Bull. Org. mond. Santé / *Bull. Wld Hlth Org.* 1958, **19**, 223-261

STUDIES ON *SCHISTOSOMA JAPONICUM* INFECTION IN THE PHILIPPINES *

3. Preliminary Control Experiments

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SYNOPSIS

Among the measures used in attempts to control the snail host of *S. japonicum* in Leyte Province, Philippines, where the terrain is unsuited to the application of molluscicides, have been removal of vegetation in and around infested streams, drainage of water-logged areas, filling low-lying areas with earth or flooding them, and digging fishponds in sluggish streams. Each of these measures is described in detail.

Experiments carried out in rice-fields, which harbour great numbers of snails, have shown that improvements in rice-growing methods will not only markedly reduce the snail population but also double the rice yield.

A campaign to promote the use of pit latrines encountered the serious difficulty that such latrines were not acceptable to the people. However, there is evidence that use of pit latrines does bring about a reduction in snail infection rates.

No single control measure is recommended for all snail habitats, the choice of method depending on local circumstances; in many areas a combination of methods proved advantageous. It is felt that mass treatment of infected persons would not be fully effective until transmission is more thoroughly under control.

INTRODUCTION

The problem of bilharziasis is a complex one, which has not only physical and biological but also socio-economic aspects. A realistic approach

* This is the third and last part of the final report on a pilot bilharziasis control project in the Philippines, jointly sponsored by the Philippine Government, the World Health Organization, the International Co-operation Administration, the Philippine Council for United States Aid, and the United Nations Technical Assistance Programme.

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to control necessarily involves a blending of what is scientifically desirable with what is necessary and practical in the socio-economic setting. It seems essential, therefore, since Leyte Province is predominantly rural, to give here some brief account of at least a few of the facets of the rural economy in the light of which the control measures to be described may be better understood. The reader is at the same time referred to the first part of this report[a] in which a number of general considerations bearing on the epidemiology of bilharziasis have been set out.

The principal crops of Leyte are coconut, rice, corn, hemp, sweet potato, cassava, sugar-cane and tobacco. Other minor vegetable and fruit crops are cultivated on a small scale; bananas grow extensively throughout the island. Rice, although one of the most important crops and a staple of the diet, is generally grown in a primitive manner. While the farmers naturally take advantage of the seasons and the terrain, there is no planning and good land utilization is not common practice; there is no grading or drainage and the fields are not even dyked. At planting time the abundant grasses are simply trampled by water buffaloes and the rice seedlings planted haphazardly; the fields are then not tended until the harvest, by which time there is a dense mass of rice and grasses. In the actual harvesting, the rice stems are not cut close to the ground but the heads alone are cut off. The tangled mass of vegetation is left in the fields until the next planting season, when the trampling process is repeated. No planned system of crop rotation is followed, although in some well-drained areas corn, tobacco, sweet potato or other cash crops may be planted.

As a result of this poor farming and of pests and typhoons the yearly production of rice does not suffice for the population, although the Provincial Agriculturist considers the area under rice great enough to meet the people's needs were the yield increased by improved, intensive cultivation. Indeed, with proper irrigation and drainage two crops a year could be grown.

Farms in Leyte are generally small, 56% of the total of some 98 000 farms being less than two hectares in size. Of this same total, 51% are operated by their owners, 8% by part-owners and nearly 41% by share tenants, known as " kasamas ". The most common form of the " kasama " system is that whereby the tenant receives two-thirds of the crop and the landlord one-third, the tenant bearing the expense of the seed, planting and harvesting as well as providing the labour and the water buffaloes. If the landlord provides the seed and the cash for the agricultural operations and the tenant the labour and water buffaloes, the crop is equally divided after deduction in kind of the expenses incurred in transplanting and harvesting. There is also a third arrangement whereby the landlord furnishes the tenant with work animals and seed, and the harvest is equally divided after deducting the operating costs. Most of the contracts are unwritten.

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[a] See *Bull. Wld Hlth Org.*, 1958, **18**, 345.

The tenant receives loans from the landlord and finds it difficult to question the landlord's account of crops produced or expenses incurred.

Poor crops and land tenure problems, here as elsewhere in the world, tend to deny the farmer the opportunity and incentive to advance and tend to check investment. The net result is that without effective action to give him a chance for farm ownership, which is his first felt need, the farmer is apt to be indifferent to other types of reform, although they may all be directed towards the improvement of his condition.

CONTROL

The WHO consultant team on bilharziasis in the Philippines expressed the opinion in 1952 that

" theoretically the most effective method of attack on a trematode disease is to control the snail intermediate hosts. Some effective molluscicides are known but they are not economically practical, unless combined with drainage, agricultural methods, etc. In Japan almost complete land utilization usually confines the snails to small, neat irrigation ditches between rice-fields. In the Philippines the snails are still in wet, swampy places covered by dense vegetation, in former rice-fields left to fallow during the drier season, etc. They often cover large areas. The situation in Japan approaches the terrain believed to be ideal for the use of molluscicides. The opposite is true in the Philippines and molluscicides will be of little or no value until environmental control has been developed ".

With this point of view we heartily agree, especially as complete land utilization in Leyte is still far off, and we regard chemical control as something of a terminal measure which should be applied in eradicating or further reducing the snail populations that remain after there have been major reductions in areas suitable for snail breeding.

It was the hope at the start of the project that some weak point would be found in the life-history of the snail that would permit a relatively inexpensive attack to be made upon it. The history of the search has been described in an earlier part of this report.[a] No such well-defined target has appeared, but there are certain facts about the biology of *Oncomelania quadrasi* that are important in considering possible methods to be tried with a view to its eradication.

The first of these is the permanence of known snail colonies; there are no spontaneous disappearances, such as McMullen, Komiyama & Endo-Itabashi (1951) record for *O. nosophora*. The major significance of this observation is that not all freshwater areas need to be considered. For whatever reasons, areas not now inhabited by snails are not likely to become dangerous, unless subjected to human interference, as in the case of road construction or irrigation canals that hamper natural drainage, thus creating what may be regarded as " man-made schistosomiasis ".

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[a] See *Bull Wld Hlth Org.*, 1958, 18, 481-544.

The second observation of possible importance is the absence of major fluctuations in density within *Oncomelania* colonies. It follows that the snail population might not be able to withstand the continual pressure of permanently changed conditions, or even the pressure of repeated disturbance. What the desirable changes are have been indicated by our study of the distribution of snails within the habitat, their life history, and their behaviour under field and experimental conditions. We do not, of course, claim originality for all of these observations. To cite one important example, the fact that newly hatched snails are aquatic has been known for a long time. Water, then, must be present more or less permanently for snails to thrive, but the marked decrease in density with increasing depth shows that too much water may be as damaging as none at all. It is also clear that both completely stagnant water and very swift water are unfavourable for snails. The reduced activity during the day and the avoidance of bright light indicates the necessity of cover, which in nature is usually provided by vegetation.

Even given these promising leads, there remains the overriding question of cost. The control of water and of vegetation is expensive wherever attempted, and the expense is greatly multiplied in the tropics (rainfall is hardly ever less than 250 cm per year in the endemic areas, and may be more than twice that amount). For this reason, we have sought measures that would result in other benefits than those of mere snail control. Land reclamation and improved land use have been important considerations in practically all our efforts to eradicate the snail host.

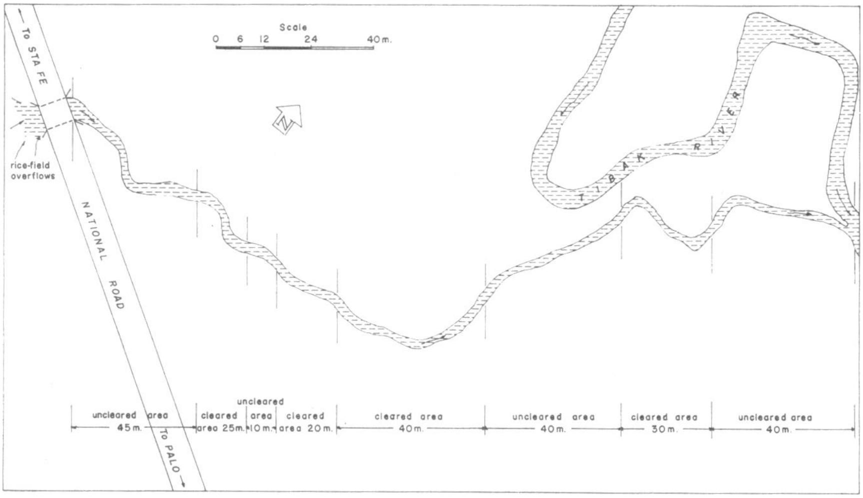
Engineering

Vegetation removal

Experimental Creek No. 1. Experiments on the effect of removing the vegetation were begun on 10 May 1954 at a snail colony inhabiting the banks of a stream designated as Experimental Creek No. 1. The work originally planned consisted of flooding, damming and clearing of vegetation in the area traversed by the stream. The stream is about 260 metres long, and has an average width of 1.2 m. The source of its water is the seepage and overflow from rice-fields on its upper portions.

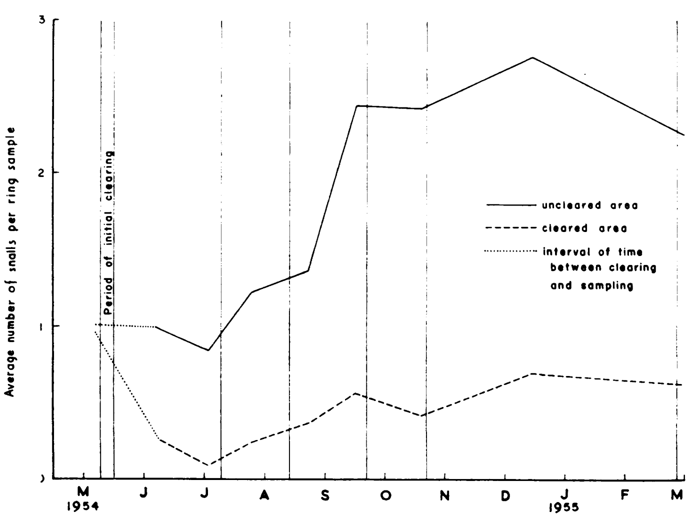
As work progressed, it was decided to study only the effect of clearing. The experimental area comprised the bed of the stream and about 5 m on either bank. The plan of the colony (Fig. 1) shows how it was divided into two distinct sets of areas for study, consisting of alternating cleared and uncleared portions. During the time of the experiment the uncleared areas showed an over-all increase in snail density, whereas the population in the cleared areas never regained its original density, and averaged 25.6% of that in the uncleared areas (see Table I and Fig. 2).

FIG. 1. EXPERIMENTAL CREEK No. 1, SHOWING CLEARED AND UNCLEARED AREAS



Although the effectiveness of clearing is quite substantial in terms of snail population reduction (34%), the principal difficulty with this control method is the frequency with which it has to be repeated. Maintenance clearing was done five times during the nine months of the experiment.

FIG. 2. EFFECT OF CLEARING ON SNAIL DENSITY AT EXPERIMENTAL CREEK No. 1



Vertical lines indicate the dates of maintenance clearing.

TABLE I. EFFECT OF CLEARING OF VEGETATION ON SNAIL DENSITY AT EXPERIMENTAL CREEK NO. 1 *

Sampling dates	Number of snails per ring sample	
	cleared area	uncleared area
6 May 1954	0.96	1.04
7 June 1954	0.26	1.00
2 July 1954	0.09	0.85
23 July 1954	0.24	1.23
20 August 1954	0.35	1.36
15 September 1954	0.55	2.50
18 October 1954	0.41	2.43
13 December 1954	0.70	2.76
28 February 1955	0.63	2.25

* Clearing started on 10 May 1954.

Continuous maintenance tends to make the method expensive in the long run, although the subsequent clearings after the initial one are much cheaper.

Cost *

Initial cost of clearing . . . Pesos $\frac{84.00}{115}$ = Peso 0.73 per linear metre

Average cost of maintenance clearings . . . . Pesos $\frac{46.00}{115}$ = Peso 0.40 per linear metre

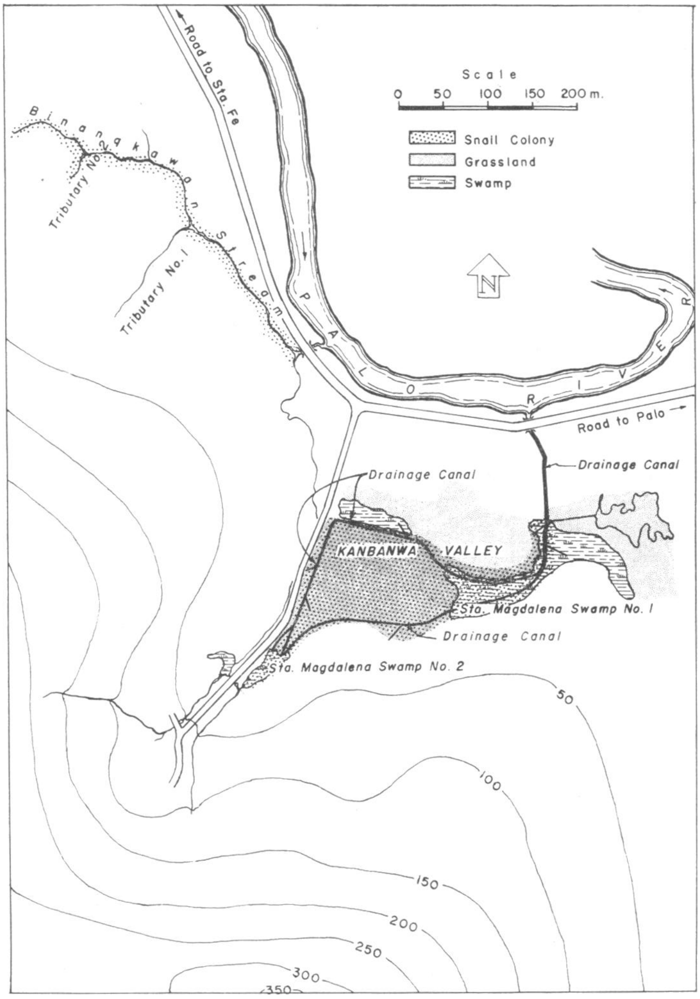
* 1 Peso = US $0.50

Binangkawan stream. The results from Experimental Creek No. 1 were sufficiently encouraging for us to apply the method on a larger scale, when we attempted zone-wide snail control in Kanbanwa-Binangkawan zone. The zone contains two distinctly separated snail colonies, one located at the Binangkawan stream and the other in the Kanbanwa valley area (Fig. 3).

Binangkawan stream is 426 m long, including one snail-infested tributary; its average width is 1 m. The water is fairly swift, and the area was originally covered by dense grasses and weeds, and surrounded by some shrubs and trees.

Our methods of clearing in this colony were somewhat more thorough. In addition to cutting the vegetation, many roots were also removed; irregularities in the surface were graded, the stream was channelled and its banks were made vertical so as to remove the gently sloping areas that are attractive to snails.

FIG. 3. KANBANWA-BINANGKAWAN ZONE, SHOWING THE TWO SNAIL COLONIES AND LOCATION OF DRAINAGE CANALS



The necessity for continued maintenance is emphasized by the changes observed in snail density (Table II and Fig. 4). The decrease in the snail population was fairly satisfactory for the first eight months, during which time the vegetation was removed twice. The colony was neglected for an additional eight months, and the population returned to its original density.

Following one additional maintenance clearing, the density again began to fall.

Because zone-wide snail control was being attempted, the colonies in the adjacent Malirong zone were used as comparison areas, so that we could be assured that the observed drop in snail density was due to our efforts and not to natural fluctuations in the snail population.

TABLE II. EFFECT OF CLEARING OF VEGETATION ON SNAIL DENSITY AT BINANGKAWAN STREAM

Date of clearing	Date of sampling	Average number of snails per sample
	21-25 October 1954	1.04
10 January 1955 (Initial clearing)		
	27 January 1955	0.36
15 February 1955 (1st maintenance clearing)		
	15-16 March 1955	1.02
	22-29 April 1955	0.72
9-15 June 1955 (2nd maintenance clearing)	13-17 June 1955	0.56
	28 July 1955	0.33
	23 September 1955	0.48
	16 November 1955	0.46
	18 January 1956	0.43
	16-17 March 1956	1.10
19-20 March 1956 (3rd maintenance clearing)		
	27 April 1956	0.54
28 April 1956 (4th maintenance clearing)		

The cost per linear metre in this experiment was no higher than for Experimental Creek No. 1 in spite of the additional methods employed, because the width of the clearing was less (2 m on each side).

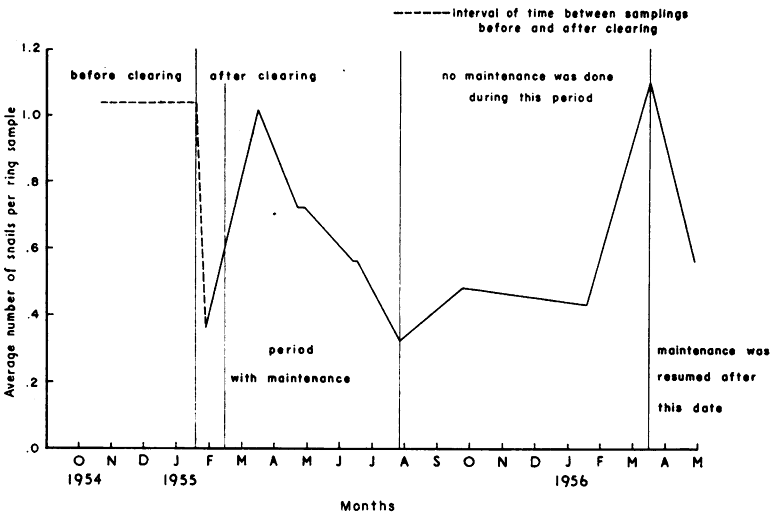
Cost

Initial cost of clearing . . . . Pesos $\frac{320}{426}$ = Peso 0.75 per linear metre

Average cost of subsequent clearings . . . Peso 0.23 per linear metre

During the experiment the snail population was reduced by 48%. This was undoubtedly due to the more thorough clearing, additional grading, stream channelling and construction of vertical walls.

FIG. 4. EFFECT OF CLEARING ON SNAIL DENSITY AT BINANGKAWAN STREAM



Vertical lines indicate the dates of maintenance clearing.

Drainage in Kanbanwa valley

After preliminary studies and investigations, we concluded that the other snail colony in Kanbanwa-Binangkawan zone would lend itself to an experiment in drainage.

The snail colony existing there was extensive, being located in a small valley, 6.9 hectares in size. This area, made up of abandoned rice-fields and deeply waterlogged meadows, supported exuberant vegetation of tall grasses, palawan and a variety of palms.

The initial topographical survey of the place showed that a gradient of 0.36% was available from the head of the valley to the Palo river. For purposes of the experiment, it was decided to construct two channels, which would serve to intercept the seepages coming into the valley from two different hillsides and later join to form a larger canal which would end in the Palo river nearby.

The over-all length of the canals is 766 m. The two tributary canals are altogether 630 m long, and are 0.60 m wide with vertical walls; the larger canal is 136 m long and 1.20 m wide, also with vertical walls. The depth of the canals varies from 0.30 to 1.75 m (see Fig. 3, page 229).

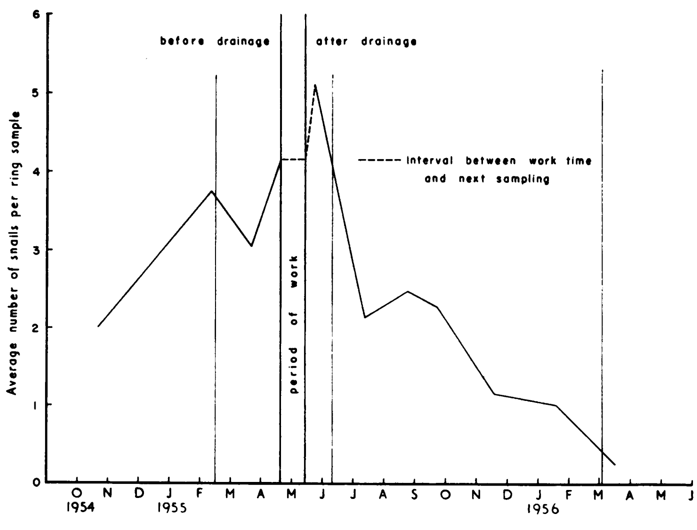
In the observations made several months after the canals were completed, it was seen that drainage was working successfully, and marked changes were noted in the area. The valley was completely dry, and a noticeable change occurred in the nature of the vegetation. The valley began to look

TABLE III. EFFECT OF DRAINAGE ON SNAIL DENSITY AT KANBANWA VALLEY *

	Date of sampling	Average number of snails per ring sample
Before drainage	26 October 1954	2.08
	11 February 1955	3.74
	21 March 1955	3.03
	20 April 1955	4.14
After drainage	23 May 1955	5.15
	11 July 1955	2.11
	25 August 1955	2.46
	22 September 1955	2.27
	17 November 1955	1.15
	19 January 1956	1.00
	15 March 1956	0.22

* Drainage work was started on 30 March 1955 and completed on 12 May 1955

FIG. 5. EFFECT OF DRAINAGE ON SNAIL DENSITY IN KANBANWA VALLEY



Light vertical lines indicate the dates of maintenance.

like a piece of grazing land, and we knew we had accomplished reclamation of several hectares of land suitable for farming.

There is no question but that the drainage canals brought about great changes in this snail colony.

Reduction of the snail population began two months after the completion of the canals. It has continued to the present in a most satisfying manner, the latest check, taken on 15 March 1956, showing a snail density of less than 7% of the average density before drainage (Table III and Fig. 5).

From thorough scrutiny of the size of snails collected in the field after the canals were established, it was noted that the smaller or younger snails were missing (snails ranging in size from 1.0 mm to 1.9 mm).

This led us to conclude that breeding had been interrupted, most probably as a result of the changes brought about in the old environment by the drainage. The new environment was characterized by lack of water, and the snails that could be found thereafter were mostly found in the canals or near the canals where moisture was present. The snails remaining in the colony were mostly adults of 2.5 mm and over.

Cost

Initial cost of digging canals	Pesos	400.00
Cost per cubic metre	Peso	0.73
Maintenance (1955-1956)	Pesos	626.00 *
Maintenance per linear metre	Peso	0.82

* Of the Pesos 626.00, 60%, or Pesos 375.60, was used for protecting the crumbling sandy banks of the canal next to the Palo river with bamboo palisades. The other 40%, or Pesos 250.40, was spent in maintenance clearing of vegetation; this, on the basis of 760 m amounted to Peso 0.33 per linear metre.

Here also it is noted that maintenance is necessary; in fact two kinds of maintenance are needed: clearing maintenance and canal maintenance. The latter item could be very expensive if the geological formations through which the canals are dug consist of sandy materials which have a tendency to cave in, as happened in the lower part of the canals in Kanbanwa. It may be mentioned here that we are aware of the possibility that open drains of the type we have used may soon become overgrown with weeds, and that the grassy eddies in these clear-water channels could encourage the breeding of the local malaria vector (*Anopheles minimus flavirostris*). Introduction of malaria in this area must therefore be scrupulously guarded against.

Combined vegetation removal and drainage in Santa Magdalena swamps

Before control activities began, certain parts of the extensive system of snail habitats at the Kanbanwa valley were densely overgrown with jungle, as was the case in the two Santa Magdalena swamps. At that time, penetration into the area was dangerous, because the floor of the valley was an unstable surface of floating grasses, beneath which was a watery, sticky mud about a metre deep. In these swampy areas grew aquatic plants such as lumbia (*Metroxylon sagu*, the sago palm), badiang (*Adocasia macrorrhiza*) and palawan (*Cyrtosperma merkusii*), a plant with large broad leaves that yields starchy edible roots. We may mention here that as a result of our experience we have often used the last two species of plants as indicators of snail habitats, although they are not always reliable.

Clearing operations were started in November 1954. The results were as encouraging as they had been in previous experiments. By April 1955, the snail population had been reduced to 41% of the original figure. The completion of the drainage channels in May made the reduction much more rapid, and in one area (Santa Magdalena No. 2), no snails have been found since July 1955 (Table IV and Fig. 6).

TABLE IV. EFFECT OF COMBINED CLEARING AND DRAINAGE ON SNAIL DENSITY AT SANTA MAGDALENA SWAMPS

	Date of sampling	Average number of snails per sample
Before operations	21 October 1954	4.75
After clearing *	11 February 1955	2.80
	21 March 1955	2.05
	29 April 1955	1.94
After drainage **	20 June 1955	0.41
	28 July 1955	0.31
	28 September 1955	0.19
	16 November 1955	0.28
	18 January 1956	0.33
	14 March 1956	0.19

* Clearing was started in November 1954.
** Drainage was carried out between 30 March and 12 May 1955.

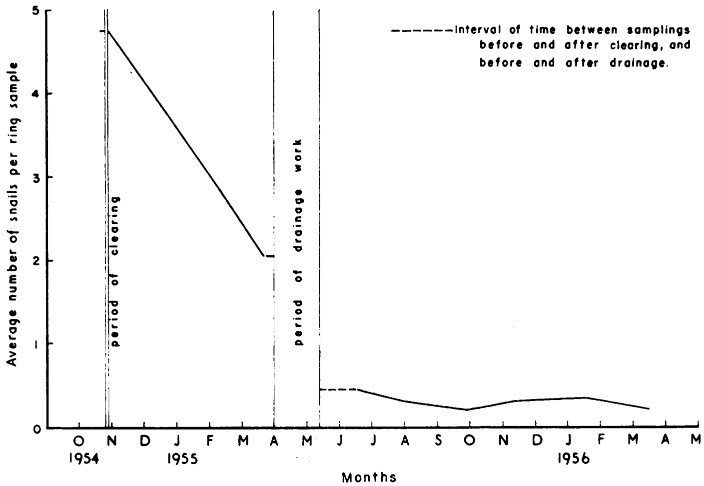
From these results, we conclude that certain control methods are more effective when combined than when used separately. In this experiment, after the vegetation had been cleared once, combined clearing and drainage further reduced snail density by 96% of the original numbers.

Cost (clearing costs before drainage at the Santa Magdalena swamps)

Area of Santa Magdalena Swamp No. 1 . . . . . . 1330 m^2
Area of Santa Magdalena Swamp No. 2 . . . . . 200 m^2

Cost of initial clearing. . . . . Pesos $\frac{462}{1530}$ = Peso 0.30 per m^2

FIG. 6. EFFECT OF COMBINED CLEARING AND DRAINAGE ON SNAIL DENSITY IN SANTA MAGDALENA SWAMPS



The question arises here whether the cost of clearing was justified in view of the fact that the subsequent drainage might have accomplished the purpose alone. From the standpoint of snail control, the clearing may have been superfluous, but for reclamation and for the land to become productive, clearing would still be necessary.

Earth filling

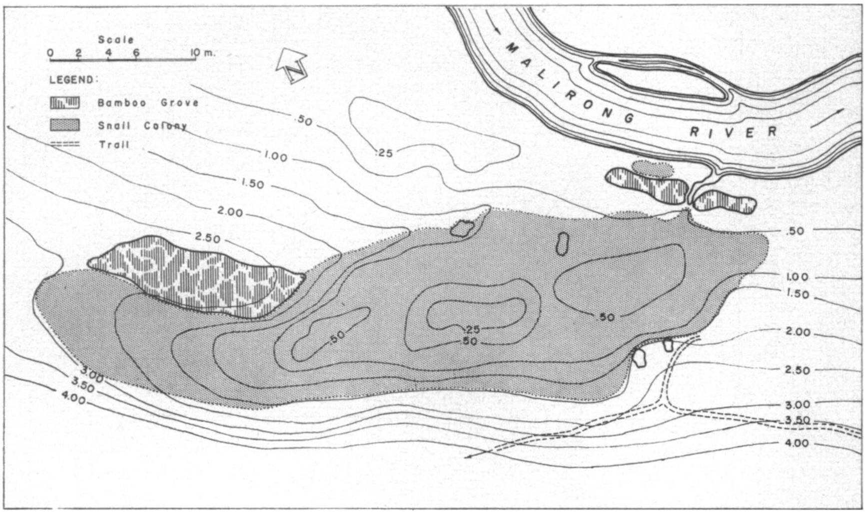
Certain snail colonies were so located that it appeared feasible to eradicate them by covering them with earth.

A good example was Malirong Pocket No. 1, which bordered a portion of the right bank of the Malirong river. This area was not very large, being 60 m by 85 m; it lay between the Malirong river and the adjacent flat coconut land above. There was a significant difference in elevation (3-5 m) between the bottom of the pocket and the land above the almost perpendicular banks (Fig. 7).

After a topographical survey of the site had been made, the first experiment in earth-filling using a bulldozer was begun. The operation consisted of gradually filling the low snail-infested grounds with earth pushed from the walls and high areas above, in such a way that a constant slope was maintained and drainage ensured. The thickness of the earth-fill varied from 0.10 m to 1.00 m.

At the end of the experiment, the wild aspect of the snail-infested area had vanished, and it had become an agricultural field ready to be ploughed and used. Already this field has produced a good crop of peanuts for its owners.

FIG. 7. MALIRONG POCKET No. 1, SHOWING SNAIL COLONY BEFORE EARTH-FILLING



At no time since the filling took place have we been able to find a snail within the site of the former colony.

There can be no doubt that the method is completely effective, and it has required no maintenance during the year of observation. Unfortunately, the method is of somewhat limited application in Palo, because it requires the presence of a nearby source of earth, and such situations are not often encountered in the area.

Cost

Total cost (excluding amortization)	Pesos 404.16
This sum represents 6 days' work of a D-6 Caterpillar bulldozer, of which the daily cost may be shown as follows:	
Cost of 8 hours' work of bulldozer, including costs of maintenance	Pesos 9.00
Cost of operation	Pesos 18.00
Cost of supplies	Pesos 40.36
Total cost per day	Pesos 67.36

The cost of filling is calculated as follows:

$$\frac{\text{Pesos } 404.16}{5100 \times 0.55} = \frac{404.16}{2805} = \text{Pesos } 0.14 \text{ per m}^3.$$

Flooding and ponding

Flooding. Since plants are sensitive to changes in the depth of the water in which they are growing, one of our early experiments was an attempt to control vegetation by fluctuating the water-levels. A suitable stream habitat (Experimental Creek No. 3) was selected and a bamboo-reinforced earth dam was constructed, provision being made for the pond to be emptied as desired. The depth of water next to the dam was increased by about 60 cm. This caused some reduction in the vegetation for a distance of about 25 m upstream but had no noticeable effect beyond that, although the water level was raised for a distance of at least 100 m.

As an attempt at vegetation removal, the experiment was not successful, but snail densities declined in the flooded area. Table V shows that excess water may be as harmful to the snails as lack of water.

TABLE V. EFFECT OF FLOODING ON SNAIL DENSITY AT EXPERIMENTAL CREEK No. 3

	Date of sampling	Number of snails per ring sample	
		flooded area	control area
Before flooding	20 July 1954	4.25	2.32
After flooding	5 October 1954	1.45	2.67
	15 November 1954	1.30	2.20
	29 December 1954	0.85	1.52
	18 February 1955	0.55	5.57
	27 April 1955	1.15	5.35
	13 June 1955	0.05	1.12
	25 July 1955	0	1.73
	23 February 1956	0.15	4.03

In this experiment the diminution of the snail population was surprisingly high; it became less than 4% of the original number. Addition of water or increased depth of their habitat proved to be detrimental to snail life. No maintenance work of any kind was necessary.

Ponding. The effect of excess water shown by the results at Experimental Creek No. 3 suggested that digging a series of ponds might make an area uninhabitable for snails because of the excessive depth of water. The vertical banks used in our drainage experiment, and also observed in use in some of the local fishponds, appeared to be an added hazard to the snails.

Ponds with these characteristics, it was felt, might provide a solution to the problem of the sluggish streams, which did not seem amenable to attack by other methods that we had used. The earth removed in digging the ponds can be used in partly filling other portions of the stream bed to make them available as small farming plots. Provision of side channels to carry the natural flow of water is necessary in this situation. In Gacao stream, where our first pond was made, a portion of the original stream bed, 3 m wide, was left untouched for this purpose.

A pond, 8 m by 28 m by 2 m deep, was dug, using a dragline attachment on a bulldozer. The walls surrounding the pond were made vertical. Less than three days were required to complete the work with the bulldozer.

The act of ponding reduced the number of snails but some remained after the work was finished. It was gratifying to observe a continual further decline in snail densities to the point where none could be found eight months after the construction of the pond. This indicated that the 100% water-habitat (with a depth of 2 m) is totally unsuitable, as we had thought, since the snails that remained were unable to repopulate the place. Adjacent parts of the stream, not affected by the ponding operation, served as comparison areas for snail densities.

The difficulty with this method lies in the requirement of vertical banks, which can be made permanent only if clay or some similar cohesive material is present. If the pond banks are of a sandy nature, maintenance costs will be much higher.

Table VI and Fig. 8 show the effect of ponding on snail density counts. Fig. 9 is a plan of the pond.

The results obtained in this experiment are very satisfactory; the snail population was reduced to zero. Some maintenance was necessary to keep the walls of the pond vertical.

Cost

Cost of bulldozer use for 3 days at Pesos 67.36 per day (excluding amortization cost)	Pesos 202.08
Cost of dyking against floods and maintenance for 12 months .	Pesos 272.00
Total cost	Pesos 474.08

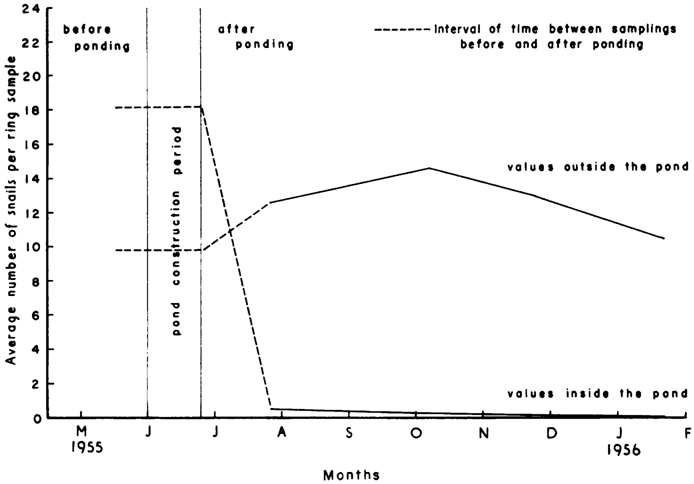
$$\text{Cost of excavation} = \text{Pesos } \frac{202.08}{488} = \text{Pesos } 0.41 \text{ per m}^3$$

TABLE VI. EFFECT OF PONDING ON SNAIL DENSITY AT GACAO FISHPOND

Date of sampling	Number of snails per ring sample	
	inside pond	outside pond
16 May 1955 *	18.12	9.79
25 July 1955	0.54	12.58
7 October 1955	0.13	14.54
23 November 1955	0.03	12.83
21 January 1956	0	10.25

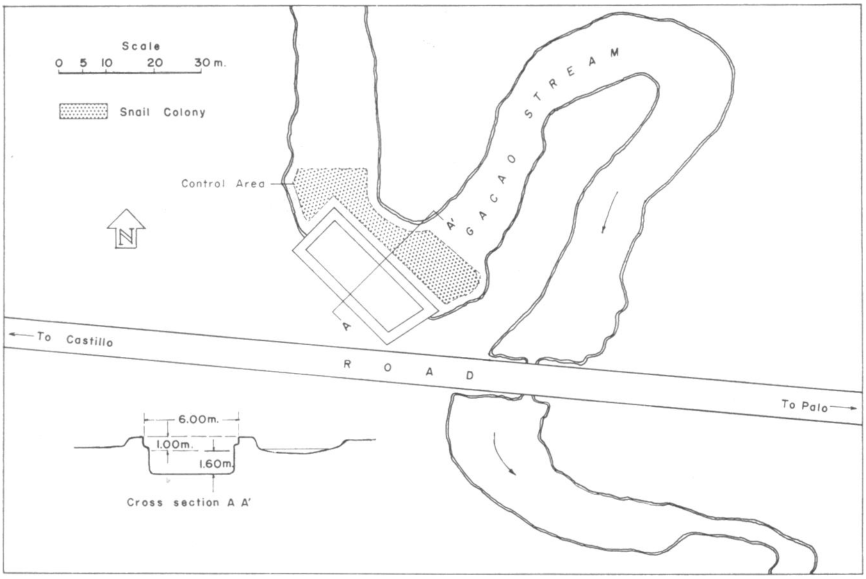
* Sampling done at pond site before construction of pond

FIG. 8. EFFECT OF PONDING ON SNAIL DENSITY IN GACAO STREAM



Ponding, although expensive, has a definite value to the people because the ponds can be utilized for fish culture. We do not yet have definite information as to the production of fish of this pond, but a similar pond

FIG. 9. PART OF GACAO STREAM, SHOWING LOCATION OF PONDING EXPERIMENT AND CONTROL AREA

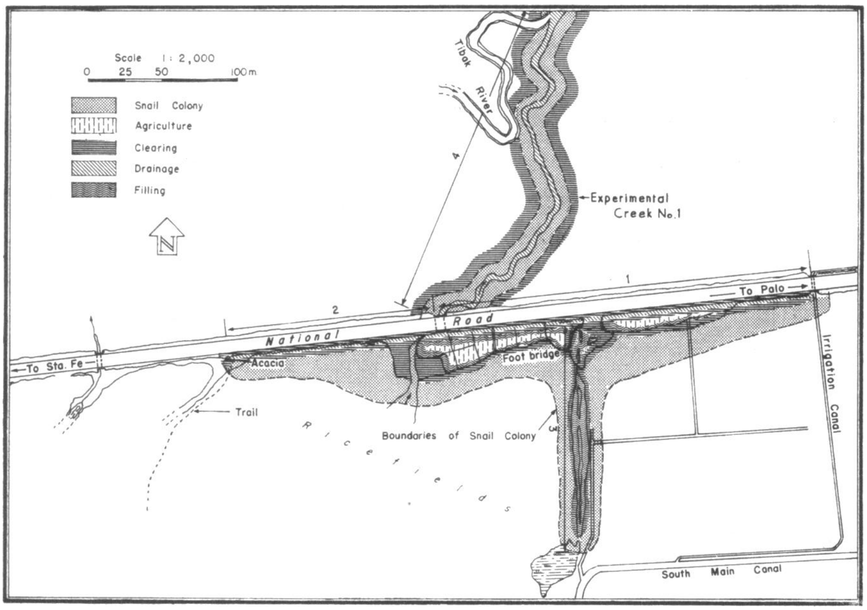


should produce 500 mudfish (or more) in the first 18 months after its establishment; three of these fish at maturity weigh 1 kg. The current market value of these would be about 250 pesos at 1.50 pesos per kilogram.

Combined methods in a single colony—Tibak

The experiments reported above were mostly performed on isolated colonies of types favourable for the methods employed. As has been stated in the discussion of snail habitats, however, most colonies represent a combination of habitats and we were anxious to discover if such colonies could be reduced or eradicated by a combination of methods.

FIG. 10. TIBAK AREA, SHOWING SNAIL COLONY AND CONTROL METHODS EMPLOYED



The numbers shown on this map correspond to those in the first column of Table VII.

The Tibak area, selected for this experiment, is an isolated one with definite boundaries and separated from other snail colonies by permanent roads, irrigation ditches, streams, etc. The colony is encompassed within an area of about 600 m by 400 m (see Fig. 10) and about 6600 m^2 are actually inhabited by snails.

In the area, snails were found in a variety of habitats; they were living along the edges of a small stream, in swampy areas, between the cogon grasses of a property-dividing hedge, underneath the shade of bamboo groves, in ditches lining the national highway, and in seepages next to the rice-fields. In other words, the Tibak area has enough different types of habitat to test the usefulness of several of our control methods.

Control work in the areas started in the latter part of December 1955. A fitting description of the work we did would be to say that we tried a general and thorough reconditioning of the land, providing good drainage through careful grading, filling holes and low areas, clearing all vegetation and removing stumps and old roots that encourage the farmers to abandon the land; finally we introduced scientific rice culture in the reclaimed portions of the area.

Some portions that required filling and grading were rather small and isolated. We found that a scraper (ordinarily used for agricultural purposes) pulled by a carabao (water buffalo) was most effective in handling situations of this sort.

The effects of work done at the Tibak snail colony are illustrated in Table VII.

TABLE VII. EFFECT OF COMBINATION OF CONTROL METHODS ON SNAIL DENSITIES IN TIBAK

Control methods *	Number of samples taken	Before control (7 July-6 September 1955)		After control (7 April-4 May 1956)	
		number of snails	average per sample	number of snails	average per sample
1. Agriculture, clearing and drainage	57	344	6.04	115	2.02
2. Clearing and drainage	56	238	4.25	143	2.55
3. Clearing, filling and grading	80	110	1.38	27	0.34
4. Clearing and grading	75	82	1.09	29	0.39
Total	268	774	2.89	314	1.17

* The numbers preceding the description of the control methods refer to the areas in which those methods were applied and correspond to the numbers shown in Fig. 10.

As we had anticipated, the control measures used accounted for a very significant density reduction in the colony. Snails showed the greatest reduction at locations where filling was performed using water buffaloes and manual methods. The density reduction in these places amounts to 75% of the original. We estimate that the area of the colony was likewise reduced by over 50% of its original size.

Agriculture comes next in efficiency in the results observed, followed by grading and clearing.

The general effect of the control measures in the Tibak area may be illustrated by the following figures:

	Before control July-August 1955	*After control April-May 1956*
Total samples taken	268	268
Total snails collected	776	306
Average number of snails per sample	2.9	1.14
Total number of male snails	319	105
Total number of female snails	457	201
Mean length of males	3.48 mm	3.92 mm
Mean length of females	3.86 mm	4.43 mm
Total mean length	3.70 mm	4.26 mm
Snails smaller than 2.5 mm	9.28%	4.58%

It will be seen that the mean length of the snails collected increased after the experiment from 3.70 mm to 4.26 mm. This would indicate that the snail population has fewer young, showing that breeding has been curtailed. This is further proved by the fact that the percentage of young snails (i.e., those smaller than 2.5 mm in length) was reduced by about 50%.

The snails left now are mostly confined to the drainage canals and to parts of the rice-fields adjacent to the canals. We expect a greater diminution in density when replanting in the rice-fields is continued.

Cost

Clearing 450 linear metres at Peso 0.75	Pesos 337.50
Drainage of 258 m^3 (430 m $\times$ 0.60 m $\times$ 1.00 m) at Peso 1.00	Pesos 258.00
Cut and fill, including carabao fill, of 88 m^3 at Pesos 1.50	Pesos 132.00
Farming (ploughing 8 m $\times$ 140 m)	Pesos 10.50
	Pesos 738.00

Total cost per m^2 . . . . Pesos $\frac{738}{6600}$ = Peso 0.112

Improved Rice Farming

The association of Asian bilharziasis with rice-growing areas has been the subject of comment by many authors (Strong, 1944; McMullen et al., 1954). In the rush of research that followed the re-occupation of Leyte in 1944, however, several workers recorded the observation that rice-fields themselves did not seem to be typical habitats of *P. quadrasi* (Abbott, 1948; McMullen, 1947). Their statements, in conjunction with detailed studies on snail distribution in Japan, served to call into question the danger that the rice-fields represent. It became a routine matter to state that although some snails were found in paddy fields, they appeared to have spread or to have been washed into them from surrounding uncultivated areas (Ritchie, 1955). It was therefore a surprise to us to discover a number of rice-fields in Palo and Tanauan which supported large populations of snails. The distribution and population structure of the snails in these fields showed plainly that peripheral areas were not responsible for their presence and that there was active breeding in the rice-fields themselves. The magnitude of the problem thus uncovered can best be illustrated by the fact that these rice-fields represent half of the total snail-infested area in Palo. Not all the fields harbour snails, however, and some do conform to the description quoted of diminishing densities away from the edge. The primary distinguishing characteristics of snail-inhabited fields is that they are all permanently waterlogged.

The system of rice culture that is practised in the endemic area of Leyte has been described earlier, and by McMullen (1947) and McMullen et al. (1954). It involves rudimentary preparation of the land by either a single shallow ploughing or by trampling the weeds into the mud by teams of carabaos, close and irregular planting of seedlings and no weeding at all. The system seemed obviously open to improvement, and when consultations with the provincial and municipal agriculturists showed us the extent of the possible improvements, we planned experiments to test their effectiveness in reducing or eliminating snails.

Experimental Rice-field No. 1

The first experiment is described only because, in its way, it is typical of what happens when public participation pays no more than lip service to public health. We selected an area with a uniformly high density of snails, and ascertained that the owner and tenant planned to plant it shortly. Together with the municipal agriculturist we had a conference with the owner and the tenant, and explained what was wanted. We described the method of good agriculture, which consisted of ploughing three times, harrowing three times, planting the seedlings uniformly in rows, building a low dyke around the plot to regulate water, and weeding two or more times during the growing season. The tenant was to treat half the field in this fashion and the other half in the way in which he would normally plant. An adjacent area of the same size was to serve as a control, as we had learned that no planting was contemplated there. To all these plans, both owner and tenant readily agreed.

The tenant did plough the plot once, at the urging of the agriculturist, but thereafter, " improved " and routine methods proved to be identical in spite of all pleadings, and the tenant was hardly ever seen in the rice-field. The snail density, which before preparation of the field had been shown to be uniform by statistical analysis, at one sampling three weeks after ploughing showed a slight but statistically significant difference in favour of the ploughed area. Before the rice was harvested, however, densities were as high as before the start of the experiment, and the changes in density in the farmed areas reflected those in the control.

Experimental Rice-field No. 2

In the second experiment, we were able to exercise control over the farming methods. A single piece of land was rented from the owner, and the tenant was hired as labourer, his work being supervised by us and the agriculturist. The experiment was planned so that we could test the effect of each feature of good rice culture on the density of snails, and also on the rice yield. The preparation of the land, the use of dykes, and the effect of post-planting care were tested singly and in combination. The experiment was carried on in two parts, both of patterns familiar to agricultural experimenters. The first was a Latin square in which were compared routine farming, good preparation (ploughing and harrowing) followed by routine planting, routine preparation followed by proper planting and weeding, and complete good farming except for the control of water. The fifth set of blocks was reserved as control area and left unfarmed.

The second pattern was a randomized block experiment comparing routine and completely good farming, each type with and without dykes, plus controls. Five randomized blocks were used rather than a Latin square because of the possible effect of dykes on contiguous plots, espe-

TABLE VIII. CHANGES IN SNAIL POPULATION IN EXPERIMENTAL RICE-FIELD No. 2, BEFORE AND AFTER PLANTING, USING RING METHOD (2 NOVEMBER-11 MARCH 1955)

Method of farming	Average number of snails per ring sample			
	before planting (2-5 November 1954)	after planting (3-9 December 1954)	after 1st weeding (19-25 January 1955)	before harvest (7-11 March 1955)
	Latin square			
PHWS	1.28	0.33	1.96	2.07
PH	1.20	0.40	1.49	1.52
TWS	1.21	0.76	1.80	2.17
Routine	1.54	0.81	1.81	2.16
Control	1.16	3.27	4.10	3.89
	Randomized blocks			
Undyked PHWS	0.81	0.44	0.95	0.48
Undyked Routine	0.61	1.27	0.65	0.68
Dyked PHWS	1.23	0.47	1.09	0.87
Dyked Routine	0.60	0.87	0.66	0.21
Control	1.43	1.32	2.22	1.48

* PHWS = ploughed, harrowed, weeded and sickled; PH = ploughed and harrowed; TWS = trampled, weeded and sickled; Routine = trampled only (traditional method); Control = unfarmed.

cially should the necessary randomization of the Latin square place an undyked plot between two or more with dykes. In both the Latin square and the randomized blocks, the individual plots measured 8 m by 12 m. Snail densities were determined initially with 20 ring samples in each plot, arranged in a grid, the distance between samples being 2 m. The results of the sampling done before preparation of the land showed that significant differences in snail densities existed among the different parts of the field, but the randomization of plot positions had had the desired result—there were no significant differences in average density among the areas to be subjected to different farming methods. Table VIII shows the average snail densities for each type of plot over four samplings. As these samplings proceeded, we became increasingly suspicious of the results because they did not appear to confirm the impressions gathered from random searching and because they were so markedly inconsistent—the ploughed plots showed a much greater rate of increase than the unploughed ones, and there was no relation between the amount of disturbance and the effect on snail density.

One significant fact shown by random searching was that in the weeded plots the snails were markedly concentrated among the stalks of the rice plants. This meant that the position of each sample made a greater difference in these plots than in the unweeded or unfarmed ones. Another observation was that the densely matted grass stalks in the unfarmed areas made collecting difficult, and we felt that a large proportion of the snails were being missed in these plots.

In an attempt to remedy these deficiencies in the sampling method, we resorted to the technique of tube sampling. The number of samples that could be taken by this method was smaller than with ring samples (four per plot, as compared to twenty rings). The locations of the four samples were predetermined by numbering all square metres available and drawing four from a table of random numbers. For the weeded plots, in the first two square metres drawn the rice plant nearest the centre of the square metre was included in the sample. Since we knew from the spacing the approximate number of rice plants in the whole plot, we could calculate the probable number of snails present from the samples taken. The results of this tube sampling, done at the end of the experiment, are shown in Table IX. The results are more reasonable than those from ring sampling. The plots on which any form of improved agriculture was practised all showed lower densities than they did when ring sampling was used and the control plots showed more than twice as many snails. The only inconsistency is in the slightly higher average density for the plots where complete good farming was performed (PHWS) than for those where only part of the farming was improved (TWS and PH). We attributed this to accidents incurred from the small number of samples that could be taken (more than half the snails collected on the PHWS plots came from two of

TABLE IX. NUMBER OF SNAILS RECOVERED FROM TUBE SAMPLES IN THE VARIOUS PLOTS* IN EXPERIMENTAL RICE-FIELD No. 2 (13 MARCH-12 APRIL 1955)

A. Latin square

Row	PHWS **		TWS **		PH **		Routine **		Control **
	without riçe stalk	with rice stalk	without rice stalk	with rice stalk	without rice stalk	with rice stalk	without rice stalk	with rice stalk	
I	0 2	0 3	0 0	1 3	0 0	0 0	3 4	0 3	9 5 5 5
II	6 0	2 1	0 0	0 0	2 1	1 0	4 3	1 1	3 11 11 7
III	0 0	0 0	0 0	7 9	0 2	2 0	0 4	4 4	19 3 6 11
IV	0 0	14 6	0 1	5 1	2 1	1 0	3 4	2 0	11 16 1 6
V	0 0	0 2	0 0	6 2	0 1	2 0	0 2	0 1	1 3 1 10
Total	8	28	1	34	9	6	27	16	144

B. Randomized block

Row	PHWS ** (undyked)		PHWS ** (dyked)		Routine ** (undyked)		Routine ** (dyked)		Control **
	without rice stalk	with rice stalk	without rice stalk	with rice stalk	without rice stalk	witth rice stalk	without rice stalk	with rice stalk	
VI	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 2 3 0
VII	0 0	1 0	2 0	0 1	0 0	0 4	0 0	0 0	2 2 0 0
VIII	0 0	3 1	0 0	0 3	0 5	0 1	0 0	0 0	0 1 1 0
IX	0 0	7 9	1 0	2 0	0 5	1 2	5 1	0 0	0 4 6 3
X	0 1	8 3	0 2	0 2	1 2	2 0	0 0	0 0	4 3 6 3
Total	1	32	5	8	13	10	6	0	40

* Four tube samples were taken from each plot.

** PHWS = ploughed, harrowed, weeded and sickled; TWS = trampled, weeded and sickled; PH = ploughed and harrowed; Routine = trampled only (traditional method); Control = unfarmed.

the 20 samples). The results leave little room for doubt that each of the three improvements introduced (preparation, weeding, and dyking) brought about marked reductions in snail density, but the failure to produce any combined effect indicated the desirability of repeating the experiment in whole or in part.

The rice yields were followed carefully because of the interest of the provincial and municipal agriculturists, and because upon the improved yields under good methods depends the possibility of attracting farmers to make the recommended changes.

The results are shown in Table X. To avoid the effect of one plot upon adjacent ones, a 1-m strip was left around each plot, the central part (6 m × 10 m) being carefully staked off before harvesting. The weights in Table X are for these 60-m² plots. The plots farmed in the manner

TABLE X. YIELD OF UNHUSKED RICE (IN Kg) HARVESTED AT EXPERIMENTAL RICE-FIELD No. 2 (21-29 MARCH 1955)

A. Latin square plots

Row	PHWS *	TWS *	PH *	Routine *
I	11.6	10.3	3.9	7.4
II	11.4	9.4	8.5	8.6
III	11.5	10.8	6.7	6.9
IV	14.0	10.9	6.7	6.8
V	13.4	11.6	6.1	4.9
Total	61.9	53.0	31.9	34.8
Average	12.4	10.6	6.4	6.9

B. Randomized block plots

Row	PHWS * (undyked)	PHWS * (dyked)	Routine * (undyked)	Routine * (dyked)
VI	9.7	7.6	3.1	4.4
VII	10.4	7.4	5.5	3.9
VIII	10.6	12.1	5.9	2.7
IX	14.1	8.0	9.6	8.8
X	10.7	10.9	10.3	4.4
Total	55.5	46.1	34.4	24.1
Average	11.1	9.2	6.9	4.8

* PHWS = ploughed, harrowed, weeded and sickled; TWS = trampled, weeded and sickled; PH = ploughed and harrowed; Routine = trampled only (traditional method).

routine for this part of Leyte yielded about 26.38 cavans; this was according to expectation and slightly better than the province-wide average of 21 cavans per hectare.[a] Ploughing and harrowing with no other improvements gave no better a yield than the routine farming, but in combination with proper spacing of seedlings and weeding it gave the best yields obtained in the experiment, almost 70% better than the routine plots. A change to this method would thus make a very material difference to the farmers' income.

The use of dykes had, in this experiment, a detrimental influence on the yield. This was most probably due to faulty management.

The provincial agriculturist, who took an active interest in the experiment, offered a certain amount of constructive criticism, which was included in 1955 in his report (unpublished) on the experiment. This included the fact that the field was dependent upon rainfall for water, that supervision and maintenance were insufficient, that only one weeding was done, and that large amounts of water were allowed to stand too long on the dyked plots.

Experimental Rice-field No. 3

In the next experiment, we attempted to correct the deficiencies listed by the provincial agriculturist as well as to overcome the difficulties that derived from sampling for snails. The location of Rice-field No. 3 was selected so that irrigation water was available. The experiment was made a joint one between the Bilharziasis Control Pilot Project and the Bureau of Agricultural Extension. A graduate of the Baybay (Leyte) Agricultural School was employed to do the farming. Since each improvement in rice-growing methods in Rice-field No. 2 had had an effect on snail density, we decided not to test these improvements separately again. The experiment, then, was simplified so that it included only three kinds of plots: complete good farming, routine farming, and unfarmed controls.

During the period 27-29 October all plots, including controls, were surrounded by dykes to allow control of water. They were also equally treated during post-control measures.

The plots to be farmed had the vegetation cut down by a sled equipped with knives on the runners. The plots where complete good farming (Masagana system) was carried out were ploughed and harrowed twice—on 5-10 November and again on 12-18 November. In the plots where routine farming was followed, only the first ploughing and harrowing were done. Planting of seedlings took place on 19-23 November. In the Masagana plots, the seedlings were carefully spaced 2-3 to the bundle at intervals of 35 cm in rows 35 cm apart. In the routine plots, the seedlings

[a] 1 cavan = 44 kg.

were planted 5-7 to the bundle in an irregular pattern, averaging about 20 cm apart.

The Masagana plots were weeded thoroughly twice—8-14 December 1955 and 5-10 January 1956. Although a third weeding was planned, it was deemed unnecessary by the municipal agriculturist. No work of any kind was done in the routine plots after the completion of planting.

The plots were harvested as the grain became ripe over the period 20 March-12 April. The design of the experiment was again a Latin square. Each of the nine plots (three of each kind) was 30 m by 20 m. Not only did this size permit easier handling of work animals in individual plots than did the smaller ones in Rice-field No. 2, but it also enabled us to take 30 tube samples from each plot, thus reducing the likelihood of sampling accidents such as those that marred the results in the previous experiment. The samples were 4 m apart in one direction and 5 m apart in the other. The sampling pattern has been shown in an earlier part of this report and need not be reproduced here.[a] Anticipating the clumping of snails among the stalks of the rice plants, we calculated the fraction of the plot covered by the stalks, and arranged that the same fraction of samples (one-sixth) should contain them. This was done by numbering the samples in advance, and selecting five out of the 30 on each well-farmed plot from a table of random numbers. These five were made to include the rice plant nearest the predetermined sample site. Thus, the 30 samples reflected as accurately as possible the number of snails actually present on the plot. One sampling was done immediately before preparation of the land, one before the second weeding and one immediately after the harvest. The results are shown in Table XI.

Statistical analysis of the data for the preliminary sampling shows that there were no significant differences in density between the plots;

TABLE XI. RESULTS OF TUBE SAMPLING AT VARIOUS STAGES IN EXPERIMENTAL RICE-FIELD No. 3

Type of farming	Total tube samples taken	Before farming (24 October-14 November 1955)		Before 2nd weeding (10-27 January 1956)		After harvest (20 March-12 April 1956)	
		total snails	average per sample	total snails	average per sample	total snails	average per sample
Masagana	90	502	5.57	7	0.08	53	0.59
Routine	90	599	6.66	61	0.67	492	5.47
Control	90	582	6.46	608	6.75	501	5.57
Total	270	1684	6.23	676	2.50	1046	3.87

[a] See *Bull. Wld Hlth Org.*, 1958, **18**, 530, Fig. 20.

the density was virtually maintained in the control plot during the course of the experiment. This confirms the general conclusion in our earlier discussion of population dynamics[a] about the constancy of snail densities. The Masagana plots showed a drop to 1.4% of the initial density, followed by a recovery to 10.6% after harvest, and the routinely farmed plots showed a drop to 10.2%, followed by recovery to 82.1%. The minor changes in the control plots consisted of a 4% increase followed by a decline to 86% of the initial density.

The following figures for the yield of rice confirm the superiority of the technique from a purely agricultural standpoint:

	Yield from routine plots (kg)	*Yield from Masagana plots (kg)*
Row I	83.0	168.5
Row II	97.5	174.5
Row III	72.0	153.0
Total	252.5	496.0
Average	84.17	165.33

The Masagana plots gave an average of 62.63 cavans per hectare, very nearly double the 31.88 obtained for the routine method, and almost three times the average for the province. It is evident that in improved agricultural methods we have the solution to the problem of vector snails in the rice-fields. The method requires no cash expenditure on the part of the farmer, and the increased yield will compensate amply for the extra work involved in correct preparation of the land and maintenance of the crops.

Because the snails have not been eliminated completely from the Masagana plots, a second crop will be grown in the same field under the same conditions in order to find out if two crops in one year of proper cultivation will achieve the desired effect of complete eradication of *O. quadrasi*.

Environmental Sanitation

The importance of sanitation in rural areas has been stressed frequently as a potential method of control not only of bilharziasis but also of intestinal pathogens of all kinds. *Schistosoma japonicum*, by infecting lower mammals, might theoretically be able to maintain itself, however, even after perfect sanitation has been achieved as far as human faeces is concerned. In order to test the effectiveness of sanitation, we initiated a campaign of latrine construction in the barrio of Malirong—one of the hyperendemic areas in Palo. The prevalence of bilharziasis among the human population had been established as 63% on the basis of a single stool examination of 365 individuals, representing a stratified sample of the 768 inhabitants of the barrio.

[a] See *Bull. Wld Hlth Org.*, 1958, 18, 528.

Through the co-operation of the municipal mayor, the councillor for Malirong District, and the barrio lieutenant, we were able to call a community assembly on 3 June 1954. The programme was explained to the people, and we showed them various phases of the parasite's life cycle and demonstrated a suitable design for a pit latrine. Following this assembly, house-to-house visits were made, in order to persuade individuals to build latrines and to advise them as to proper locations.

The project was not in a position to offer financial or material help to the people and could not, therefore, insist upon any standards as to the type of latrine constructed. As might be expected, a considerable variety of latrines arose in the barrio, most of them sub-standard, but some of acceptable design. In all, 119 of the 142 families in the barrio constructed latrines between 3 June and 17 June 1954.

Because of the long life of the worms in the human host, we decided to judge the effectiveness of the latrines in terms of the infection rate in the snails. Knowing little about natural fluctuations in these rates, we selected for observation one group of five colonies of *O. quadrasi* located in the immediate vicinity of houses, and another group of five colonies sufficiently distant from houses so that the construction of latrines would have no effect upon the amount of infective faeces that they received. The second group thus served as comparison areas for observing natural changes in snail infection rates. The two groups are referred to hereafter as " near " and " far " colonies.

It was decided that sampling should cover as large an extent of each colony as possible, and that the samples should be evenly spaced. This procedure allowed us to estimate the infection rate of the whole colony rather than a part of it. In order to have a sufficiently large number of snails, sampling in each colony was continued until at least 300 snails had been obtained. If the limit of the colony was reached before obtaining this number, additional samples were spaced midway between those already taken. Ring sampling was used throughout the study. The distribution of houses and of the ten colonies observed have been shown in Fig. 17 of the second part of this report.[a]

One sampling was done during the period 17 May-4 June 1954, or immediately before the latrines were constructed. The influence of the proximity to houses is clearly shown in the infection rates which averaged six times as high in the near as in the far colonies. The latrines, imperfect though they were, apparently had an effect on the snail infection rates in the near colonies. The sampling done during the latter part of August showed that the rates for the far colonies trebled, while those in the near colonies had fallen slightly. In October 1954 and January 1955, the far colonies actually had higher average infection rates than the near ones,

[a] See *Bull. Wld Hlth Org.*, 18, 525.

reversing the situation of the preceding May, before the latrines were built. (The relevant figures have been published earlier.[a])

After about five months, the effect of the poor design and construction of the latrines became increasingly apparent. When a storm on 29 November 1954 blew down many superstructures, no effort was made to replace them, and the latrines fell into disuse. By March 1955, the average infection rate in the near colonies was again higher than it was in the far colonies, and it has remained so ever since.

We felt that sanitation had not been given a fair trial on this experience alone, but at the same time it was obvious that the people could not be expected to provide themselves with latrines that would meet the standards required for an adequate test of the method. Added to the desire for a satisfactory experiment was the necessity of testing the theoretical importance of humans in the transmission of bilharziasis. Based on the daily output of hatchable eggs, the contribution of man in Palo amounts to three-fourths of all of the miracidia produced.

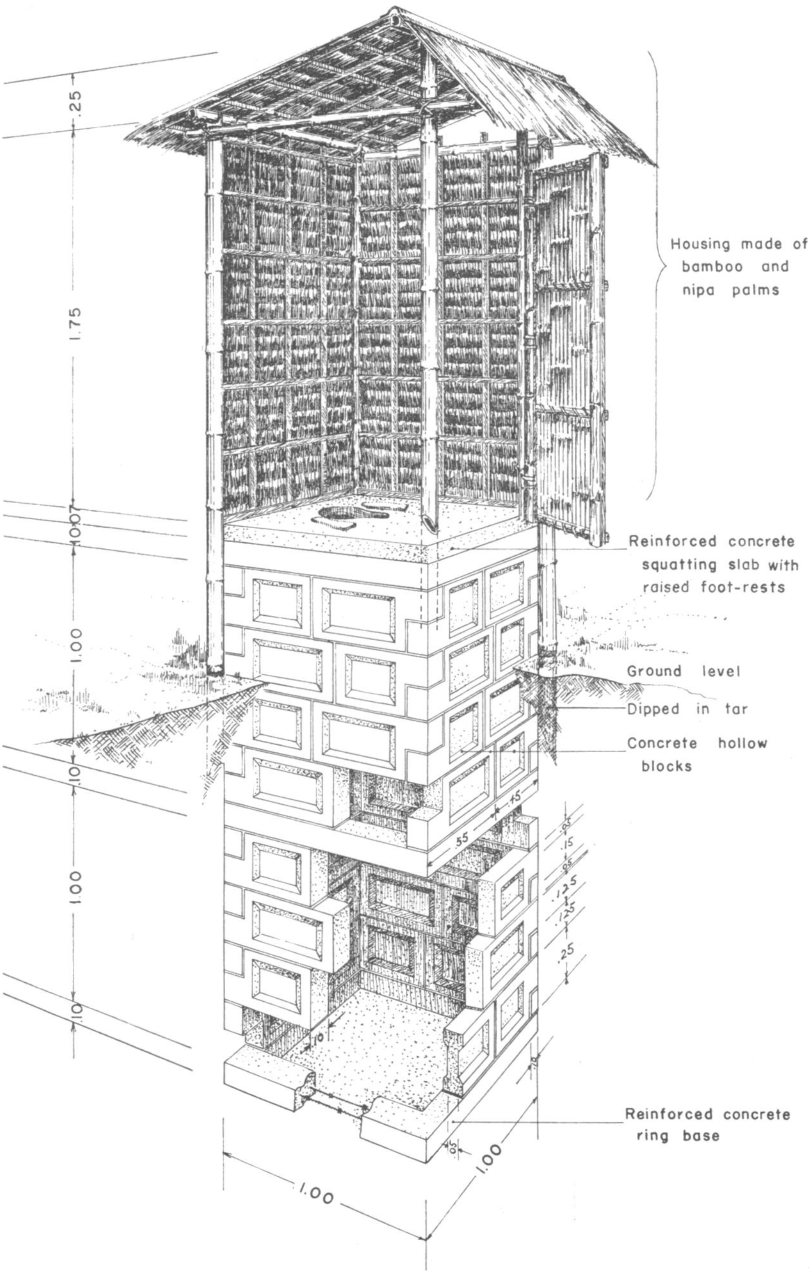
It was on this experimental basis that the Philippine Government agreed in March 1955 to provide the materials necessary for the construction of a good latrine for every family in Malirong. After considerable discussion, study, and calculation of costs, it was decided to build two types of latrine in approximately equal numbers. The difference is in the type of material to be used in casing the pit, which is 1 m square and 2 m deep. Certain parts of the barrio are low-lying and subject to flooding at frequent intervals. In these places it is necessary to raise the latrine floor above maximum high water, and in order to prevent the floods from washing out the contained faeces the part above the ground must be waterproof. Under such conditions the only solution seemed to be to design a casing of concrete blocks and to carry it above ground to the necessary height (Fig. 11). This technique has proved very effective during floods.

In the parts of the barrio not subject to flooding, a less expensive casing was provided in the form of a palisade of whole mature bamboo around a supporting wooden frame (Fig. 12). The slab used for both types is of conventional design, 1.00 m × 1.00 m × 0.07 m, of concrete reinforced with barbed wire. At the request of the people, foot-rests were incorporated. The digging of the pit and the construction of the superstructure are done by the family concerned. Cost figures for these two types of latrine are given in Table XII.

Construction of latrines was started in July 1955, and was completed in April 1956. Up to the date of completion of the latrines, the snail infection rates have not reflected the effect of the campaign. The colonies near houses have shown the increase to be expected from the high rainfall from November on,[b] and there has been no indication that the near and far

[a] See *Bull. Wld Hlth Org.*, 1958, **18**, 574-576, Table XLVII and Fig. 38.
[b] See *Bull. Wld Hlth Org.*, 1958, **18**, 575.

FIG. 11. PIT LATRINE CASED WITH CONCRETE BLOCKS



Measurements are shown in metres

FIG. 12. PIT LATRINE CASED WITH BAMBOO

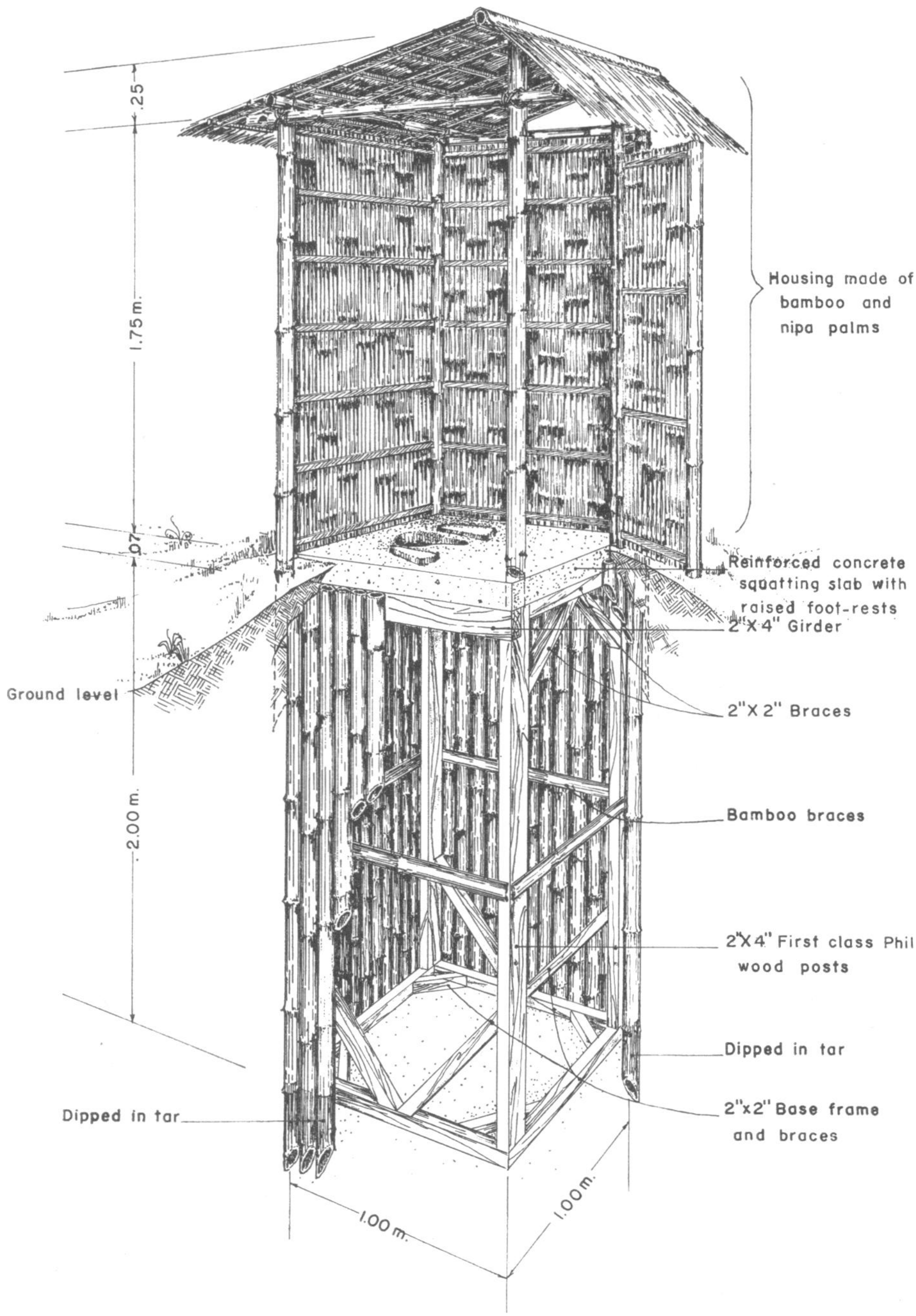


TABLE XII. ANALYSIS OF COST OF THE TWO TYPES OF LATRINE CONSTRUCTED IN MALIRONG ZONE

	Cost in pesos *			
	bamboo casing		concrete casing	
Materials:				
Slab	2.69		2.69	
Cement, gravel, sand and barbed wire				
Wood, bamboo, wire, nails, tar, etc.	18.99		19.20	
Mortar			1.00	
Labour:				
Installation	4.00		4.00	
Slab construction	1.50		1.50	
Concrete block construction			7.00	
Total cost to project		27.18		35.39
Materials furnished by the barrio people (estimate)	4.00		4.00	
Labour furnished by the barrio people (estimate)	4.00		4.00	
Total cost to barrio people		8.00		8.00
Grand total		35.18		43.39

* 1 peso = US $ 0.50.

colonies have reversed their relative positions as they did during the first campaign. It may well be that it is too early to expect results. Another explanation would appear to lie in the reluctance of the people to use their latrines.

Our close contacts with the people have shown that the reluctance comes from a variety of sources, all of which seem completely reasonable to them. The first reason appears to be that the germ theory of disease is not widely accepted, especially in rural areas such as Malirong, where death and disease are believed to be caused mainly by the malevolence of fairies (" encantos ") and witches (" aswangs "). The second reason, and perhaps the most important, is that the pit latrine is not regarded as a superior means of faeces disposal. There are many complaints of foul odours which do not occur when defaecation is done in the open, where pigs quickly find and eat the faeces. This brings up the additional objections that the latrines deprive the pigs of an important source of food. The third reason for non-use of latrines is that to obtain materials for the construction of the shelter some expense is involved, which, although apparently trifling to an outsider, may indeed be important to people as poor as they are.

That these attitudes can be partly changed through persistent personal contact is shown by the fact that we have been able to persuade all families to dig their pits and nearly all to build their shelters. The question of actual use is a somewhat different matter, but faeces could be found in over one-half of the latrines when the construction programme was completed. We feel that continued efforts will increase this proportion.

Monthly checks are being performed on the use and condition of the latrines. These include observations on cleanliness, maintenance, fly breeding, odour, condition and amount of faeces, and the reaction of the householder. It is not possible to be certain that all members of a family are using a latrine, but making the assumption they do, the observed rate of filling for a family of six is 3 cm per month. Since the pit is 2 m deep, the latrine should last about five years.

Discussion on Control Methods

Attack on the molluscan host

Our experience has shown that snail habitats are so varied that no single line of attack can be devised that will apply to all places harbouring snails. Removal of vegetation and the digging of fishponds are obviously unsuitable for a rice-field or a swamp covering several square kilometres, and drainage is impossible in streams; earth-filling demands sufficient earth near by; and scientific agriculture requires that the area be suitable for rice-growing. Clearly each snail colony demands individual study before a decision can be made as to the best approach for snail control.

From the relative effectiveness of the various methods that we have described, it is clear that the degree of success is related to the amount of change brought about in the habitat. The more radical the change, the greater the reduction in snail density. It also appears that after the more radical changes less maintenance is required. The lesson to be learned here is that half-way measures are likely to be ineffective, and that compromising to reduce the initial cost will prove to be false economy. None of the methods are really new to public health engineering—most of them have proved their worth in malaria control. The cost of such measures is high, and we have directed our efforts at simultaneous improvement in land use, so as to provide a broader basis for costing and also to make the method more attractive to the individual landowner.

It is possible that this feature of land improvement will eventually make it possible to adopt measures whereby the individual landowners bear the cost of such improvement or at least contribute to it.

Attack on the parasite through sanitation or treatment

It has been argued in the past that proper disposal of human faeces would not play an important role in the control of *S. japonicum*, owing to the fact that the infection is one in which several domestic animals act as transmitters of the disease to man. On the one hand, the importance of the animal reservoirs is heightened by the fact that we have established that no strain differences of the parasite exist in this area, but on the other hand we have also established that their relative role is small compared to that of man. This would obviously point to the importance of sanitary disposal of human excreta in the control of transmission. We have earlier pointed out the need for a wider programme of rural sanitation as part of a broad-based rural development project aimed at raising living standards, and we believe that until this is done and the use of latrines becomes a habit of life, the role of latrines will continue to be of doubtful value. We have had only limited experience locally with pit latrines, and have enumerated the difficulties encountered in this constantly inundated area, but we feel rather sceptical as to the possibility of an early solution of this problem, which remains one of the unsolved rural health problems of many economically under-developed countries. Stoll (1947) summarized the situation well when he said:

"... logically necessary as is the pit latrine to combat soil pollution, the esthetic affront it gives to those who are supposed to use it vitiates its virtues and drives adults as well as children back to the out-of-doors where the air is free. That is true even in this latitude, and the closer to the tropics the truer it is. No wonder latrine construction and use is hard to establish there."

Treatment could no doubt play a part in the ultimate control of the disease when transmission has been reduced to an insignificant level, and we fully agree with the observation of the WHO consultant team on bilharziasis in the Philippines that:

" In other helminth infections the treatment of human patients has not been effective as a public health measure. There is no reason to believe that schistosomiasis differs from this ... A patient with schistosomiasis and two or three parasitic infections and showing malnutrition is not apt to respond well to the treatment of only one of these conditions."

We do not have an effective and safe drug for the treatment of bilharziasis japonica that could be used on a large scale in the rural areas, where hepatomegaly of multiple etiology, infection with two or more parasites and undernourishment are the rule. Such a situation will militate against the unguarded use of antimonials in any control programme.

Although treatment as a method of control of bilharziasis has been practised in Egypt for many years and made compulsory since 1941, there is no clear evidence that this has made any impression on the prevalence of the disease in that country. Shousha (1949) summarizes the situation in these terms:

> " For those who have taken the full course of infections, cure is not certain, whereas reinfection is almost certain. Even though treatment has been established for 20 years, there is more schistosomiasis at the present time than ever before in history."

The latter is no doubt partly accounted for by the opening-up of large areas to perennial irrigation. He points out, however, that extensive treatment has diminished both the number and the severity of the complications. Statistics collected from the in-patients and out-patients of general and district hospitals have been quoted in support of this view, but we are well aware of the selection and other factors associated with hospital admission and of the difficulties of drawing valid and acceptable conclusions from them.

On the basis of our experience in this area we are becoming increasingly convinced that bilharziasis japonica is a biosocial problem, and since economic life so largely determines social existence the two must be taken as a single factor. McMullen (1955) regards the problem of bilharziasis in general as an " extremely complicated bio-economic problem ", requiring the concerted efforts of several disciplines for its solution. The broader approach of improving the total environment, and thus operating both on the host and on the parasite, is not limited to the physical aspects only but must also include the biological and the social. All these factors are intimately interwoven.

We feel we have done well to follow the advice of the WHO consultant team on bilharziasis by starting with the environmental control methods which we have described above. They seem promising and we are now going into the next stage of establishing the effectiveness of these methods in controlling the disease in man, their acceptability by the community, and their economic feasibility. We cannot at present make any claims regarding their effectiveness in reducing the incidence of bilharziasis. We have begun a large-scale test in Palo and estimate that about three years will be needed to complete the test, because a long interruption of transmission is necessary before its effect can be measured in human terms. The test will also allow us to compute the *per caput* cost much more accurately than can now be done.

We have found staunch allies in the agriculturists, who endorse our recommendations for improved rice culture, which, as we have shown, reduce the snail densities considerably and more than double the rice production at the same time. Our recommendations in this regard coincide in every detail with the agricultural bureau's proposals for stepping up rice production. There are probably few instances of such unanimity of views between two government agencies to be found in public health work. There is a saying in Italy that " malaria flees before the plough ". Whether or not that saying is true for malaria, there seem to be considerable grounds for hope that it may hold good for bilharziasis in the larger part of the endemic areas in the Philippines.

ACKNOWLEDGEMENTS

We are grateful to the Honourable Secretary of Health of the Republic of the Philippines, Dr Paulino J. Garcia, for permission to publish these studies. To Dr H. de Lien, Chief of the United States International Cooperation Administration's Health and Sanitation Division and to the administrators of the co-operating agencies—United Nations Technical Assistance Board and the Philippine Council for United States Aid—we are indebted for all the assistance received. We wish to record our deep appreciation of the encouragement received from Dr Walfrido de Leon, Director of the Public Health Research Laboratories, Philippines Department of Health; Dr I. C. Fang, Director, WHO Regional Office for the Western Pacific; Dr T. M. Gan, Director of Health Services; the Regional Advisers of WHO Regional Office for the Western Pacific; and to Dr Henry K. Beye and his successor, Mr T. McNeel, of the Health and Sanitation Division, International Cooperation Administration.

For the unlimited technical advice received from the responsible operational officer from WPRO, Dr John H. Strahan, Regional Public Health Administrator, and his predecessor, Mr Paul Bierstein, Regional Adviser on Environmental Sanitation, we wish to record our deep gratitude.

We are appreciative of the interest shown in our project by the Hon. Daniel Z. Romualdez, Speaker Pro-tempore, House of Representatives, and for the support and co-operation extended by Governor Bernardo Torres and other provincial officials of Leyte, and the two successive Mayors of Palo, Mr Manuel Acebedo, sr, and Mr Severo Peñero. To the Mayors of Tanauan and Carigara and the officials of the municipalities in Eastern Leyte and the many barrio lieutenants and others who have extended their co-operation and hospitality to us we wish to express our special gratitude.

We have received constant co-operation and support from Dr Mariano G. Legaspi, the Provincial Health Officer, from the provincial officers of the Social Welfare Administration, the Bureau of Public Works and the Irrigation Office, and from the Municipal Health Officers of Palo and of the different towns where our work has taken us. To all of them we are most grateful.

Thanks are due to Mr Elpidio F. Galado, Provincial Agriculturist, and Mr Pedro Fornillos, Municipal Agriculturist, for all their help in connexion with the agricultural experiments in which they wholeheartedly collaborated with us. We are indebted to the Director and the team of soil technologists of the Bureau of Soil Conservation, who carried out a detailed soil survey of the Palo-Tacloban Irrigation District, for their valuable report and for permission to adapt two of their maps and utilize their data. We also thank the Principal of the Baybay Agricultural School for permission to establish a weather station in the college grounds and for recording the data for the project.

To Mr R. T. McMillan, Social Science Adviser, International Cooperation Administration, for reading through the manuscript of the first part of our paper, and to the many experts and distinguished visitors who have visited the project from time to time, we extend our sincere thanks for their helpful suggestions and encouragement.

We are thankful to the team of WHO consultants for the valuable guidance contained in their report which we have often consulted and followed in many respects. To Dr D. B. McMullen, who headed the team, we feel particularly indebted for his keen interest in our work, for going through our quarterly field reports critically and for his constant encouragement.

The studies reported are the product of the sustained efforts of the whole staff of our project and to them most grateful acknowledgement is made. The whole work was so integrated that it is difficult to sort out the endeavours of invididual persons into clearly defined sections; the personnel have been frequently exchanged between the different sections. While living in Palo, away from their home towns, under somewhat trying conditions, they have performed their duties with a devotion and enthusiasm without which this work could not have been done. The following merit special mention: Dr P. S. Acob, Dr E. Alikpala, Dr I. M. Capistrano, Mr B. C. Dazo, Mr R. G. Moreno, Mr M. J. Santos, Mr L. Duran and Mr F. V. Galang.

RÉSUMÉ

Cet article est la troisième et dernière partie du rapport consacré à la bilharziose aux Philippines. Les auteurs y rendent compte des expériences préliminaires de lutte qu'ils ont conduites dans l'île de Leyte. Ils décrivent le régime des cultures, en particulier celle du riz, qui est encore au stade empirique et dont le développement peut influer sur la pullulation des mollusques, puis ils passent en revue les diverses méthodes de lutte mises à l'épreuve. Si l'on n'a pas trouvé dans la biologie d'*Onchomelania quadrasi* « le » point vulnérable que l'on cherchait, on a réuni des données qui peuvent orienter les méthodes de lutte visant, à longue échéance, à l'éradication de l'hôte intermédiaire de *Schistosoma japonicum*. La première est la permanence des colonies de mollusques connues. Ainsi, point n'est besoin d'envisager la lutte dans toutes les régions irriguées par des cours d'eau — pour autant du moins que l'industrie humaine ne crée pas de nouveaux gîtes virtuels. Le second fait important est la stabilité de la densité des colonies qui, par là même, sont plus facilement affectées par le retour fréquent de conditions adverses, telles que le traitement chimique de l'eau. Malgré ces indications favorables, la lutte chimique serait excessivement coûteuse et sans effet durable tant que l'on n'aura pas pris des mesures d'assainissement réduisant les zones favorables aux mollusques. On s'est donc orienté vers des méthodes qui ont d'autres avantages économiques que la seule destruction des mollusques: la mise en valeur du terrain et l'amélioration des techniques de culture du riz.

La suppression de la végétation qui abrite les mollusques, le drainage, le comblement des gîtes, les fluctuations artificielles du niveau de l'eau, le creusement d'étangs profonds sont autant de procédés qui, seuls ou combinés, ont entraîné une forte réduction du nombre des mollusques — atteignant 75% dans certains endroits. L'amélioration des méthodes de culture du riz résoudrait la question de la lutte contre les mollusques dans les rizières, tout en doublant le rendement de la récolte, ce que des essais limités, soigneusement organisés et contrôlés, ont prouvé.

Les projets d'assainissement qui concernent non seulement la bilharziose mais les infections intestinales en général, ont porté d'abord sur la construction de latrines. L'éducation sanitaire individuelle a donné quelques résultats, malgré une certaine résistance de la population à modifier ses habitudes, le peu de crédit qu'elle accorde à la théorie des germes, sa crainte devant les dépenses encourues pour la construction, et la perte de la nourriture que représentent pour les porcs les fèces déposées dans les champs. Ces changements de mœurs ne peuvent s'établir que progressivement.

Il n'y a pas de solution générale au problème de l'éradication des mollusques. Le cas de chaque colonie doit être étudié pour son compte. Plus le changement dans l'habitat est radical, plus la réduction du nombre des mollusques est sensible. Des demi-mesures, adoptées pour diminuer les frais, sont illusoires. Aucune des méthodes n'est nouvelle. Presque toutes ont été préconisées dans la lutte antipaludique. Elles sont coûteuses. Mais celles sur lesquelles on fonde le plus d'espoir — l'amélioration des méthodes de culture — ont l'avantage d'amener une revalorisation du sol et des cultures et d'entraîner plus facilement l'adhésion du cultivateur et la collaboration des services publics. On a dit du paludisme qu'« il fuit devant la charrue »; on peut en dire autant de la bilharziose.

La bilharziose est un problème dont les facteurs biologiques sont étroitement liés aux facteurs sociaux et économiques.

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