifferi* collected in each of 12 sampling sites in a minor canal, El Bara, in the Gezira Agricultural Scheme by monthly sampling over three years, i.e. (1) November 1983-October 1984, (2) November 1984-October 1985, and (3) November 1985-October 1986. Site number 12 is close to the offtake, while site number 1 is the most distant (based on data from Karoum, 1988).

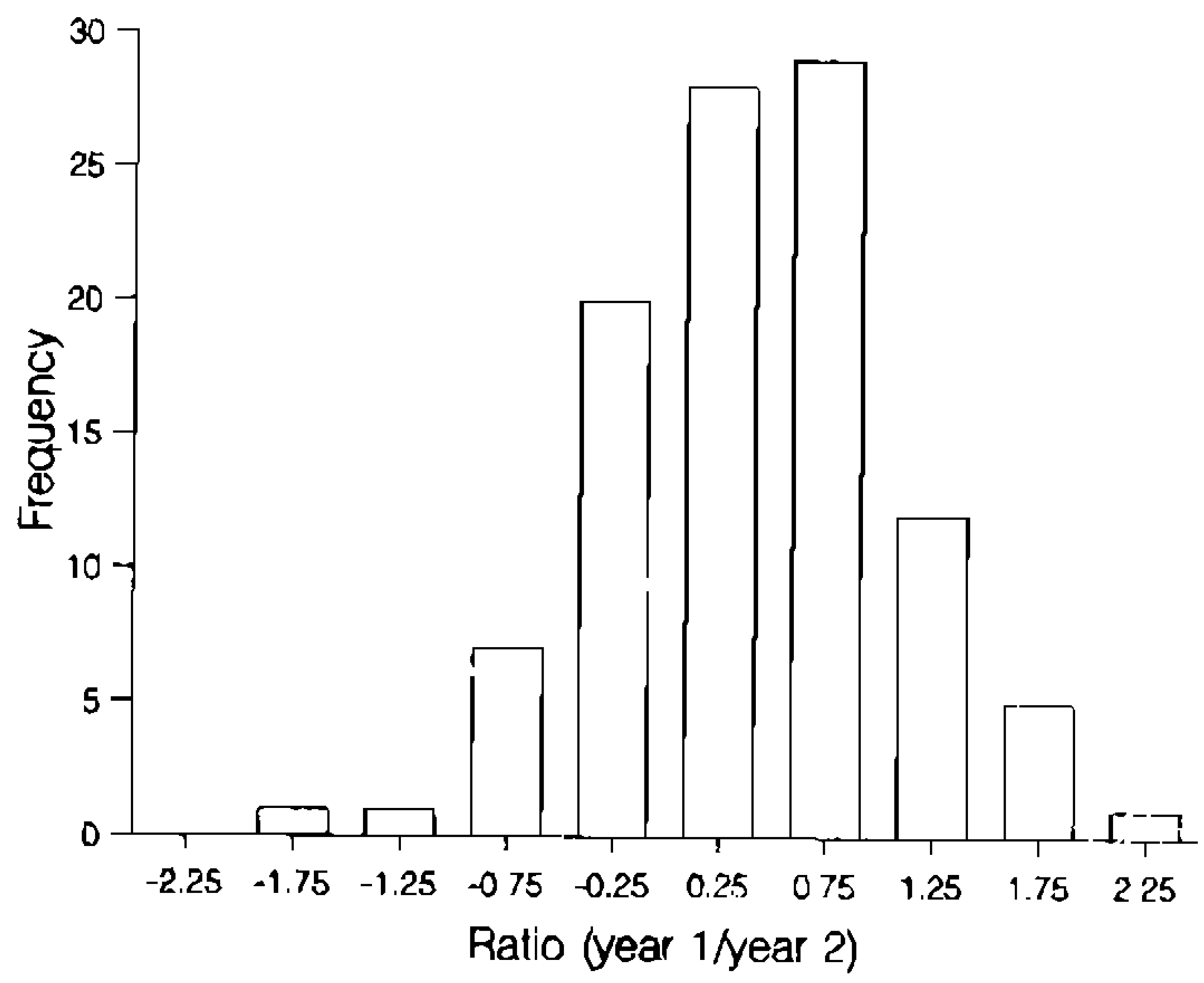

Fig. 2: ratio between total numbers of *Biomphalaria pfeifferi* collected by monthly snail sampling during year 1 (November 1983-October 1984) and year 2 (November 1984-October 1985), i.e. $\log_{10}$ [(snail count year 1 + 1)/(snail count year 2 + 1)] in 104 sampling sites in the Gezira Agricultural Scheme (based on data from Karoum, 1988).

Although the minor canals may appear rather homogeneous there is a marked variation in physical and chemical conditions of the water and some of this variation was related to the density and composition of the aquatic plants (Madsen et al., 1988).

Infected snails are widespread in these areas though the percentage infected is generally low (Madsen et al., 1988). However, infected snails are mainly found in the human water contact stretches. Thus, about 90% of all infected snails recorded from one village area were found in a few water contact sites close to the village (Babiker et al., 1985).

The density of *Biomphalaria pfeifferi* in minor canals is generally low during the period September-November when canal water turbidity is very high (Karoum, 1988). Density increases gradually from December and reaches a maximum in March-June when also the number of schistosome-infected *B. pfeifferi* shows a peak. Schistosome-infected *B. pfeifferi* were found every month of the year except September, i.e. period of high turbidity (Karoum 1988). There was a marked variation in the size of the peak from year to year (Karoum, 1988).

A standard procedure of applying molluscicide to all major human water contact sites, which are primarily located in minor canals in the proximity of villages, has been developed (Daffala et al., 1982). One Kg of niclosamide 70% WP is applied 300 m upstream from the contact site over a period of 30 min and this will give a concentration of 2-3 ppm, which has been shown to be effective in killing snails in the target canal stretch. However, there has been certain problems in this technique when carried out by village workers, and the programme is operationally difficult when conducted by a central team.

CONCLUSIONS

Schistosome transmission occurs in a wide range of habitats, and is generally of a focal and seasonal nature. There are clear differences in the distribution patterns of the intermediate hosts in the irrigation schemes in Mali and Sudan. In Sudan snails may be widely distributed at high densities while in Mali, snails showed a focal pattern of distribution with an association to sites where human water contact occurs. Schistosome infected snails, however, are generally found in WCS close to villages in both these irrigation schemes and such WCS may be exposed to a degree of organic pollution which may favour the intermediate host populations. Intermediate host snails are often associated with submerged or emergent aquatic macrophytes.

Focal molluscicide application implemented seasonally, according to the transmission pattern, is presently the most realistic approach to snail control (Klumpp & Chu, 1987). However, the approach may pose considerable operational problems and the development of alternative and long-lasting control measures such as ecological or biological methods is highly desirable.

A number of environmental control measures exists that could be used to reduce snail population densities especially in irrigation schemes. These methods have proved particularly effective against amphibious snails, though less promising against aquatic species. Aquatic macrophytes seems to constitute an important element in the habitat of the intermediate hosts, which often are strongly associated with aquatic macrophytes, particularly the submerged species (Thomas & Tait, 1984; Hilali et al., 1985; Thomas 1987; Madsen et al., 1988). If these macrophytes could be controlled, it is likely to have a profound effect on the intermediate host snails. Aquatic weeds may be controlled by mechanical removal or by biological means. Fish may be used to control aquatic macrophytes, for example the Grass Carp, *Ctenopharyngodon idellus,* endemic to eastern Asia, has proved useful in the control of weeds in irrigation canals and reservoirs outside this area. However, endemic fish may also be used for weed control. Thus, certain species of *Tilapia* are used to control weeds in irrigation canals (Lingen et al., 1960). Certain species may cause significant reduction in larval mosquito populations in paddy fields. Aquatic weed control, using the Grass Carp, also reduces the abundance of *Biomphalaria alexandrina* and *Bulinus truncatus* (Schayck, 1986). It would be highly desirable to combine the objective of controlling intermediate hosts or vectors of water related diseases with the objective of enhancing the potential for food production.

Biological control of snails is still at an experimental stage (Madsen, 1990). The most promising candidates are other non-susceptible snails that may act as competitors of the intermediate hosts. There is a need to undertake ecological studies, that would determine the role of interspecific competition and predation, parasites or pathogens in determining snail distribution patterns or population dynamics of the intermediate hosts and thereby evaluating the potential of utilizing biological measures of controlling the intermediate hosts.

In conclusion, ecological studies on the intermediate hosts are thus extremely relevant, either to optimally apply existing control measures or to develop alternative measures of snail control.

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