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Use of Indigenous Fishes to Control Schistosome Snail Vectors in Malaŵi, Africa

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The expansion of water resource development projects in the tropics and subtropics resulted in an increased transmission of human schistosomes. This study was conducted to test the feasibility of using two snail-eating fishes, *Trematocranus placodon* (Trewavas) and *Maravichromis anaphyrmis* (Trewavas), as biocontrol agents of schistosomes in fish ponds. The results suggest that *T. placodon* has a potential for controlling the snail vectors of *Schistosoma mansoni* (Sambon) and *Schistosoma haematobium* (Bilharz). The use of *M. anaphyrmis*, however, to control schistosome-carrying snails was not satisfactory. © 1991 Academic Press, Inc.

KEY WORDS: *Trematocranus placodon; Maravichromis anaphyrmis; Schistosoma mansoni; Schistosoma haematobium; Bulinus tropicus; Bulinus globosus; Lymnaea; Oreochromis shiranus; Tilapia rendalli*; biological control; schistosomiasis; vector; molluscicides; miracidia; molluscivore; snails.

INTRODUCTION

Snails are an important component of the fauna of both temporary and permanent aquatic habitats (Cridland, 1957). In Africa and other tropical and subtropical countries, many pond-inhabiting snail species transmit schistosomes, the causative agents of human schistosomiasis (McMahon *et al.*, 1977). When aquatic habitats are used for aquaculture, agriculture, and domestic water supply, some of the conventional methods for controlling snails such as the application of molluscicides and prolonged draining are not practical. Application of molluscicides may not be acceptable because of their toxicity to fish and other nontarget organisms. Also, draining of ponds may not be consistent with national and local development needs in many countries in which schistosomes are endemic (Appleton, 1983; Teesdale, 1986; Chiotha and Morgan, 1987). Biological control might be an alternative for controlling snails in aquatic habitats (Chiotha and McKaye, 1986).

Malaŵi has a long history of high infection rates fo human schistosomes (Cullinham, 1945; Teesdale an Chitsulo, 1985), and the present expansion of aquacul ture and other water resource projects in the countr have increased snail habitats (Teesdale and Chitsul 1985). The earliest attempt to use biological contr agents against vectors in Malaŵi probably occurred i the late 1930s when crayfish from Madagascar were ir troduced into the Mulunguzi and Domasi Rivers in th Zomba district (E.A.R., 1938). The crayfish ventur however, was unsuccessful because they had no effe on snails, and the survival of the crayfish could not b verified. Attention has since shifted to other biocontr agents, particularly fish (McCullough, 1981). With ove 20 snail-eating fishes in Malaŵi, several researche have suggested that these fishes might offer a means f biocontrol of schistosomes (Jackson *et al.*, 196 Chiotha and McKaye, 1986). We assessed the impact two native Lake Malaŵi snail-eating fishes, *Tremat cranus placodon* (Trewavas) and *Maravichromis an phyrmis* (Trewavas), on snail populations in fish pond

MATERIALS AND METHODS

Studies were conducted at Bunda College, Malaŵi, 12 cement ponds, each of which was 5 × 3 × 1 m. Pr vious aquaculture experiments in these ponds had cr ated favorable conditions that supported large popul tions of snails. The most common snail species in t ponds were *Bulinus tropicus* (Krauss), *Bulinus globos* (Morelet) (vectors of *Schistosoma* spp.), and *Lymna* spp. The study began with a survey to estimate the sn populations in each pond. Five random samples we collected from each pond using a scoop (30 × 30 cm or 1.50-m handle) described by WHO (1965) a Choudhry and Teesdale (1982). Previous studies h established that five samples provided fairly accur estimates of the snail population in the ponds (J. Stauffer, personal communication). The sampling tec nique was standardized by holding the scoop at arn

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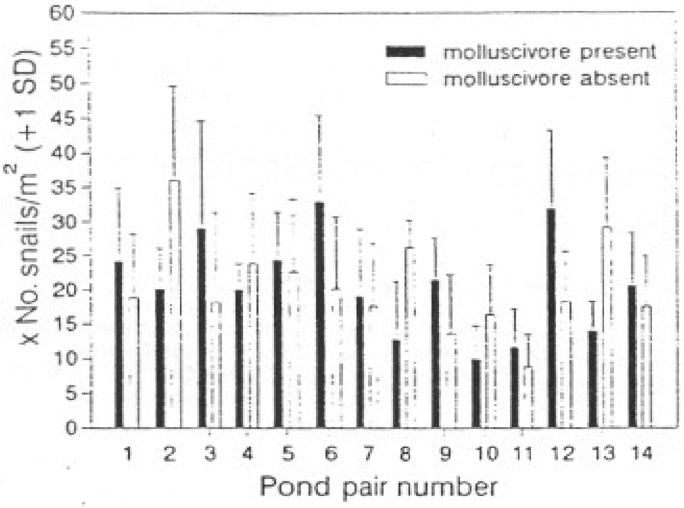

FIG. 1. Initial density of *Bulinus* spp. snails in ponds treated with *T. placodon* and control ponds. Difference in population estimates for snails in ponds treated with *T. placodon* and control ponds was not significant ($P > 0.05$).

length and dipping along the edges as well as the center of the ponds. Individual samples from each pond were placed in a sieve, where the mud was separated and the snails were counted. The snails were then returned to their respective ponds after counting was completed.

The experimental design was paired blocks with random assignment of treatments in each block. The two treatments were presence and absence of molluscivores. Each treated pond (presence of molluscivores) was stocked with 5 *T. placodon* and 20 *Oreochromis shiranus* (Boulenger). Each control pond (absence of molluscivores) was stocked with 25 *O. shiranus*. This stocking rate equated with approximately 17,000 fish/ha and was within the range of recommended stocking density in Malaŵi (Pruginin and Arad, 1977). *O. shiranus* is a nonmolluscivorous fish used in aquaculture in Malaŵi. Each pond received a daily food supply of maize bran at the rate of about 5% of body weight of resident fish, as suggested by Pruginin and Arad (1977). The experiment was terminated at the end of 4 weeks and another snail survey was conducted. The experiments were repeated three times, but in one investigation, some ponds were stocked with the molluscivore *M. anaphyrmis*. The ponds were coded so the people who were sampling snails did not know which ponds were stocked with molluscivores.

Two ponds of each of three rural farmers in the Namikango area of Zomba District were selected for study. All the ponds (within a radius of ca. 2 km) were earthen, were less than 1 m deep, and relied on ground water supply for filling. The ponds had sparse marginal emergent vegetation, mostly grasses. The most common snail in the earthen ponds was *B. globosus*, but *Lymnaea* spp. also were present. These ponds were about 10 times larger than the experimental, cement-lined ponds. Because the rural farm ponds were larger than the experimental ponds, 20 samples were collected as described previously along their shores.

Treatments (presence and absence of molluscivores) were randomly assigned to the two ponds of each farmer as before. Each farmer was provided with 30 *T. placodon* for stocking the treated ponds. All the fish ponds had been stocked with tilapine nonmolluscivorous fishes [*O. shiranus* and *Tilapia rendalli* (Boulenger)] prior to the introduction of *T. placodon*. Snail surveys were conducted at the beginning and at the end of the investigation as before. Stocking and management of the ponds were done by the farmers to ensure that *T. placodon* was tested under conditions in which the rural farmers manage their fish. This experiment lasted 5 months (February–June 1989).

The results were analyzed using the Mann–Whitney *U* test to determine whether the null hypothesis, that is, whether the numbers of snails in treated and control ponds were the same, could be rejected. The Mann–Whitney *U* test is a nonparametric test and the analysis was based on procedures described by Conover (1980).

RESULTS

Experimental Ponds Study

The average number of snails per square meter of surface area in treated ponds (those stocked with *T. placodon*) dropped dramatically in 4 weeks and approached zero in some ponds. The dramatic drop in snail population in the treated ponds was significant ($P < 0.05$) (Figs. 1 and 2). There was no significant differ-

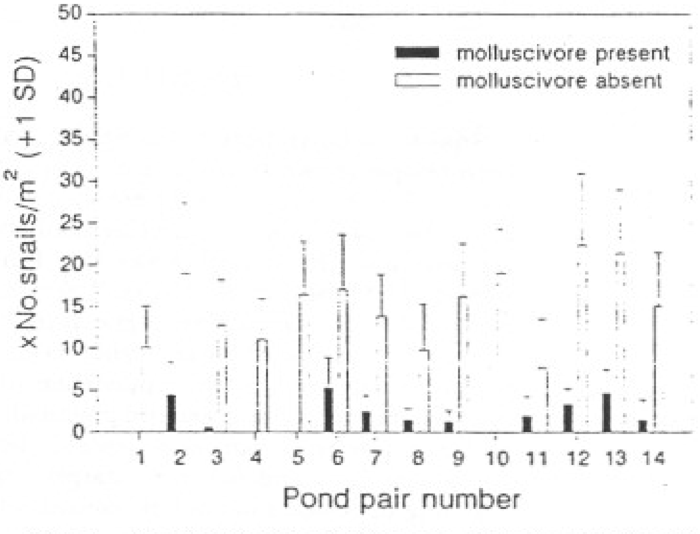

FIG. 2. Final population of *Bulinus* spp. snails in ponds treated with *T. placodon* and control ponds at Bunda College, Malaŵi, after a 4-week period. Ponds treated with *T. placodon* had significantly fewer ($P < 0.05$) snails than ponds without the molluscivore.

ence ($P > 0.05$), however, between the number of snails in ponds treated with *M. anaphyrmis* as the molluscivore and the number of snails in the untreated ponds (Table 1).

Farmers' Ponds

After 5 months, every pond with *T. placodon* had significantly fewer ($P < 0.05$) snails than the ponds without the molluscivores (Table 2).

DISCUSSION

This study demonstrates that *T. placodon* has potential as a biological control agent against *S. mansoni* and *S. haematobium*. In both the experimental and the rural farmers' ponds, the reduction in snail populations in ponds treated with *T. placodon* was significant ($P < 0.05$). Every pond with molluscivores had significantly ($P < 0.05$) fewer snails than ponds without molluscivores. Even more encouraging was the fact that the only ponds in which we did not detect snails were those that had been stocked with *T. placodon*.

Despite the above advantages of using *T. placodon*, we consider the results preliminary. Further trails will be needed to confirm the possible role of molluscivorous fish in controlling schistosomiasis and to answer broader practical questions. For example, the failure to completely eliminate snails in some of the treated ponds raises questions about the epidemiological significance of a few snails that survive predation. Some studies have shown that chances for snails to become infected by *Schistosoma* spp. might improve at a low snail density (Appleton, 1983). The reduction of populations in our investigations, however, should probably be below the optimal level for infection by miracidia (larval stages that initiate infection in snails). Another consideration regarding the few snails that survive a control program is that they can generate a population recovery. Even when molluscicides are used, however, hardy snails may persevere after most of the snail population has been destroyed (Dzik, 1983). The use of a facultative biological control ensures that the molluscivore is still present should recruitment of the *Schistosoma* spp. occur.

TABLE 1

The Effect of *Maravichromis anaphyrmis* (Molluscivore) on Snails in Ponds at Bunda College, Malaŵi, after a 4-Week Period

Treatment and pond number	Average number of *Bulinus* spp. (snails/m^2)[a]	
	Initial (SD)	Final (SD)
M. anaphyrmis		
2	12.0 (6.10)	10.7 (6.80)
4	11.0 (6.23)	21.3 (8.26)
6	10.4 (4.04)	12.9 (5.59)
7	13.6 (5.72)	16.7 (7.65)
Control		
1	15.3 (8.01)	17.3 (6.80)
3	12.7 (8.85)	10.9 (3.56)
5	6.2 (5.34)	9.1 (6.38)
8	8.0 (5.58)	5.3 (3.35)

[a] The difference between initial and final snail number was not significant ($P > 0.05$, Mann-Whitney-*U*); $n = 5$.

TABLE 2

The Effect of *Trematocranus placodon* (Molluscivore) on Snails in Rural Farmers' Fish Ponds at Namikango, Malaŵi

Treatment and pond number	Average number of *Bulinus* spp. (snails/m^2)[a]	
	Initial (SD)	Final (SD)
T. placodon		
2	4.5 (4.40)	0 (0.0)
4	24.3 (12.91)	1.1 (1.11)
5	7.0 (5.30)	0.3 (0.47)
Control		
1	4.3 (4.14)	8.5 (6.67)
3	13.2 (7.19)	10.8 (6.67)
4	7.7 (7.15)	13.45 (7.64)

[a] Ponds with *T. placodon* had significantly ($P < 0.05$, Mann-Whitney *U*) fewer snails than control ponds; $n = 20$.

We believe that the goal for the use of *T. placodon* should be to reduce populations of snail vectors of *Schistosoma* spp. This goal is realistic, and we agree with McCullough (1981) that the total elimination of snail vectors will probably never be achieved with biological control. Above all, reducing populations of snail vectors is realistic because there is no way to tell with available techniques and equipment whether all snails are eliminated from a natural habitat. As Brower and Zar (1984) have argued, accurate estimates of absolute density are difficult to obtain in aquatic environments. Nevertheless, available techniques are useful for demonstrating snail population trends.

What does the goal of reducing snail populations mean in terms of human health benefits? For insect pest control programs, it is generally accepted that a useful biological control agent should at least keep a pest population at some equilibrium below the density causing economic damage (Flanders, 1966; Clarke, 1970). The same objective can apply to snail control because it does not seem necessary to exterminate a snail species to control its transmission of schistosomes (Van Schayck, 1986). Several field studies have demonstrated that the rate of infection of snails in endemic areas is characteristically low (Sturrock, 1973; Michella and Loverde, 1983). In some areas, snail infection rates of less than 3% have been recorded (Van Schayck, 1986). Such observations suggest that a high prevalence of schistosomiasis in humans cannot be explained by a low infection rate in snails, but rather by the high population of snail vectors (McDonald, 1965; van Schayck, 1986). Hence, reducing the population of snails should in principle result in the reduced transmission of schistosomes by snail vectors. This was demonstrated on Vieques Island, where the transmission of schistosome was controlled by keeping snail vector populations low with chemicals (Fergusson *et al.*, 1965). Combining biological control of snails by fish with other environmentally compatible techniques, such as weed removal and pond drainage between stocking seasons, also could be advantageous. Because schistosomiasis in humans is closely linked with human behavior, health education also should be part of control programs for this disease (Teesdale, 1986).

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REFERENCES

Appleton, C. C. 1983. Wetlands and public health. *J. Limnol. Soc. South. Afr.* **9**(2), 117–122.

Brower, J. E., and Zar, J. H. 1984. "Field and Laboratory Methods for General Ecology." Brown, Dubuque, IA.

Chiotha, S. S., and McKaye, K. R. 1986. Possible ecological control of schistosomiasis (bilharzia) by Lake Malaŵi molluscivores. *Luso* **7**(1), 11–24.

Chiotha, S. S., and Morgan, R. P. 1987. Molluscicides used to control schistosomiasis. *Luso* 8(1, 2), 11–12.

Chodhry, A. W., and Teesdale, C. H. 1982. "Bilharzia: A Manual for Health Workers in Malaŵi." Ciba-Greg Ltd., Nairobi.

Clarke, L. R. 1970. Analysis of pest situation through the life systems approach. *In* "Concepts of Pest Management" (R. L. Rabb and F. E. Guthrie, Eds.), pp. 45–47. North Carolina Univ. Press, Raleigh.

Conover, W. J. 1980. "Practical Non-parametric Statistics," p. 493. Wiley, New York.

Cridland, C. C. 1957. Ecology factors affecting the numbers of snails in temporary bodies of water. *J. Trop. Med. Hyg.* **60**, 287–293.

Cullinham, E. R. 1945. Medical disorders in East Africa. *Trans. R. Soc. Trop. Med. Hyg.* **39**(5), 353–372.

Dzik, A. J. 1983. Snails, Schistosomiasis and irrigation in the tropics. *Public Health (London)* **97**(4), 214–217.

E.A.R. 1938. "Crayfish and Bilharzia." East Africa and Rhodesia, 17th February 1938, Malaŵi National Archives S1/284/37.

Fergusson, F. F., Dawood, J. K., and Blondeau, R. 1965. Preliminary field trials of Acrolein in the Sudan. *Bull. WHO* **32**, 243–248.

Flanders, S. E. 1966. The circumstances of parasitic replacement among parasitic Hymenoptera. *Can. Entomol.* 1009–1024.

Jackson, P. B. N., Iles, T. D., Harding, D., and Fryer, G. 1963. "Report on the Survey of Northern Lake Nyasa: 1945–1955." Joint Fisheries Research Organization, Gov. Printer, Zomba, Nyasaland.

McCullough, F. S. 1981. "Appraisal of the Potential of the Use of Fish for Control of Disease Vectors Other Than Mosquito." TDR/BCV/IC.18.2.WP.22, Geneva, Switzerland.

McDonald, G. 1965. The dynamics of helminth infection with special reference to Schistosome. *Trans. R. Soc. Trop. Med. Hyg.* **59**, 489–506.

McMahon, J. P., Highton, R. B., and de Marshal, T. F. 1977. Studies on biological control of intermediate hosts of schistosomiasis in Western Kenya. *Environ. Conserv.* **4**, 285–289.

Minchella, D. J., and Loverde, P. T. 1983. Laboratory comparison of the relative success of *Biomphalaria glabrata* stocks which are susceptible and insusceptible to infection with *Schistosoma mansoni*. *Parasitology* **86**, 335–334.

Pruginin, Y., and Arad. 1977. "Fish Farming in Malaŵi." FAO Report, Rome, FI: DB/MLW/71/516/10.

Sturrock, R. F. 1973. Field studies on the transmission of *Schistosoma mansoni* and on the bionomics of its intermediate host, *Biomphalaria glabrata*, on St. Lucia, West Indies. *Int. J. Parasitol.* **3**, 175–194.

Teesdale, C. H. 1986. The role of health education to reduce transmission of schistosomiasis. *Trop. Med. Parasitol.* **37**, 184–185.

Teesdale, C. H., and Chitsulo, L. A. 1985. Schistosomiasis in Malaŵi —A review. *Trop. Med. Parasitol.* **36**, 1–6.

Van Schayck, C. P. 1986. The effect of several methods of aquatic plant control on two bilharzia-bearing snail species. *Aquat. Bot.* **24**, 303–309.

WHO, 1965. "Snail Control in the Prevention of Bilharziasis." Mon. Ser. No. 50, Geneva.