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Evaluation of an experimental mollusciciding programme to control *Schistosoma mansoni* transmission in St Lucia

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The size and number of colonies of Biomphalaria glabrata *were reduced after four years of a surveillance/treatment snail control programme using an emulsifiable concentrate of niclosamide (25 % active ingredient). Surveys among the human population showed that the incidence of new* Schistosoma mansoni *infections in 0–10 year-old children fell from 22 % to 4.3 %, while in a comparison area the incidence remained at 20 %. With reduced transmission over four years, the prevalence of infection in a cohort of children examined in 1971 and 1975 fell from 34 % to 23 %. The fall in prevalence and intensity of infection led to a reduction of 66 % in the index of potential contamination, which was reflected in a reduced rate of infection among sentinel snails and representative samples of* B. glabrata *collected during surveillance searches.*

The overall annual cost of the programme was US $3.24 per capita.

Control of the snail intermediate host, *Biomphalaria glabrata*, was attempted in order to reduce transmission of *Schistosoma mansoni* among 7000 persons in the Cul-de-Sac Valley of St Lucia. The scheme was part of a comparative evaluation of different methods of control (*2*, *5*, *6*).

The strategy and details of the surveillance/treatment method of snail control have been described previously (*8*, *9*) and preliminary parasitological results from children have been reported (*6*). The results now presented extend the period of observation to cover four years of snail control and show the effect of reduced transmission on the prevalence of *S. mansoni* infection in adults.

AREAS OF STUDY

Details of Cul-de-Sac Valley and the adjacent comparison valley, Riche Fond Valley, have been given elsewhere (*6*, *9*). Pre-control studies from 1967 to 1970 showed similar transmission patterns and indices of infection in the two valleys, with high rates of transmission (incidence between 1969 and 1970 greater than 15% amongst 0–7-year-old children) in settlements near the main rivers and lower rates in hillside settlements (*6*).

Although infected *B. glabrata* were found in static water habitats, (i.e., marshes and banana drains), flowing-water habitats such as rivers, streams, and main drains were considered the important transmission sites (*8*).

During the course of this control programme banana cultivation was abandoned over a large area near the mouth of the valley. Banana fields and drains became overgrown with dense vegetation, making surveillance and mollusciciding impossible. Snail control was therefore stopped in this area.

MATERIALS AND METHODS

Mollusciciding with an emulsifiable concentrate of niclosamide (25% active ingredient) started in Cul-de-Sac Valley in late 1970 in all areas where *B. glabrata* had been found in the pre-control study period. These areas were virtually the same as those where high *Schistosoma mansoni* transmission rates were found.

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After an initial blanket treatment, 120 areas were defined for detailed surveillance and treatment as necessary. These areas comprised 28 sites in flowing water and 47 banana fields with static water.

As reported previously (*8*), a second blanket treatment was applied in November 1971 to a limited number of flowing-water habitats, marshes, and banana fields. A further intensive treatment of 3 banana fields and associated collector drains, ravines, and marshes was required in July 1974 after a build-up of snails.

In surveillance operations, the number of snail colonies found was recorded, and a representative collection of snails was dissected for evidence of *S. mansoni* (*3*). On alternate weeks, laboratory-bred sentinel snails were exposed in 2 sites in each of 2 locations in the valley (i.e., 4 sites in all). The snails were examined after 11–14 days for daughter sporocysts (*10*).

As the results of annual parasitological surveys of children became available, there were occasional indications that new infections of *S. mansoni* had occurred in children living in areas where *B. glabrata* had not been found prior to control and where mollusciciding was not being carried out. These areas were therefore subjected to an intensive search but no snail colonies were found.

Untreated areas were re-surveyed at 3–5-month intervals. A few colonies were found adjacent to known infested areas and these sites were brought into the surveillance/treatment routine.

Details of the survey, laboratory, and statistical techniques used in the collection and examination of stools have been reported previously (*7*). Stools were collected during house-to-house visits and examined by means of a sedimentation and concentration technique, three slides being examined before the stool was considered negative. (Examination of additional stools from persons apparently negative would have detected more infected persons, but this was not possible in a field operation of this nature.) Stools positive for *S. mansoni* ova on qualitative examination were examined quantitatively by the filtration and staining method (*1*).

In Cul-de-Sac Valley, adults were examined in 1971 and in 1975 after 4 years of snail control; younger age groups were examined annually.

In Riche Fond Valley, all age groups were examined in 1970, 1972, and 1975, while children were examined every year.

A detailed cost analysis was made of the control programme.

RESULTS

Biological findings

The number of snail colonies (defined as one or more live snail) gradually declined in Cul-de-Sac Valley (Table 1), with snails being found less frequently in all types of habitat (Table 2). This resulted in a marked reduction in the area of the valley in which snails were found.

The prepatent and patent *S. mansoni* infection rates found in representative collections of *B. glabrata* in the course of surveillance are shown in Table 3. Of the 11 snails found infected only 1 was from a flowing-water habitat.

The results of exposing sentinel snails (80 snails on alternate weeks at 4 sites) are shown in Table 4. The

Table 1. Number of snail colonies found in different habitats during the mollusciciding campaign

Year	Banana fields	Marshes	Streams & rivers
1971–72	170	71	11
1972–73	150	60	0
1973–74	117	48	2
1974–75	71	30	2

Table 2. Frequency of finding *B. glabrata* between July 1973 and April 1975 compared with earlier findings (printed in italics) [a]

Type of habitat	No. of visits	No. of sites yielding living *B. glabrata*		
		Never	⩽ 4 times	> 4 times
Flowing-water				
25 streams	46	23 (92 %) (*72* %)	2 (8 %) (*28* %)	0
3 rivers	15	3 (100 %) (*33* %)	0 (*67* %)	0
Static-water				
47 marshes [b]	46	37 (79 %) (*50* %)	7 (15 %) (*40* %)	3 (6 %) (*10* %)
45 banana fields [b]	45	20 (44 %) (*20* %)	13 (29 %) (*41* %)	12 (27 %) (*39* %)

[a] Previously reported data for April 1971–June 1973 (*9*).

[b] One less than reported by Sturrock (*9*). One marsh was drained and two banana fields were combined for convenience.

Table 3. Infection rates in wild *B. glabrata*

Year	No. of snails examined	Prepatent		Patent		Total %
		No.	%	No.	%	
1972–73	6849	4	0.06	2	0.03	0.09
1973–74	5827	2	0.03	1	0.02	0.05
1974–75	4134	1	0.02	1	0.02	0.04

Table 4. *S. mansoni* infection rates in sentinel snails exposed in two settlements in Cul-de-Sac Valley

Year	Ravine Poisson		Souci	
	Infected examined	% infected	Infected/ examined	% infected
1971	12/845	1.42	56/920	6.09
1972	7/905	0.77	75/918	8.17
1973	4/722	0.55	46/792	5.81
1974	5/803	0.62	14/881	1.59

high infection rate among snails exposed at the Souci settlement may be due to the fact that the site was below a small bridge (these are popular places for defaecating in St Lucia) over a main road.

Human population parasitological results

Cohort studies. The incidence of new infections among children in Cul-de-Sac and in the comparison valley between successive surveys in 1970 and 1971—the year prior to the start of snail control—and between surveys in 1974 and 1975 are shown in Table 5. The falls in incidence in the high and low transmission areas of Cul-de-Sac are significant at the 0.1% and 5% levels, respectively.

The changes in the status of *S. mansoni* infection among cohorts of children and adults examined in 1971 and 1975 are shown in Table 6, and are compared with cohorts from the comparison valley.

Among children below the age of 14, in both the high and low transmission areas in Cul-de-Sac Valley the number of apparent lost infections (reversions) was greater than the number of apparent new infections (conversions). The ratios of conversions to reversions were 0.34 and 0.71, respectively, and pre-

Table 5. Final pre-control incidence of *S. mansoni* infection (1970/1971) among children of Cul-de-Sac Valley (control area) and Riche Fond Valley (comparison area) and incidence after four years of molluscicidng (1974/1975) [a]

Age at first of 2 surveys (years)	High transmission settlements		Low transmission settlements	
	1970/1971	1974/1975	1970/1971	1974/1975
Cul-de-Sac (control)				
0–2	4/83 (4.8 %)	3/86 (3.5 %)	0/107 (0.0 %)	1/134 (0.7 %)
3–5	28/126 (22.2 %)	5/149 (3.4 %)	9/173 (5.2 %)	3/195 (1.5 %)
6–7	19/68 (27.9 %)	2/115 (1.7 %)	3/93 (3.2 %)	3/146 (2.1 %)
8–10	25/68 (36.8 %)	12/158 (7.6 %)	10/126 (7.9 %)	8/212 (3.8 %)
0–10	76/345 (22.0 %) [b]	22/508 (4.3 %) [b]	22/499 (4.4 %) [c]	15/687 (2.2 %) [c]
Riche Fond (comparison)				
0–2	7/75 (9.3 %)	8/66 (12.1 %)	1/44 (2.3 %)	1/67 (1.5 %)
3–5	16/120 (13.3 %)	11/70 (15.7 %)	3/72 (4.2 %)	4/81 (4.9 %)
6–7	28/86 (32.6 %)	16/53 (30.2 %)	1/46 (2.2 %)	3/70 (4.3 %)
8–10	27/54 (50.0 %)	16/63 (25.4 %)	13/49 (26.5 %)	12/80 (15.0 %)
0–10	78/355 (22.0 %)	51/252 (20.2 %)	18/211 (8.5 %)	20/298 (6.7 %)

[a] Denominator = number of children negative for *S. mansoni* at first of two surveys; numerator = number converting to *S. mansoni* positive at next survey.

[b] Difference significant at 0.1 % level.

[c] Difference significant at 5 % level.

Table 6. Changes in status of *S. mansoni* infection among cohorts of children and adults from high and low transmission areas of Cul-de-Sac valley examined in 1971 and 1975 after four years of snail control and among similar cohorts examined in 1970 and 1975 from the comparison area

Area	High transmission area age groups (years)		Low transmission area age groups (years)	
	0–14	15 +	0–14	15 +
Cul de Sac (control)				
No. examined	643	361	665	319
1st cohort prevalence (1971)	34 % (216)	55 % (197)	7 % (48)	21 % (66)
Conversions	33	30	22	10
Reversions	98	96	31	42
Ratio (con : rev)	0.34	0.31	0.71	0.24
2nd cohort prevalence (1975)	23 % (151)	36 % (131)	6 % (39)	11 % (34)
Riche Fond (comparison)				
No. examined	601	345	275	180
1st cohort prevalence (1970)	35 % (212)	72 % (248)	13 % (37)	56 % (100)
Conversions	222	31	54	15
Reversions	56	90	16	43
Ratio (conv : rev)	3.96	0.34	3.38	0.35
2nd cohort prevalence (1975)	63 % (378)	55 % (189)	27 % (75)	40 % (72)

Table 7. Changes in point prevalence and intensity of *S. mansoni* infection in the high transmission areas of Cul-de-Sac between 1971 and 1975 after four years of snail control. Also shown are the IPC[b] for each age group and the relative IPC

Age group (years)	% of population	1971					1975				
		No. examined	% positive	GM[a]	IPC[b]	Relative IPC (%)	No. examined	% positive	GM[a]	IPC[b]	Relative IPC (%)
0–4	18.4	313	8	21	31	1.9	336	2	15	6	1.1
5–9	17.5	426	38	30	200	12.3	447	6	15	16	2.9
10–14	13.8	282	67	48	444	27.3	430	28	24	93	17.0
15–19	9.6	148	70	55	370	22.8	236	45	28	121	22.1
20–29	11.6	153	65	33	249	15.3	210	51	25	148	27.0
30–39	7.8	139	58	26	118	7.3	164	37	19	55	10.0
40–49	7.5	148	48	24	86	5.3	142	31	16	37	6.8
50–59	6.3	69	44	18	50	3.1	132	22	23	32	5.8
60 +	7.5	94	37	28	78	4.8	117	33	16	40	7.3

[a] Geometric mean of *S. mansoni* eggs per ml faeces.

[b] IPC = index of potential contamination, calculated as follows: $\text{IPC} = \frac{\text{prevalence (\%)} \times \text{GM} \times \text{\% of age group in population}}{100}$ (e.g fo 1971 ,0–4 years age group, $\text{IPC} = \frac{8 \times 21 \times 18.4}{100} = 31$).

valence among the cohorts fell over the 4-year period from 34% to 23% in the high transmission areas, and from 7% to 6% in the low transmission areas. For adults in the high and low transmission areas, there were similar falls in prevalence among the cohorts.

In the comparison areas, prevalence in the cohorts of children increased over the 4-year period (35% to 63%, and 13% to 27%) but decreased in the cohorts of adults.

Cross-sectional surveys. The prevalence and intensity of infection (the geometric means—GM—of egg output per millilitre of faeces) in 1971 and 1975 are shown in Table 7, together with the index of potential contamination (IPC). For each age group this is calculated as follows:

IPC = prevalence (%) × GM × % of age group in population/100.

The sum of the IPC values for all age groups in 1971 was 1626. After four years of snail control, with falling prevalence and intensity of infection, the total IPC in 1975 was 548, or 33.7% of the 1971 value.

Similar calculations for the areas of low transmission show the total IPC for 1975 to be 35.8% of that in 1971.

Cost analysis

The mean annual cost of snail control per capita protected was US $3.24 for a population of 7000. A breakdown of the annual costs of the scheme is shown in Table 8.

Labour costs, which cannot be substantially reduced in a scheme based on surveillance, represented 65% of the total. The programme employed an average of 12 men. Although there were occasional variations, 2 field assistants (average pay US $5.35 per working day) worked with 10 field attendants (average pay US $3.15 per working day).

Expenditure for molluscicide decreased during the period of the study, reflecting the reduction in the amount of chemical required.

In determining the transport costs, the initial value of the 3 vehicles assigned to the programme was taken into consideration and written off in depreciation over a period of 5 years. Insurance, repairs, and petrol costs were taken into consideration.

DISCUSSION

The decreasing number of snail colonies and the decreasing area from which snails were recovered were all indications that snail populations were being drastically reduced. These results might lead one to be optimistic that continued snail control would lead to their eventual eradication from the valley. However, dense vegetation in the marshes and in some banana drains makes this unlikely as molluscicidng in such areas is extremely difficult and unsatisfactory.

Although reduced snail populations may indicate success of the main object of the control approach,

Table 8. Annual cost of snail control September 1970–April 1975 for a population of 7000 [a]

	1970 [b]	1971	1972	1973	1974	1975 [b]	Total
Labour & supervision	2 881 (36 %)	16 450 (66 %)	11 825 (62 %)	13 205 (67 %)	16 443 (71 %)	5 175 (70 %)	65 979 (65 %)
Equipment & supplies	1 946 (25 %)	733 (3 %)	490 (3 %)	725 (4 %)	1 084 (5 %)	364 (5 %)	5 342 (5 %)
Molluscicide	2 735 (34 %)	4 203 (17 %)	2 747 (15 %)	1 815 (9 %)	889 (4 %)	270 (4 %)	12 659 (12 %)
Transport	384 (5 %)	3 582 (14 %)	3 860 (20 %)	3 941 (20 %)	4 645 (20 %)	1 589 (21 %)	18 001 (18 %)
Total	US$ 7 946	24 968	18 922	19 686	23 061	7 398	101 981
Cost per capita	US$ 1.14	3.57	2.70	2.81	3.29	1.06	— [c]

[a] Given in US$ based on 1975 rate of US$ 1 = $ 2 Caribbean.

[b] Approximately three months only.

[c] Mean cost/capita per year = $3.24.

the effect on transmission of human infections can be determined only by parasitological indices of infection in the population.

The incidence of new infections in children, the only direct measure of transmission, was found to be significantly reduced in areas of both high and low transmission. While changes in incidence occurred in the comparison areas, these did not show the consistent decrease found in Cul-de-Sac Valley and reflected natural changes due mainly to variations in climate.

Reduced incidence indicates less transmission, but from cohort studies, where the number of new infections (conversions) and lost infections (reversions) are calculated, it is possible to determine whether the reduced transmission is sufficient to lead to reduced prevalence in the cohort of children.

As point prevalence rates usually increase rapidly among children in endemic areas, the number of new infections (conversions) usually greatly exceed the number of apparent lost infections, with the ratio of conversions to reversions being greater than 1. This is seen among the 1970–1975 cohort of children from the comparison area (Table 6). In Cul-de-Sac, however, where snail control had been in operation for 4 years, reversions exceeded conversions with the result that prevalence in the cohort fell during the 4-year period.

Among adults, point prevalence rates are normally lower in the older age groups; in a cohort study, therefore, the number of lost infections would be expected to be greater than new infections. Thus, in the comparison valley, the ratio of conversions to reversions was 0.34 and 0.35 in the high and low transmission areas, respectively, and prevalence fell in the 4-year period from 72% to 55% and from 56% to 40%.

With control of transmission in Cul-de-Sac Valley, it might have been expected that the ratio of conversions to reversions among adults would be lower than in the comparison areas. That they were not is probably due to the fact that the Cul-de-Sac cohort was studied for a year less than the cohort in the comparison valley, which, had therefore had more time to lose infections.

With reduced transmission, infections acquired before control started gradually died out and intensities of infection decreased.

The reduced prevalence and intensity of infection among all age groups resulted in a marked reduction in the potential contamination of the environment with *S. mansoni* eggs. This was presumably the cause of reduced infections of sentinel snails and in wild *B. glabrata*.

In 1971, the 10–19 age group was responsible for 50% of the potential contamination, but with snail control the group responsible for 50% of the potential contamination was the 15–29 age group, although the actual level of potential contamination from them was only one-third that from the 10–19 age group in 1971. The importance of this lies in the fact that when chemotherapy was given after snail control, emphasis had to be placed on young adults of 15–29 years of age—an age group which in St Lucia is consistently less cooperative than others. Where chemotherapy is a primary control tool, emphasis must generally be on a younger age group.

Parasitological data show conclusively that snail control is an effective method of reducing transmission of *S. mansoni* in Cul-de-Sac Valley of St Lucia, in spite of the topography that included many different types of water body and snail habitat, and a complex transmission pattern with infection potentially taking place throughout the year.

Although molluscicides were applied to approximately half the valley floor (where snails had been found in pre-control investigations), indices of transmission and infection fell in the areas of low transmission as well as those where it was high. Thus, this form of " focal " control was effective in reducing transmission among persons living some distance from the main transmission foci—believed to be flowing-water habitats on the valley floor.

The mean annual cost of control of US $3.24 *per capita* protected should be considered in relation to the health budget for the island. This has steadily increased over the past few years, and in 1975 it was 14% of the national budget or approximately US $12.00 *per capita*. *S. mansoni* is not endemic over the whole of St Lucia, but it is obvious that continued use of a disease-specific control scheme costing US $3.24 *per capita* protected would be unrealistic if transmission is reduced to a low level and the infection becomes of relatively lower priority. (It is of interest, however, that the health budget includes the equivalent of approximately US $0.75 *per capita* for control of *Aedes aegypti*, which is potentially responsible for transmitting yellow fever and dengue.)

The high *per capita* cost of snail control is due to the fact that year-round transmission requires continuous surveillance of the vast network of banana drains, the marshes, and the streams. Labour charges are therefore high (65% of total costs) while mollusciciding costs (12% of total) are low. The cost of control in irrigation schemes, where routine mollusciciding can be carried out, is lower than control in natural habitats, and a detailed analysis of control in an irrigation scheme in Tanzania showed the annual cost to be US $1.31 *per capita* (*4*). However, as this scheme was costed for 1968-70, prior to the commencement of the Cul-de-Sac experiment, it can be assumed that the molluscicide and labour costs were lower.

Having reduced the chance of persons becoming reinfected, treatment was offered to all persons remaining infected and a modified form of snail control was implemented. This phase will be reported later, but it is becoming clear that while it is comparatively easy to reduce prevalence of infection to a very low level with mollusciciding followed by chemotherapy, it may be difficult to bring about a further significant reduction and to confirm that transmission has stopped or that the " breakpoint " (if such exists) has been reached. If this stage were reached, the conditions that brought it about would have to be maintained in some form or other to prevent a recurrence of transmission, particularly in areas where immigration of infected persons could be expected. If the parasite could be virtually eradicated, it would be necessary for any scheme for maintenance of control to be relatively inexpensive. Of equal importance would be an effective system of monitoring for any breakdown in control so that immediate steps could be taken to deal with any epidemic of schistosomiasis that might result.

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RÉSUMÉ

ÉVALUATION D'UN PROGRAMME EXPÉRIMENTAL DE LUTTE CONTRE *SCHISTOSOMA MANSONI* PAR L'EMPLOI DE MOLLUSCICIDES A SAINTE-LUCIE

A Sainte-Lucie (Indes occidentales), un programme de lutte contre *Biomphalaria glabrata*, mollusque hôte intermédiaire de *Schistosoma mansoni*, a été lancé à la fin de 1970. On a utilisé le concentré émulsifiable de niclosamide (25% de composant actif) dans une opération initiale couvrant toutes les zones de la Vallée Cul-de-Sac où des enquêtes préalables menées pendant 4 ans ½ avaient permis de déceler *B. glabrata*. Un programme de surveillance effectué tous les quinze jours a été institué, complété par de nouveaux épandages de molluscicide chaque fois que la présence de gastéropodes était constatée. Des collections représentatives de mollusques et des mollusques « sentinelles » exposés durant 24 heures ont été examinés pour déceler d'éventuels sporocystes.

Des examens annuels de selles ont permis de surveiller l'évolution des indices d'infestation humaine par *S. mansoni*.

Après 4 ans ½ de lutte, la proportion des zones infestées par le mollusque dans la vallée avait bien diminué. Et, dans les zones infestées elles-mêmes, les mollusques étaient devenus plus rares à la fin de cette période qu'au début du programme.

La recherche de parasites dans la population humaine a mis en évidence chez les enfants de 0 à 10 ans une réduction de l'incidence des infestations nouvelles de 22% à 4,3% dans les zones de forte transmission (vallée proprement dite) et de 4,4% à 2,2% dans les zones de faible transmission (pentes latérales de la vallée). Dans une cohorte d'enfants de 0 à 14 ans, la prévalence, qui était de 34% en 1971, est tombée à 23% en 1975. Dans tous les groupes d'âge, la prévalence et l'intensité de l'infestation ont diminué au point de réduire de quelque 66% les risques de contamination de l'environnement par des œufs de *S. mansoni*. Cette évolution était associée à une baisse du taux d'infestation des mollusques sentinelles et des gastéropodes *B. glabrata* recueillis sur le terrain.

Le coût total du programme a été de US $3,24 par personne protégée.

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