Schistosomiasis host snail control in irrigation night storage reservoirs

(TDR Project R 5837)

Report OD/TN 83
February 1997

HR Wallingford

ODA

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Contract

This technical note describes two biological control methods to control the host snails of schistosomiasis in irrigation night storage reservoirs. The study was funded by the Overseas Development Administration (ODA) of the British Government's Foreign and Commonwealth Office under the ODA Technology Development and Research (TDR) programme. The project details are as follows:

Theme	To increase protection of water resources, water quality and aquatic ecosystems
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The study was a three-way collaboration between HR Wallingford, the Blair Research Institute and the Danish Bilharziasis Laboratory (DBL). The Department of Agricultural, Technical and Extension Services (ARITEX), Zimbabwe collaborated in the main Schistosomiasis control study at Mushandike, Zimbabwe but were not involved in this study. The study includes the unpublished findings of M Phil and PhD theses by B Ndlela and M Chimbari of the Blair Research Institute, respectively. These theses were prepared at the DBL who provided financial and logistical support to Ndlela and Chimbari and who were involved throughout the project as partners.

The HR Wallingford job number was TPS 113/02.

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Approved by ....

Date ...March 97...

Summary

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The control of the host snails of schistosomiasis in irrigation night storage reservoirs is important if the users of irrigation water and the occupants of the villages served by the irrigation scheme are to be protected from excessive transmission of the diseases.

This technical note describes two biological control methods to control the host snails of schistosomiasis. Night storage reservoirs were of particular attention as previous studies by the joint HR Wallingford, AGRITEX and Blair Research Institute team in Zimbabwe, had shown that other snail control methods in night storage reservoirs were ineffective.

The two biological control methods studied were a) the introduction of competitor snails, and b) the introduction of two species of fish, one to reduce aquatic vegetation and the other to predate snails. The snail competition study examined in the laboratory and semi-natural ponds the interspecific competition between *Bulinus globosus* (a schistome host species) and *Bulinus tropicus* (a non-susceptable species).

B. Tropicus has a faster reproductive rate, predates the egg masses of *B. globosus* and in the short time period of the study appears to out compete *B. globosus*.

The fish study examined two species of fish, both indigenous to Zimbabwe, *Sargochromis codringtoni*, a malacophagous species (snail eating) and *Tilapia rendalli* a mainly herbivorous species (vegetation eating). The study on fish is continuing but early results indicate that the fish if used in combination can eat most species of aquatic snails including the target host species and remove the vegetation which offers some protection.

These biological methods have not been put into practice yet and larger scale studies on the practical use are needed. The methods look promising especially if combined with other operational methods previously recommended in the collaborative study, such as fluctuating water levels, desiccating reservoir beds and removing aquatic weeds. The Blair Research Institute is investigating a natural molluscicide, endod. The reported low toxicity of endod to fish may allow it to be used in combination with, for example, the fish predation method. The methods, if properly applied and managed, offer the opportunity of low cost acceptable snail control.

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1 Introduction

It is estimated that over 200 million people in numerous tropical and sub-tropical countries harbour the schistosome parasite that lives within the blood vessels of man and his livestock. Infection results in a debilitating disease known as schistosomiasis or bilharzia.

Part of the life cycle of the schistosome parasite takes place in various species of aquatic snails. In Africa, South America and the Middle East, the intermediate host snails of human schistosome species are pulmonate snails of the family *Planorbidae*. In Southeast Asia, prosobranch snails of the family *Pomatiopsidae* serve as intermediate hosts.

The construction of dams and the establishment of new irrigation systems can create habitats suitable for aquatic snails. Development policies in Africa and Latin America have given prominence to irrigation schemes in order to increase food production and reduce imports. Between 1974 and 1984 the rate of irrigation expansion in Madagascar, Mali and Nigeria exceeded 100%. In other parts of the world, such as Brazil, China, Indonesia, Malaysia, the Philippines and Thailand, large areas of irrigation have been developed. These areas are all potential sites for colonisation by the snail intermediate hosts of schistosomiasis.

There are many examples of increased transmission of schistosomiasis as a result of irrigation, the most dramatic being found along the Nile Valley in Egypt and Sudan. In 1990 the total number of infected individuals in Egypt was estimated to be between 5 and 6 million. The development of irrigation schemes in northern Cameroon resulted in an increase in the prevalence of urinary schistosomiasis, rising from 15% in 1950, to 30% in the early 1960's and up to 40% more recently (WHO, 1993).

Small reservoirs in particular, whether part of large irrigation schemes or constructed to provide a constant source of water for villages, create ideal conditions for the transmission of vector-borne diseases. The human and animal contact with water in these small impoundments is usually high and they can quickly become infested with the snail intermediate hosts.

In Nigeria and Zimbabwe, the total surface area of these small reservoirs has been estimated to be 8 to 10 times that of the larger, more obvious, reservoirs. In response to population pressure and seasonal hunger in Ghana between 1958 and 1960, 104 small reservoirs were constructed in the north-east of the country. As a result, the prevalence of *Schistosoma haematobium* infection in the local population tripled from 17% to 51% in 38 survey areas. The prevalence of urinary schistosomiasis in Mali was found to be five times as high in villages with small reservoirs, 67%, compared to only 13% in savanna villages (WHO,1993).

Night storage reservoirs store overnight flow from main canals or flow during periods when no irrigation is taking place, Figures 1 & 2. These small shallow reservoirs can provide an ideal habitat for snails. Certain species of snails can become hosts of the schistosomes if the water they live in becomes contaminated by infected humans. Schistosomiasis control therefore requires treatment of the infection through chemotherapy, improved public health and reduction of water contact to prevent contamination and infection and control of the snail hosts. From experience in the Sudan, Jobin (1973) reported that a promising method of control centred on the elimination of the snail in which the schistosome must spend part of its life.

Numerous methods for the control of snails, in order to reduce the transmission of schistosomiasis, have been tested, including pesticides and drainage. It is however recognised that new methods and engineering techniques need to be developed which can be incorporated into irrigation schemes, and in particular, night storage reservoirs to prevent colonisation of snails.

1.1 Control of schistosomiasis

The treatment of schistosomiasis has been transformed in recent years by the introduction of the anti-schistosomal drug, praziquantel. This has been found to be highly active against a wide range of trematode parasites, including all species of schistosomes pathogenic to humans. Along with the development of more simple, yet robust diagnostic techniques, emphasis in the control of schistosomiasis has changed over the last 20 years from snail control to chemotherapy for infected individuals.

The cost of praziquantel has declined significantly since introduction of the drug in 1981. Patent expiry in 1991 stimulated greater competition in its manufacture and further reduced the selling price. Govindaraj *et al* (1996)[1] report that as well as a reduction in producer prices, there exists a declining trend in the price that international agencies sell praziquantel to developing countries. WHO sold praziquantel to developing countries at a price close to US$1 per tablet in 1981. The current price is closer to US$0.20. Whilst the basic costs of chemotherapy may appear lower, the import of praziquantel still represents a foreign exchange burden for many African countries.

There is also some evidence that some patients, treated with praziquantel, continue to excrete a small number of eggs, particularly among children in endemic areas where transmission and morbidity are also high. Experience from the few control programmes conducted, based on this strategy, reveals that the maintenance of low levels of morbidity requires repeated chemotherapy at a frequency which is neither logistically nor economically feasible (Butterworth *et al*, 1987: Wilkins, 1989).

Chemotherapy will reduce morbidity in the short term, but other options are still needed to control the disease, the parasite and the hosts. Snail control operations remain important, as part of the overall control strategy, to achieve sustained reduction in transmission (Madsen, 1992).

1.2 Snail control

All types of aquatic snail prefer a permanent or semi-permanent source of well oxygenated water, preferably out in the open and rich in aquatic plants and organic matter on which to feed.

Eradication of host snails has only been possible in a few situations, eg oasis in Tunisia, and in all other situations, snail control is perpetual (WHO, 1993).

The ability of some aquatic snails to aestivate in order to survive periods when their habitat water dries up in summer, has been confirmed by a number of studies (eg Goll & Wilkins, 1984, Malek, 1972, Greany, 1952). In natural pools, aestivation has been observed to commence as the pools gradually dry out and some snails start to bury themselves into the soft sediment. During the dry season some snails can aestivate for 6-8 months or even longer.

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[1] http:// www.hsph.harvard.edu:80/Organizations/takemi/pzq/pzq.html

Studies on control measures, such as frequent and irregular periods of rapid desiccation, applied outside the snails natural aestivation periods, have been reported (eg Muller, 1978, Jobin, 1973). These measures, aimed at subjecting the snails and the egg masses to short terms of stress, have recorded some success.

Chemicals have been used for some time to destroy snails and hence break the life cycle of the parasite. Synthetic molluscicides are not particularly specific to freshwater snails (Jordan, 1985) and all forms of aquatic life are affected by their use. The two strategies for using molluscicides are (a) area wide control and (b) focal control, Jordan (1985) describes these strategies in detail, using the example of studies in St Lucia. Full details of the costs of materials, chemicals and staff inputs to undertake molluscicide treatments are not available for Zimbabwe though it is expected that the relative advantages and disadvantages of the strategies will be similar to the St Lucia experience.

In Zimbabwe, many different chemicals have been used as molluscicides in the past but at present niclosamide[2] is the only commercially available compound. In terms of foreign exchange niclosamide continues to be an expensive option for snail control.

The experience in Zimbabwe is that area wide use of niclosamide on irrigation schemes can only be afforded by the large commercial companies. The focal application of niclosamide to known transmission sites reduces chemical consumption, but increases the operational and labour costs. Where human contact with contaminated water occurs over a wide area, extensive surveillance programmes are required to locate all of the transmission sites. In addition, rapid re-colonisation by the intermediate host snails usually follows focal molluscicniding and regular applications are, therefore, necessary. Furthermore, synthetic molluscicides have undesirable environmental impacts. They are non-specific pesticides and are toxic to fish and other aquatic organisms. There is also the possibility that snails may develop resistance. It was consideration of these factors that made it desirable to search for other control strategies.

The extent to which engineering / environmental measures could reduce the problem of schistosomiasis in small scale irrigation schemes, without the use of molluscicides, has been implemented and monitored at the Mushandike irrigation development which is located in southern Zimbabwe, Figure 3. This project, which was funded by the British Overseas Development Administration (ODA), adopted a three-way multi-disciplinary approach between HR Wallingford engineers, the agricultural engineers and planners of AGRITEX, and the health experts of the Blair Research Institute.

HR Wallingford reports on the first two phases of this project have been published, in OD 123 (Chimbari *et al*, 1991) and in OD 128 (Chimbari *et al*, 1993), respectively. Practical guidelines for the control of schistosomiasis in irrigation developments have been produced, aimed primarily at non-health specialists, HR Wallingford Report OD/TN 78 (Thomson *et al*, 1996).

Although the control measures were found to be effective at limiting the extent of snail colonisation over most of the irrigation network, the night storage reservoirs were found to be a particular problem area. Observations made during the field surveys on the distribution and abundance of the various aquatic snail species,

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[2] Niclosamide is produced by Bayer AG under the registered trade name Bayluscide®

led to the view that biological control methods could play an important role in controlling the host snail species in night storage reservoirs.

Snail control measures can be classified into three; (a) chemical, (b) engineering / environmental, and © biological. This technical note focuses on laboratory and field experiments in Zimbabwe to develop biological control methods involving; (a) a non-susceptible competitor snail species, and (b) two species of fish, one primarily herbivorous and one malacophagous (snail-eating) as biological agents to control schistosomiasis host snail species.

2 Biological control of snails by competition

The introduction of non-susceptible snail species which may act as competitors of the intermediate host species is considered by the World Health Organization (1984) to be a promising approach for the biological control of the intermediate host snails of schistosomes.

The most extensively studied competitors are *Marisa cornuarietis, Helisoma duryi, Thiara granifera* and *Melanoides tuberculata*. These competitors may be effective in certain habitats, but as the habitat preferences of each species only partially overlap with those of the host snails their use is limited.

The greatest success so far has been in the Caribbean area where there is evidence that *M. tuberculata* and *T. granifera,* which were introduced about 40 years ago, have spread and reduced populations of *Biomphalaria glabrata* in certain habitats (Pointer and McCullough, 1989).

M. tuberculata is widely distributed in Africa and studies in certain areas have reported that it apparently coexists with schistosome intermediate host species. In Sudan, for example, there is no negative association between *M. tuberculata* and *B. pfeifferi* (Madsen *et al*, 1988).

There is some evidence, from studies conducted in Brazil and Martinique, that schistosome-resistant strains of *Biomphalaria straminea* can replace the closely related *B. glabrata.* However, this approach was not recommended by an informal WHO consultation (WHO, 1984). In other parts of Brazil, *B. straminea* is an important intermediate host and, although insusceptible strains can be found, there is no guarantee that they will remain resistant or that they will be resistant to new *S. mansoni* strains that might be imported (Madsen, 1990).

Other problems may arise with introduced species of aquatic snails. They may cause damage to crop plants or serve as intermediate hosts for various other flukes which are of veterinary importance. For example, there are reports that *M. cornuarietis* may harm young rice seedlings (Ortiz-Torres, 1962; Seaman and Porterfield, 1964), and diseases caused by liver flukes (Fasciola) and stomach flukes (paramphistomes) result in major economic losses in cattle, sheep and goats. The worldwide economic losses from these parasitic flukes has been estimated at more than US$3 billion per year (FAO, 1994).

Stringent precautions are necessary, therefore, before initial experiments with introduced species and the possible impact on crop plants, harmless native species and its medical and veterinary host potential has to be carefully evaluated. For these reasons there is, understandably, strong opposition against the introduction of foreign species into an area for biological control. It is much preferable to search for possible competitors among indigenous species of snails.

This study investigates the potential of the closely related and indigenous, non-susceptible *Bulinus tropicus* species as a possible competitor to *Bulinus globosus*, a host species of *S. haematobium* in Zimbabwe and other parts of Africa.

The objective was to investigate the competitive inter-relationships of *B. tropicus* and *B. globosus* under controlled laboratory and under semi-natural field conditions. The aim being to estimate the potential of *B. tropicus* to competitively displace *B. globosus*.

2.1 Laboratory investigations

The laboratory work investigated the influence of *B. tropicus* snails on the reproductive capacity, growth and survival of *B. globosus* snails under laboratory conditions. The studies were carried out at the Chiredzi laboratory of the Blair Research Institute (BRI) which is part of the Zimbabwean Ministry of Health and Child Welfare, Figure 3.

Two sets of transparent plastic aquaria, each measuring 150mm square by 60mm deep, were used. One set did not have any partitions while the second set did. The screens forming the partitions were made of nylon mesh with a pore size of 0.5mm and they divided the aquaria into two compartments. The mesh allowed free movement of water but created a barrier for the snails. The purpose of the screens was to investigate whether chemical factors were possibly involved in inhibiting the growth of competitor snails.

Various combinations of the two species were placed in mixed and "control" aquaria. The combinations are shown in Table 2.1 for the aquaria without partitions and in Table 2.2 for aquaria with partitions.

Table 2.1 Number of *B. globosus* & *B. tropicus* in single and mixed species aquaria without partitions

Single species aquaria	Mixed species aquaria		Single species aquaria
B. globosus	*B. globosus*	*B. tropicus*	*B. tropicus*
-	-	-	8
2	2	6	6
4	4	4	4
6	6	2	2
8	-	-	-

Table 2.2 Number of *B. globosus* & *B. tropicus* in single and mixed species aquaria with partitions

Single species aquaria	Mixed species aquaria		Single species aquaria
B. globosus	*B. globosus*	*B. tropicus*	*B. tropicus*
2/6	2	6	-
4/4	4	4	4/4
-	6	2	2/6

First generation laboratory bred snails measuring between 3.5 and 4.0mm were used. The aquaria were filled with filtered pond water and the water was changed twice a week. The snails were fed on blanched and dried lettuce, supplemented with trout food.

Once every week egg masses were removed, counted and the number of eggs in each egg mass recorded. Identification of egg masses was also made. Every second week, shell height and live weight were measured. Shell heights were measured to the nearest 0.10mm with vernier callipers. Live weights were measured to the nearest 0.1mg after drying the shell on a soft tissue paper for approximately two minutes. Growth, survival and reproduction were monitored for ten weeks. Separate incubation experiments and the time taken for each species to reach reproductive stage were also carried out.

2.2 Results of laboratory studies

B. globosus reproduction appears to be significantly reduced when in direct competition with *B. tropicus.* In mixed aquaria without partitions, egg mass and egg production of *B. globosus* was significantly reduced compared to the control aquaria.

The presence of damaged (partly consumed) *B. globosus* egg masses in mixed aquaria without partitions and increased *B. globosus* egg mass counts in mixed aquaria with partitions, suggests that *B. tropicus* preys on B. *globosus* egg masses.

There was no indication of any chemical effects.

B.tropicus started laying eggs at an earlier age than *B. globosus.* Also *B. tropicus* eggs had a shorter hatching time than *B. globosus* eggs. This would seem to represent a major competitive advantage of *B. tropicus* over B. *globosus.*

2.3 Field work

Semi-natural investigations were conducted at two locations; (a) in small ponds constructed in the grounds of the Chiredzi laboratory, and (b) in fish breeding ponds at the Triangle Sugar Estate. The town of Triangle is located about 12 km west of Chiredzi and the fish breeding ponds were not in use at the time the field work was carried out.

At Chiredzi, nine ponds 0.6m deep and measuring 3.5m by 2.0m at the surface and 2.5m by l.0m at the bottom, were excavated and lined with a commercial waterproof pond lining material. The lining material was covered with approximately 70mm of fine loam soil. A total of ten plants of *Vallisneria sp.* were planted in each pond. The ponds were filled with tap water and the water level maintained at 0.5m by topping up once every week.

At Triangle, nine existing cement lined ponds each measuring 3.0m by 2.7m and l.0m deep were used. Since the ponds had been in use prior to the study, they were emptied and left to dry for three weeks. The loam to sandy soil at the bottom of the ponds was levelled to approximately 100mm and the ponds refilled. As with the Chiredzi ponds, ten *Vallisneria sp.* plants were planted in each pond. The ponds were filled with water from a nearby canal which was supplied from one of the storage reservoirs of the Triangle Sugar Estate. The water level was maintained at 0.6m and topping up was by means of spilling water from the first pond through to the last via overflow pipes. The ponds had been constructed such that each was slightly lower than it's upstream neighbour so all of the ponds could be filled by gravity from the canal. The overflow pipes were covered with a nylon mesh (mesh size of 0.5mm) to prevent snails moving between ponds. The supply pipe was also covered with mesh to prevent the introduction of snails and other aquatic organisms from the canal.

At both Chiredzi and Triangle the ponds were left for one month to settle after filling, before the snails were introduced. The snails were left for two weeks to acclimatize before sampling commenced. The ponds at Chiredzi and Triangle are shown in Plates 1 and 2, respectively.

The nine ponds selected for this investigation gave three sets of three replicates. Tables 2.3 and 2.4 show the numbers and sizes of the *B. tropicus* and *B. globosus* snails which were introduced into the Chiredzi and Triangle ponds, respectively.

Table 2.3 Numbers and sizes of snails introduced into Chiredzi ponds

Size range (mm)	*B. globosus*	*B. tropicus*	*B. globosus* and *B. tropicus*
3–4	50	50	25 + 25
5–6	50	50	25 + 25
8–10	50	50	25 + 25

Table 2.4 Numbers and sizes of snails introduced into Triangle ponds

Size range (mm)	*B. globosus*	*B. tropicus*	*B. globosus* and *B. tropicus*
3–4	100	100	50 + 50
5–6	-	-	-
8–10	50	50	25 + 25

For the snail sampling, the pond's surface area was divided into nine rectangles by fixing strings over the water surface. Each rectangle measured 1.6m by 1.25m for the chiredzi ponds and l.0m by 1.25m for the Triangle ponds. Snail density was estimated by the number of snails collected in six standard passes from each rectangle by a snail scoop. The snail scoop was made from a kitchen sieve mounted on a 1.5m long rod.

At the Chiredzi ponds, snail sampling was carried out once every week for the first 20 weeks and once every second week for the following 10 weeks. At Triangle, the sampling was carried out once every second week for 24 weeks. Shell height of snails was measured to the nearest 0.1mm using a vernier calliper. Size categories were recorded over 1mm ranges, ie. 2.0–2.9mm, 3.0–3.9mm. At the termination of the study, the water was drained and all live snails and empty shells were counted and measured. Water pH, percentage oxygen saturation, conductivity and temperature were recorded just prior to the start of sampling (usually between 9am and 11am).

2.4 Results of field studies

The total numbers of live snails and empty shells of the two species collected in the Chiredzi and Triangle ponds are shown in Figures 4 and 5.

The snail populations were, generally, thriving in the Triangle ponds compared to the Chiredzi ponds. The reason why there was high mortality in the Chiredzi ponds remains open to speculation. Possible explanations relate to the differences in the source of the water supply and consequently differences in the quality of the water. Noticeable differences were found in the water chemistry, for example, the average pH in the Chiredzi ponds was around 10, whereas in the Triangle ponds it was around 8.5.

Dense mats of filamentous green algae developed in most of the Chiredzi ponds. This may have directly affected the snails by restricting their movement to the surface for air, or indirectly by altering the water chemistry. In the time available it was not possible to investigate this further.

However, the results shown in Figures 4 and 5 do indicate a consistent difference between the two species. There were clearly more *B. tropicus* than *B. globosus*; a doubling in the Chiredzi ponds and a quadrupling in the Triangle ponds. This tends to confirm the findings from the laboratory study that *B. tropicus* has a higher reproductive rate than *B. globosus*.

Although the results indicate a slight suppressive effect of *B. tropicus* on *B. globosus* in the mixed ponds, this was found to be not statistically significant.

However, the Chiredzi and Triangle semi-field studies were carried out over a relatively short time period, 30 and 24 weeks respectively. Compared to many examples given in the literature survey (Ndlela, 1996), this is a relatively short period to draw conclusions from this type of study. The evidence from other studies is that the interrelationship between species may be realised only after a greater length of time.

2.5 Conclusions of the snail competition studies

Over the relatively short time period of this study, it was not possible to confirm either interference or resource competition between the two species.

However, in both laboratory and semi-field experiments, it was possible to demonstrate the higher reproductive rate of *B. tropicus* and this would give this species a competitive advantage over *B. globosus.*

3 Biological control of snails by fish predation

Many predators have been suggested as biological control agents against *Biomphalaria* and *Bulinus spp.*, the main snail host species of *S. mansoni* and *S. haematobium* (Michelson, 1957; Ferguson, 1977).

Some predators may consume a wide range of prey species (polyphagous) while others are very specialised in their prey choice (monophagous or oligophagous). Monophagous predators or species with a narrow range of prey (oligophagous) are more likely to have a potential in biological control (Greathead & Waage, 1983).

Predators of freshwater snails include species of virtually every major group of the animal kingdom. Most of these, however, are polyphagous predators. Specific snail predators primarily comprise larvae of the *Sciomyzidae* group of flies, certain species of leeches and cichlid species of fish.

The *Sciomyzidae* fly larvae feed exclusively on molluscs and extensive reviews of their biology have been prepared (Berg & Knutson, 1978; Greathead, 1980). Species of the *Tetanocerini*, whose larvae are predators of aquatic or subaquatic molluscs, are considered to be the most promising candidate for biological control of snails. However, little information is available on the bionomics of these fly larvae and their gastropod prey.

Many species of leech are known to include gastropods in their diet. Glossiphoniids, in particular, are considered major gastropod predators (Wrona *et al*, 1980; Young & Procter, 1986).

Fish predation, through selective consumption of prey, is believed to be a major structuring force of benthic fresh-water gastropod communities (Gilinsky, 1984; Bronmark, 1988). Some studies have indicated that certain species of cichlid fish may feed exclusively on fresh-water gastropods (Louda *et al*, 1984; Slootweg, 1987).

Intermediate host snails are mostly associated with aquatic plants, as they provide food and shelter from predators. Submerged aquatic plants are often abundant in transmission sites and a reduction in their density should assist in reducing snail numbers.

In his conclusions on biological control agents of schistosome intermediate host snails, Madsen (1992), stated that the use of molluscivorous fish in combination with herbivorous species showed particular potential and should be evaluated.

In this study, the food selection behaviour of two fish species, both indigenous to Zimbabwe, one a known snail eater and the other primarily herbivorous, was investigated under controlled laboratory and semi-field conditions, (Chimbari *et al*, 1996)

Sargochromis codringtoni, a molluscivorous species belonging to the family *Cichlidae*, was obtained from Lake Kariba. The second species, *Tilapia rendalli*, a primarily herbivorous species which was once used in the Lowvelt area of Zimbabwe to try to control weeds in irrigation channels (Lingen *et al*, 1960), was obtained from Lake Mtirikwi.

3.1 Laboratory study

The laboratory study was carried out at the Chiredzi laboratory of the Blair Research Institute.

Seven large glass aquaria, each measuring l.0m long by 0.6m wide and 0.6m high and seven smaller aquaria, measuring 0.5m by 0.3m by 0.3m were used. A sandy substrate with a depth of 80mm at one end and 40mm at the other end was provided in each aquaria. The water placed in the aquaria was filtered, natural pond water and was continuously aerated with electric aerators.

In a series of controlled experiments, the following variables were changed:

- numbers and species of introduced snails
- numbers of aquatic plants
- species and size of introduced fish
- provision of alternative trout food

The aims of the experiments were to study:

- Food selection behaviour of *T. rendalli* and *S. codringtoni*
- Role of macrophytes in providing food and shelter
- Snail size and species preference of *S. codringtoni*

A specimen of *S. codringtoni* in one of the larger aquaria at the Chiredzi laboratory is shown in Plate 3.

3.2 Results of the laboratory studies

The results confirmed that *S. codringtoni* is malacophagous and *T. rendalli* primarily herbivorous. Although the presence of trout food seemed to make no difference to their preferred food selection, there were indications that *T. rendalli* was consuming some of the trout food. Fish with access to the food supplement gained more weight and length.

T. rendalli consumed about twice it's own weight of the plant *Najas pectinata* in one week and confirms other observations (Lingen *et al*, 1960; Coates & Redding-Coates, 1981) that this species of fish has potential as part of an aquatic weed control strategy.

S. codringtoni is capable of consuming large numbers of snails. A single fish, when provided with trout pellets as an alternative food, not only chose to eat the snails but consumed approximately 800 snails within three weeks.

The addition of macrophytes to the aquaria appeared to offer the snails no protection from predation. However, the extent of the protection offered by the macrophytes in the aquaria may not be as intense as that found in natural ponds and caution is required in drawing conclusions.

For *S. codringtoni* measuring 150mm to 180mm in length, there was found to be no size preference among snails up to 12mm in shell height. In addition, no species preference was observed for *B. globosus, B. tropicus* and *M. tuberculata.*

S.codringtoni were observed to crush *B. globosus* greater than 3.0mm in shell height in their pharynges and eject the shell fragments, but swallow smaller snails of this species whole. This species of fish has developed pharyngeal teeth and can even crush the relatively strong-shelled *M. tuberculata*. Their ability to consume the maximum size of *B. globosus* found in Zimbabwe (up to 12mm), is a useful attribute for considering this species for biological control of schistosomiasis snails.

3.3 Field studies

The semi-natural field study was carried out at fish breeding ponds belonging to the Triangle Sugar Estate. Eight of the nine cement lined small ponds, used in the semi-natural competitor snail study, were used for part of this study, Plate 2. For the second part, forty-two similar enclosures placed along two edges of an adjoining large pond, were used (Plate 4).

Each of the eight cement lined small ponds were similarly planted with three species of aquatic plants and stocked with 600 *B. globosus*, 150 *B. tropicus* and 180 *M. tuberculata* snails. Four weeks after the introduction of the snails, nine *S. codringtoni* fish were put in four of the ponds. The other four ponds served as controls. The effect of this malacophagous fish on the snail populations was monitored over 30 weeks by weekly snail sampling.

Forty two enclosures were placed along two edges of a larger pond (approximately 10m by 10m), each measured 0.6m by 0.6m square and l.0m high. They were made of a tygan mesh with a pore size of 0.5mm, supported by a wooden frame. The enclosures were pushed 80mm into the substrate and all existing aquatic vegetation removed. In half of the enclosures, two plants of three aquatic species, *Ludwigia stolonifera*, *Nymphaea caerulea* and *Lagarosiphon major,* were planted. The other half of the enclosures were left without plants and acted as controls.

Four weeks after the enclosures were erected and the plants established, three species of snails were introduced. Wild caught as well as laboratory bred snails were used because of the large numbers required. The total numbers of snails introduced into each enclosure were, 228 *B. globosus*, 191 *B. tropicus* and 61 *B. pfeifferi.*

From one week after the introduction of the snails, the snail numbers within each enclosure, were estimated by weekly sampling. On week 11 of the sampling, one *S. codringtoni* fish was introduced into seven enclosures with plants and seven without plants. Similarly, one *T. rendalli* fish was introduced into another seven enclosures with plants and seven without plants. For each of these enclosures, another enclosure served as a control. The particular enclosures were selected at random. Snail sampling was continued for another three weeks when the experiment was terminated.

On termination, the pond was emptied and the total numbers of snails and intact shells counted in each enclosure. Plants in each enclosure were dried at room temperature for two weeks and weighed. The fish were also weighed and measured.

3.4 Results of field studies

The mean numbers of snails in the small ponds with fish and those without, for the three species of snails, are shown in Figure 6. It can be clearly seen that, for all three species, their numbers were reduced significantly in the ponds where *S. codringtoni* were present.

B. tropicus of all sizes seem vulnerable to predation, while for both *B. globosus and M. tuberculata,* those with a shell height greater than 10mm, seem less vulnerable.

In the enclosure experiments, the *S. codringtoni* significantly reduced snail numbers but this effect was less pronounced in the enclosures with plants. This suggests that in a more natural environment, the plants were providing the snails with some degree of protection from predation.

Contrary to expectation, *T. rendalli* did not significantly reduce the particular plants placed in the enclosures. In the laboratory study, *T. rendalli* showed a liking for the plant *Najas pectinatus*. More studies are required over a longer period of time, to find out if this species of fish is a selective herbivore and whether this would limit it's ability to control aquatic vegetation.

3.5 Conclusions of the fish predation studies

The laboratory study confirms that *S. codringtoni* is malacophagous and *T. rendalli* primarily herbivorous.

The semi-field study, which simulates more accurately the natural environmental conditions, indicates some of the factors which may limit their effectiveness as biological control agents. Aquatic vegetation provides some degree of protection from predation by *S. codringtoni* and smaller, immature snails are preferred to larger snails. *T. rendalli* may be a selective herbivore.

Nevertheless, the results suggest that the two species of fish may complement each other in the biological control of schistosome intermediate hosts and further investigations, on a larger scale, seem justified.

4 Engineering and environmental control of snails

Collaborative research was undertaken in Zimbabwe over a six year period, to assess the extent to which the transmission of schistosomiasis can be reduced by an agreed package of engineering and environmental control measures covering the design, implementation and operation of a typical small-holder irrigation scheme, including night storage reservoirs.

This chapter outlines the various environmental and engineering control measures which were reported in the design note, OD/TN 20 (Draper & Bolton, 1986), for schistosomiasis control at the Mushandike Irrigation Scheme, Zimbabwe, at the start of the research project. Unfortunately, insufficient supervision during irrigation periods has meant that many of the engineering controls were not properly implemented. Therefore the effectiveness of the engineering measures on snail colonisation and breeding in night storage reservoirs is difficult to judge.

At Mushandike, in order to make farms suitable for small-holder families, reconstruction of the irrigation scheme was necessary. During the reconstruction, engineering and environmental measures aimed at controlling schistosomiasis, were incorporated into the design (Draper & Bolton, 1986).

The interventions introduced in Mushandike were classified as either engineering or environmental. Engineering measures were aimed at creating conditions inimical to snail colonisation and breeding within the scheme. Environmental measures were aimed at reducing contamination of surface water with human faecal matter.

The two basic environmental control measures implemented were; (a) to reduce contamination of waterbodies with parasite eggs from human excreta and urine by providing sanitation, and (b) to discourage human contact with potentially contaminated water bodies by providing adequate and safe water supplies.

Advice was also given on the location of the reservoirs. The suggestion that night storage reservoirs should be located away from main areas of human activity proved to be successful. The final conclusions stated that the parasitological survey pointed to a strong correlation between distance of village from known transmission sites and levels of schistosomiasis in the village (Chimbari, M. *et al*, 1993).

As snails prefer stable conditions and either stagnant or slow flowing water, the engineering control measures to discourage snails were based upon providing; high water velocities, fluctuating water levels and periods of desiccation.

In the Mushandike Irrigation Development, Zimbabwe, a number of engineering control measures were investigated. Modified designs included shoreline steepening, improved outlets and by-pass canals. Operational changes included periodic draining and water level fluctuation. These control measures are outlined in more detail below.

4.1 Water level fluctuations & drying out of reservoirs

In night storage reservoirs some fluctuation does occur due to the gradual use of water by day for irrigation and then replenishment at night This fluctuation is however thought not to be enough to eliminate the snails from the reservoirs.

It was recommend that the method employed to maximise water level fluctuations should be based on the characteristics of the irrigation scheme rather than the night storage reservoir itself.

If an irrigated block is commanded by a single night storage reservoir, then the reservoir should be divided by a central bund and each half of the reservoir should have its own feeder canal.

During periods of low water demand, first one half of the reservoir and then the other half should be dried out to try and eliminate or at least discourage the snails.

If however irrigation blocks are supplied by several night storage reservoirs, then it has been suggested that there is no need for this subdivision to take place, instead, canals should be constructed to allow reservoirs to be by-passed on occasion in order to let the reservoirs dry out. The by-pass canal is used by inserting a gate across the reservoir feeder canal immediately downstream of the weir.

During the research period at Mushandike, periodic drying out of night storage reservoirs was not properly implemented. It is therefore not possible to say if any effect was likely to occur on the snails. However, in the same project, periodically drying out sections of the irrigation canals was found to be very effective in maintaining snail numbers at very low levels, suggesting that periodic drying of night storage reservoirs could have been successful if properly implemented.

4.2 Reservoir construction and size

The design notes recommended that the total reservoir capacity for each irrigation block should be as close as possible to the calculated need for peak demand ie. large overcapacity should be avoided as this would reduce the magnitude of daily fluctuations in water level and thus reduce the controlling effect on snail populations. The total number of sites for night storage reservoirs should also be kept to a minimum.

The design note also stated that night storage reservoirs constructed of three bunds and one steep section of sloping land should be avoided. When the water level is low, a gently sloping shore line is created, which causes snails to be stranded more readily as the water level drops. However, it does encourage the growth of aquatic vegetation and development of shallow pools is encouraged allowing snails to survive for short periods of low water levels.

4.3 Vegetation clearance

Night storage reservoirs also pose a particular threat from infestation by various types of vegetation including floating weeds. Some snails such as *B. glabrata*, one of the snail hosts of *S. mansoni* are attracted to weeds and are often found close to the surface of water in floating vegetation. Studies have shown that physical stimuli such as light and gravity cause the miracidia of *S. mansoni* to move to parts of the habitat where suitable species of snails are likely to be found (Thomson *et al*, 1996) such as areas shaded by weeds.

Weeds should only be cleared from the night storage reservoirs when they have no water in them in order that maintenance workers are not unnecessarily exposed to infection. Weed clearance can be undertaken using herbicides approved for use in and around water. The removal of weeds using hand tools and small machines may be more appropriate in terms of rural work opportunities and foreign exchange. What ever system is adopted needs to be carefully supervised and monitored.

4.4 Molluscicide — Endod

Use of the synthetic molluscicide niclomaside was mentioned in the introductory chapter. Due to financial constraints and concern about the risk of environmental damage its use on Zimbabwean small scale irrigation schemes is limited. An alternative molluscicide is being investigated by the BRI (Ndamba & Ndhlovu, 1995). This makes use of a natural molluscicide extract obtained from the berries of *Phytolacca dodecandra* or endod plant.

The effect of the endod plant (soap berry) was discovered in Ethiopia in 1961 and over the next two decades high yielding, pest resistant plants were developed. These have been transplanted to Kenya, Tanzania, Uganda, Swaziland and

Zimbabwe. In Ethiopia the plant has been intercropped with maize and potatoes and the berries harvested and sold in areas of high schistosomiasis risk. The extract of the berries is used as a molluscicide. No harmful effect to fish, animals and humans has been reported and the extract breaks down within 48 hours[3].

BRI are continuing their research to investigate the social and economic aspects of involving communities to grow the plants and extract sufficient material to effectively dose the water to control the snails. No reports are yet available showing how endod has been used in small scale irrigation on a regular basis.

5 Conclusions

Snail competition studies performed under laboratory conditions in Zimbabwe indicate that the reproduction of *B. globosus* (the snail host of *S. haematobium*) is significantly reduced in the presence of *B. tropicus*. The laboratory study suggests that *B. tropicus* eats the egg masses of *B. globosus*. The ability of *B. tropicus* to out compete and interfere with *B. globosus* could not be confimred when examined in the semi-natural ponds, a longer period of study is thought necessary. In both the laboratory and semi-natural field studies *B. tropicus* was found to have a higher reproductive rate and this should give the species a competitive advantage over *B. globosus*.

The laboratory fish studies indicate that *S. codringtoni* will eat large numbers of snails and that *T. rendalli* can consume large quantities of aquatic vegetation. In this case *Najas pectinata* a nuisance weed found in many irrigation systems. The two species of fish used together may work well to remove host snails. A herbivorous fish is needed to control aquatic weed colonies which would otherwise protect snails from the attentions of *S. codringtoni*. The results from the semi-natural field studies are still being analysed but preliminary findings of the study are encouraging and further investigation on a larger scale is justified.

Both biological methods studied offer the opportunity to control schistosomiasis host snails. Both methods require modifications to the operation and management of the irrigation system. If fish are to be kept in the night storage reservoirs then a minimum level of water will be required. The option of annual desiccation may be possible if fish can be captured and then released afterwards or reintroduced from another source. Division of the night storage reservoir by a central bund could assist in managing fish and maximising water level fluctuations. Fish are better at controlling aquatic weed if coarse, old and unpalitable weeds are removed once a year during the desiccation period.

The removal of weed from the night storage reservoirs needs to be done at regular intervals without endangering the work force to schistosomiasis infection. Manual or mechanical methods can be used in conjunction with weed eating fish.

The development of endod as an appropriate molluscicide is promising. The Blair Research Institute is continuing with trials to introduce the cultivation and use of endod.

The response of users and irrigation managers to the biological control methods reported upon has not yet been assessed. For example, if trials of fish predation

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[3] http://fadr.msu.ru:80/rodale/agsieve/txt/vol2/6/art3.html

are to be scaled up for use in small-scale irrigation schemes the acceptability of the method, either as a replacement or in conjunction with existing snail control methods needs to be assessed, from the point of view of farmers, villagers and irrigation staff.

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Figures 4 and 5 and Plates 1 and 2 are from Ndlela (1996). Figure 6 and Plates 3 and 4 were provided by Moses Chimbari.

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Figures

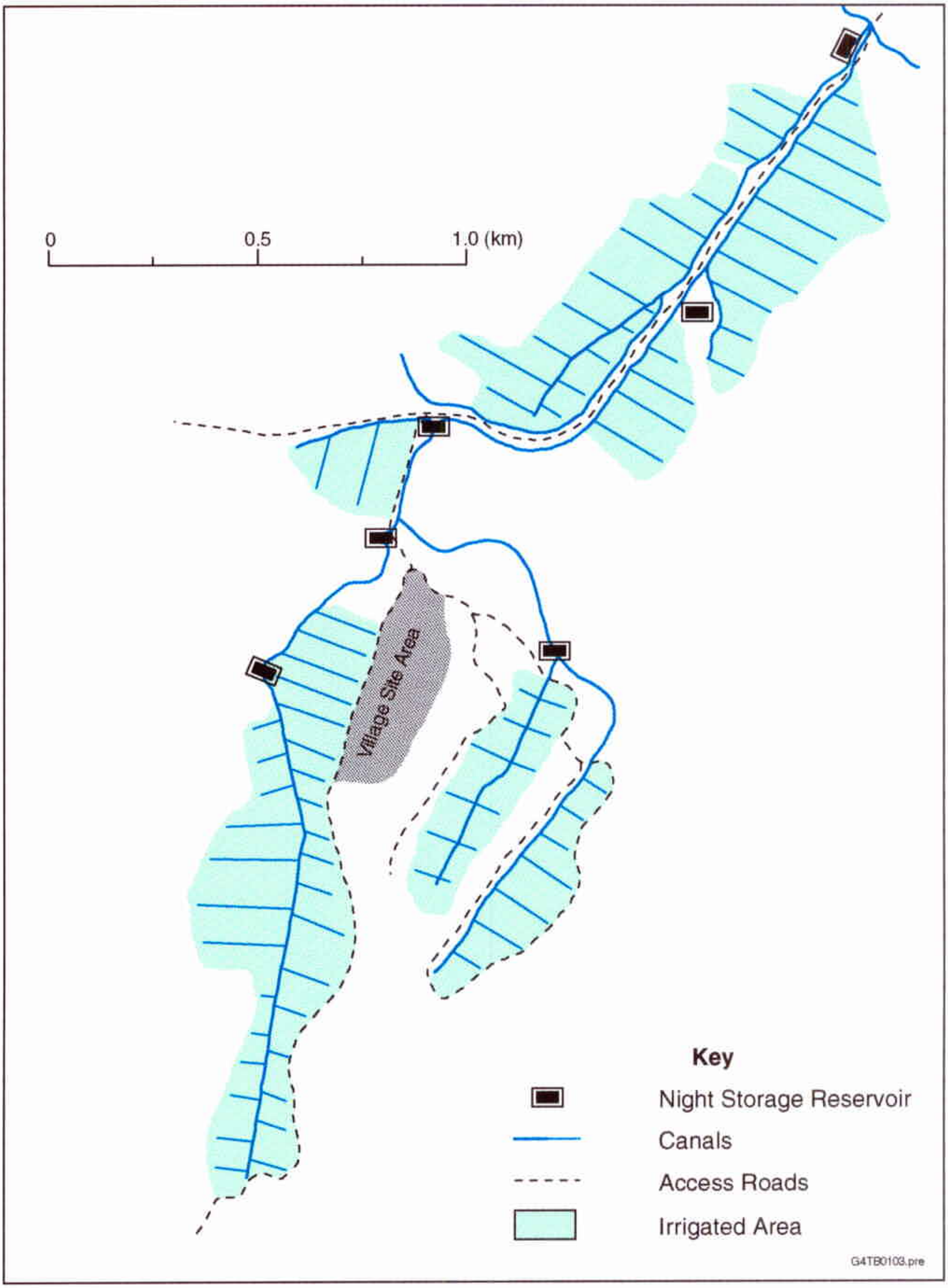

Figure 1 Typical layout of an irrigation scheme (based on Mushandike, Zimbabwe)

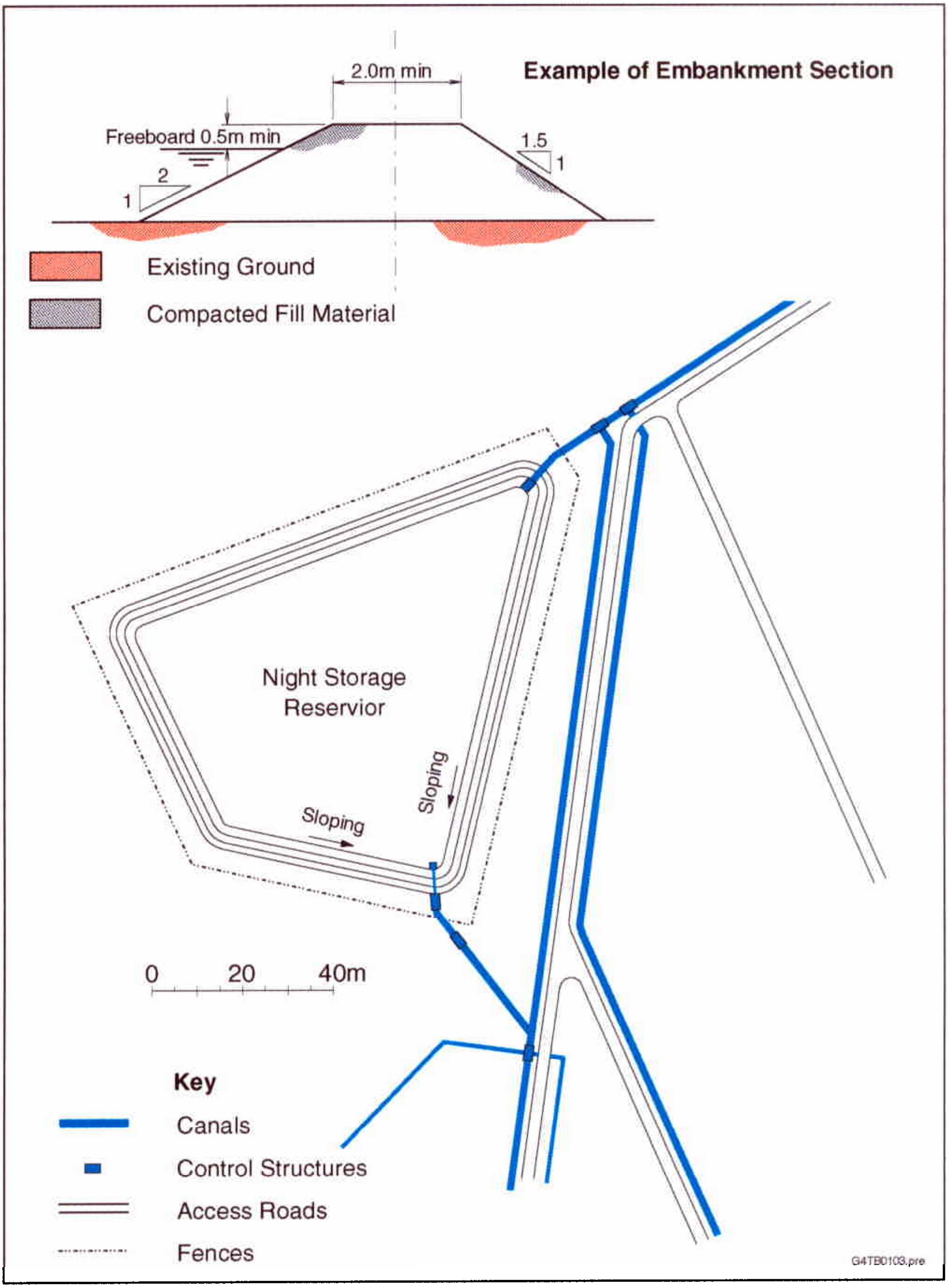

Figure 2 Typical layout of a night storage reservoir

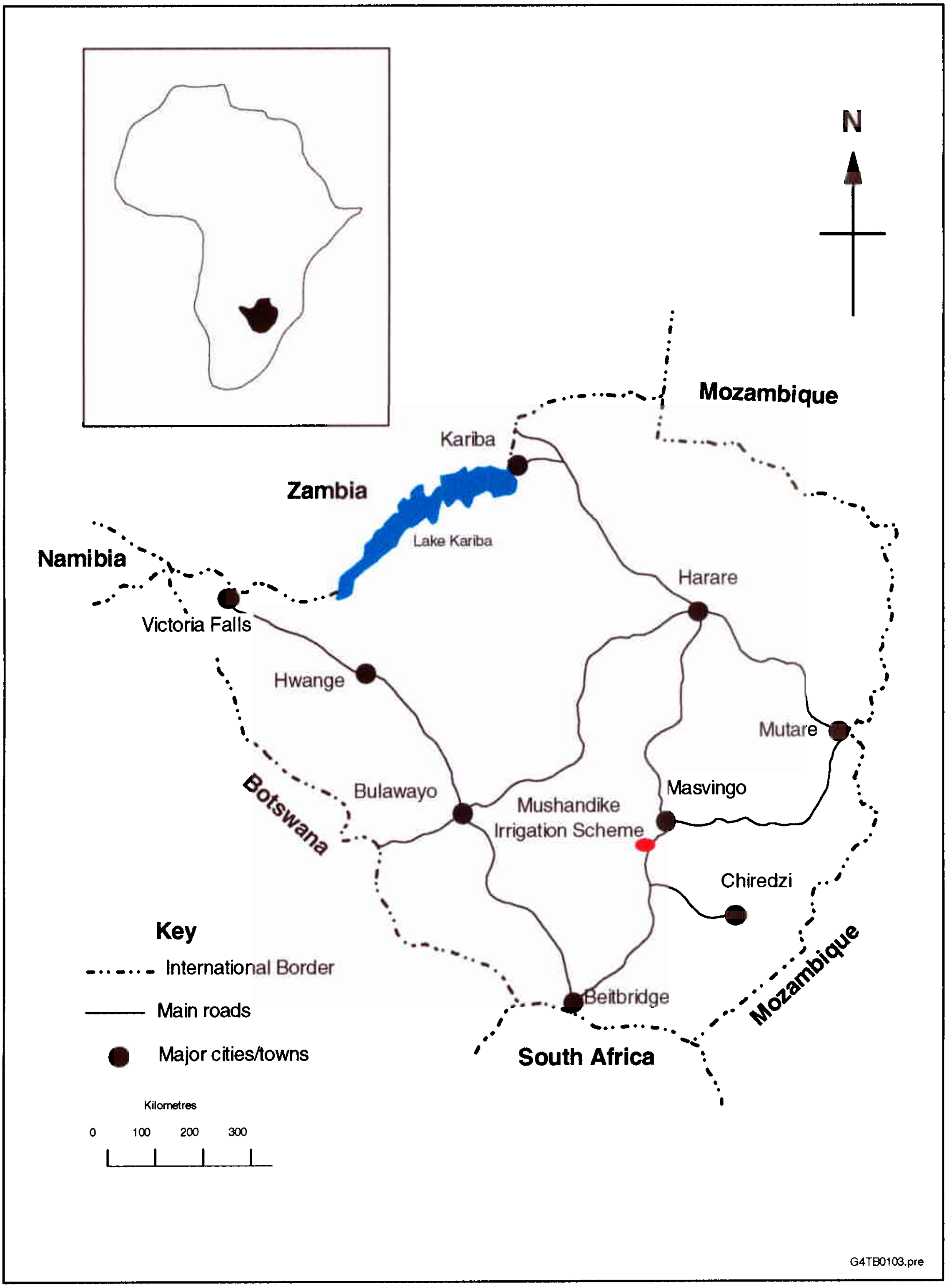

Figure 3 Location Map

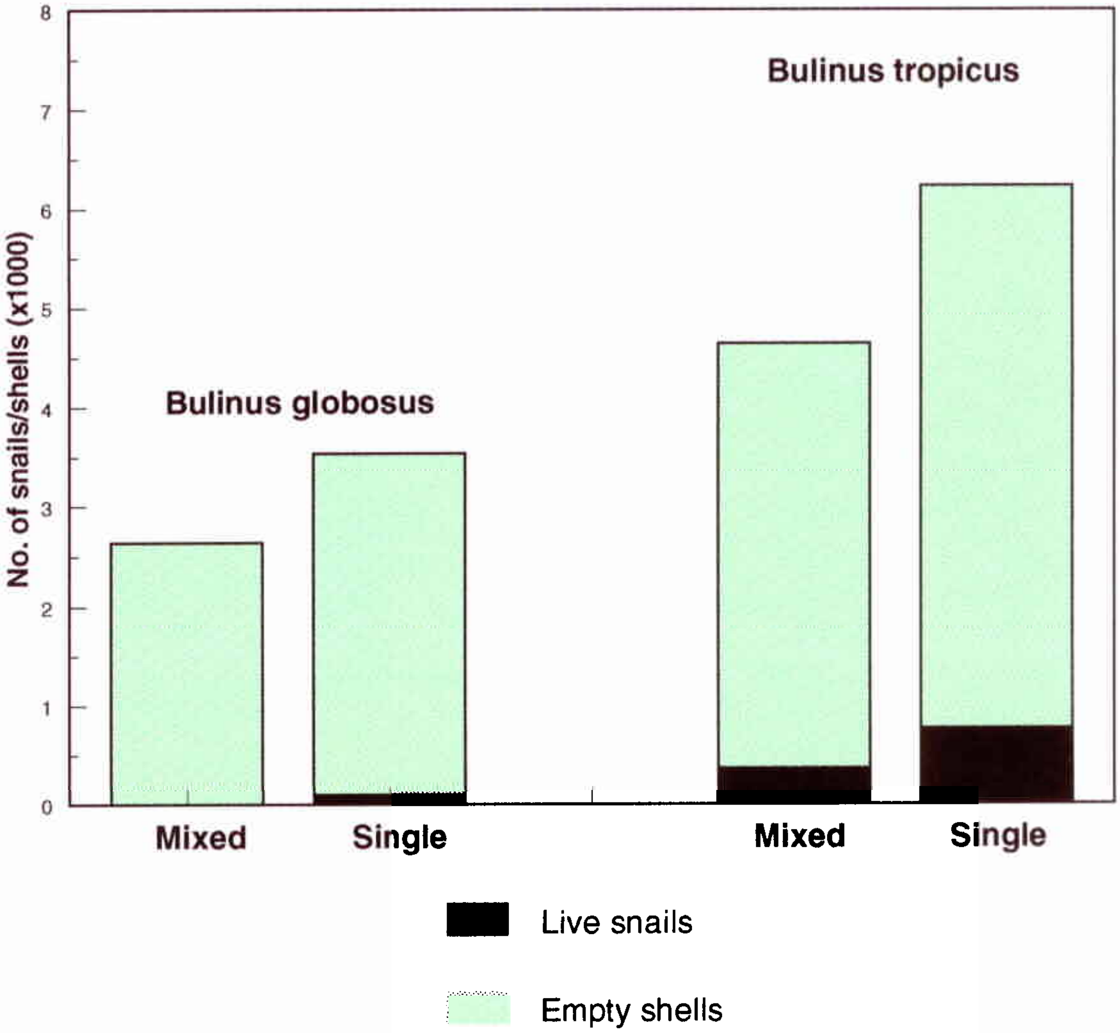

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Figure 4 Total number of live snails and empty shells, Chiredzi

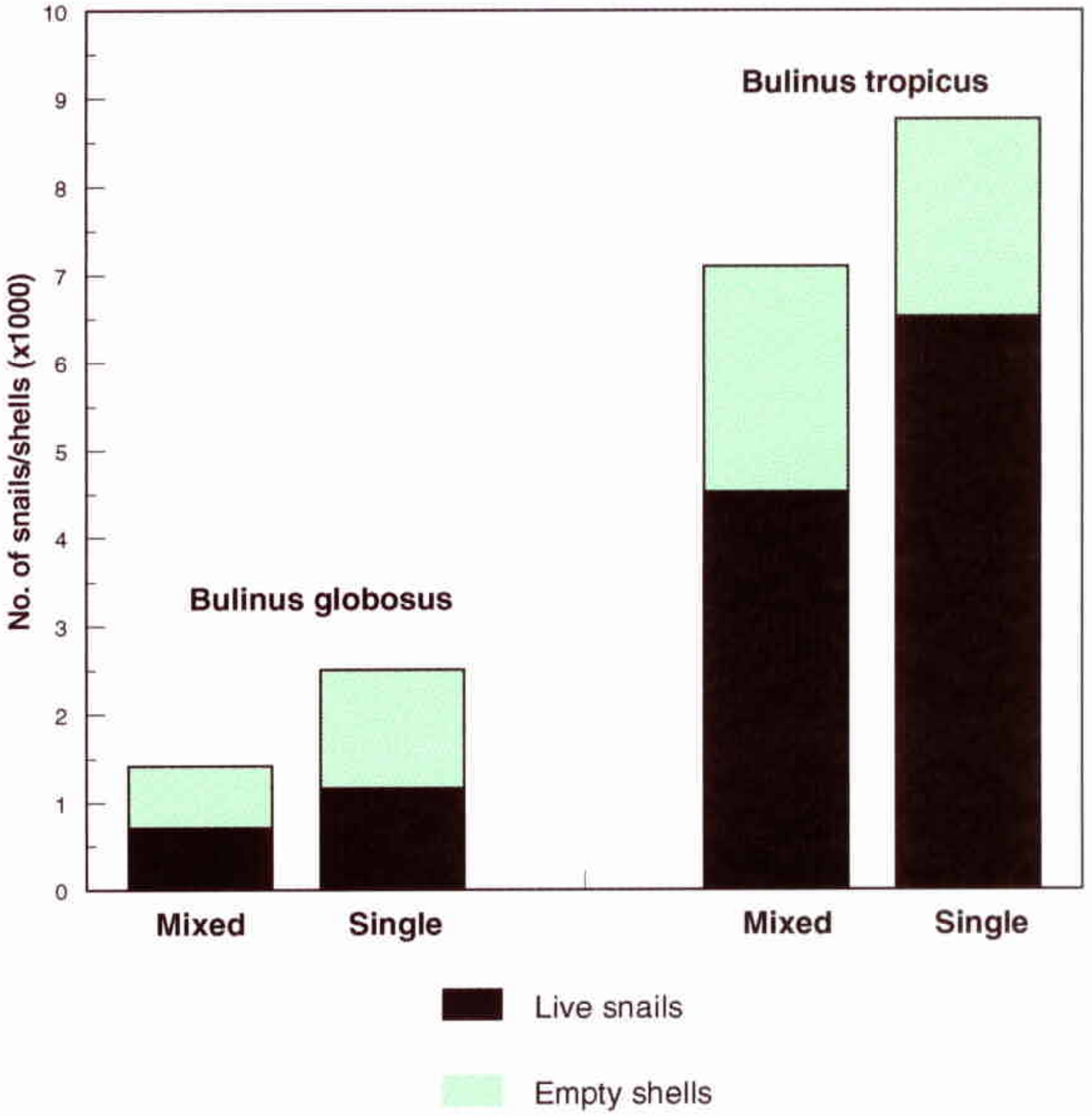

Figure 5 Total number of live snails and empty shells, Triangle

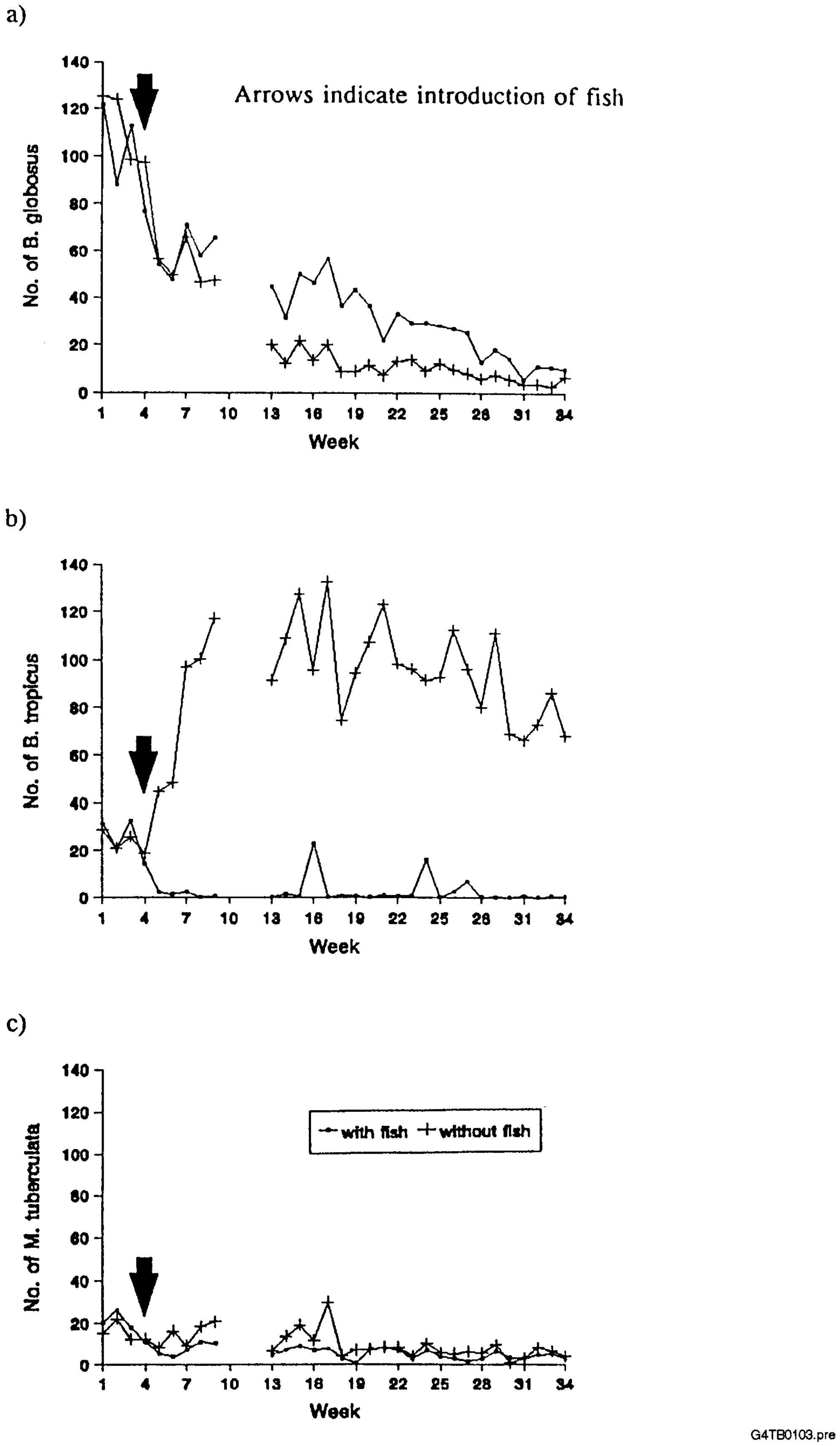

Figure 6 **Numbers of snails in small ponds with and without fish**

Plates

Plate 1 Semi-natural ponds, Chiredzi

Plate 2 Semi-natural ponds, Triangle

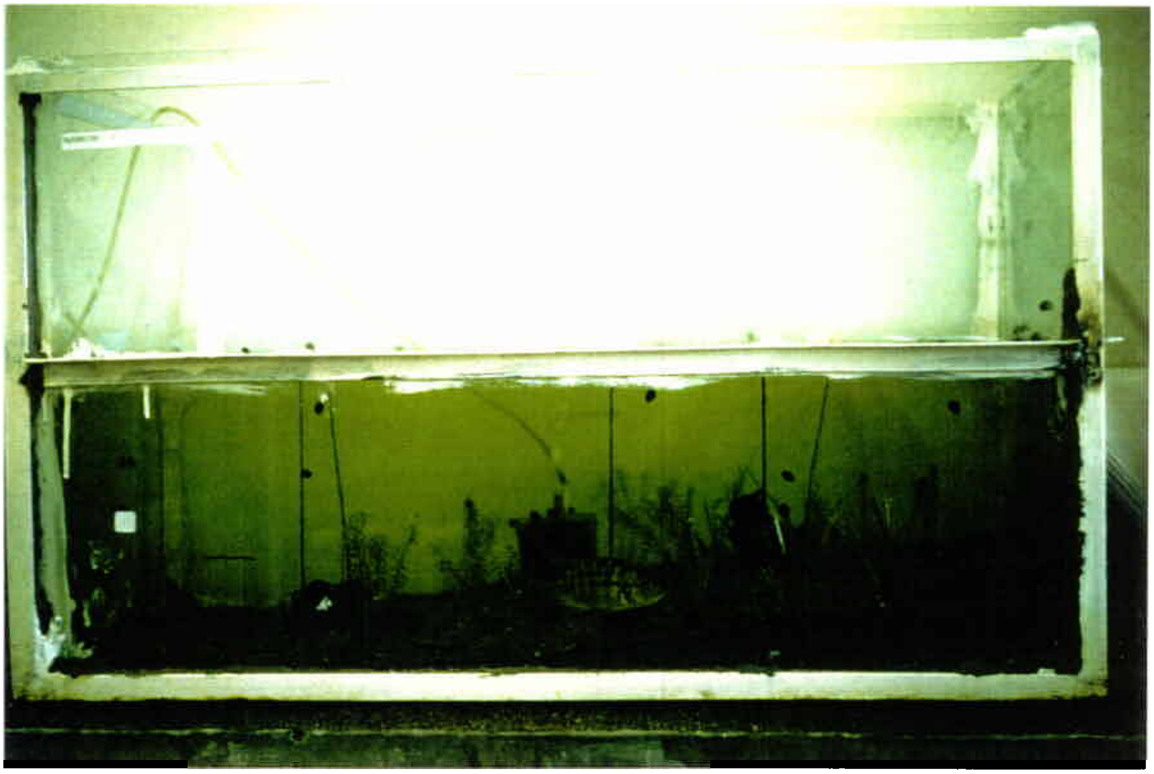

Plate 3 *Sargochromis codringtoni* in large aquarium, Chiredzi

Plate 4 Fish enclosures, Triangle

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