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1. THE IMPACT OF AGRICULTURAL DEVELOPMENT ON AQUATIC SYSTEMS AND ITS EFFECT ON THE EPIDEMIOLOGY OF SCHISTOSOMES IN RHODESIA.

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RHODESIA.

CONFERENCE ON THE
ECOLOGICAL ASPECTS OF
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INTRODUCTION

It is reasonable to presume that the schistosomes have been parasites of man for some considerable part of his evolutionary history. Under the ecological conditions which prevailed in the past, the inter-relationship between both primary and secondary hosts and the parasite itself had evolved towards an equilibrium; thus the schistosomes were in a position to maintain their numbers among the sparse and nomadic populations of man and the temporary and rather unstable populations of aquatic snails without causing excessive stress on the infected persons.

This pattern of host-parasite relationship probably existed in Rhodesia right up until modern times when rapid economic and agricultural development have resulted in settlement and massive increase of the human population. Latterly, the need to conserve natural resources and the implementation of soil and water conservation procedures in the country has produced major changes in the overall hydrological picture. The construction of dams has stabilised water-flow and resulted in less flash floods in the streams and rivers, most of which are now of a perennial nature. Thus there has been an increase in the extent of snail habitat over the country; and because the water-

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bodies are more durable, aquatic snail populations can increase as a result of the general amelioration of the environment.

Where agricultural projects are based on irrigation, large populations now live in close relationship with stable water systems; snails invade and breed, water contact and pollution increases, and this in turn produces a major upsurge in the prevalence of bilharzia (schistosomiasis); and, what is probably more serious, an increase in the worm load of infected persons.

The aquatic environment and schistosome transmission

An association between the level of schistosome transmission and geographical extent of surface water was noticed as early as 1915 when Orpen (1915) recorded a 31% infection among 592 gaol prisoners, the majority of those infected coming from the northern damper parts of the country. This pattern was strikingly demonstrated more recently by Clarke (1966) who analysed the age prevalence of both *Schistosoma haematobium* and *S. mansoni* in several different communities in Rhodesia. In Table 1 the association between climate, topography, extent of water availability, and prevalence of the parasite (*S. haematobium*), are clearly shown. In particular, the high prevalence seen in an established irrigation scheme some 40 years old (5) in the hot lowveld approximately 2000 feet above sea level, shows the degree of transmission which can develop. Under these conditions there is no appreciable fall off in the prevalence among the older age groups, which is a characteristic of all the other populations surveyed, even from the newly established irrigation scheme, No.6.

The pattern of transmission seen in Table 1 is further accentuated in Table 2 which deals with the prevalence of S. mansoni in the same localities. Where waterbodies are inclined to be unstable and temporary as with communities 3 and 4, the parasite is rare. It becomes more common in those communities existing in association with stable waterbodies, especially where temperature and contact increase. Again the prevalence in community 5 shows a particular and high rate of transmission.

The close association between S. mansoni and the communities living close to stable water systems is a direct result of the ecology of Biomphalaria pfeifferi, the intermediate host snail involved in its transmission cycle. The response of a species to a set of environmental conditions can be measured by rearing individuals under those particular conditions and calculating from the age specific birth and death rates, a parameter, the intrinsic rate of natural increase. The influence of temperature on the intrinsic rate of natural increase (r) of this species has been investigated by the writer (Shiff and Garnett 1967, Shiff and Husting 1966). It will be seen in Fig. 1 that over the optimal range of temperature B. pfeifferi has a moderately high and stable value of r. This is different from the parameter calculated for Bulinus (Physopsis) globosus under similar conditions. The value for r in this species, which is the intermediate host for S. haematobium, shows a high peak value at the optimum temperature of 25 C. (Shiff 1964a, b.). It can be inferred from these data that B. pfeifferi is better adapted to existence under stable, well buffered temperature conditions which normally are found in large waterbodies. B. globosus, on the contrary, shows the characteristic adaptation to temporary habitats. It can breed rapidly during relatively short periods when conditions are ideal, and thus build up sufficient numbers to survive ensuing catastrophies such as flooding or desiccation, both of which are an annual feature of the season pattern in this latter biotope.

The impact of development on the problem of bilharziasis in rural Africa has produced an illness of increasing severity. The effects of increasing S. haematobium infections, with concomitant kidney and bladder damage, are slowly being superceded in the population by an increase in the more dangerous parasite, S. mansoni. This is because populations of B. pfeifferi are becoming more widespread in the increasing number of stable waterbodies appearing over the country. The changing picture can be seen in two different ways. White school children from rural areas are inclined to swim and fish in farm dams, while their counterparts, the black school children, have more contact with river water in the rural areas. In a recent survey of 490 white children in the Victoria province, the ratio of mansoni to haematobium was 3 : 1. In Bantu children from the same province the mansoni haematobium ratio was 1 : 9.6.

A recent survey among the population of a small irrigation scheme in the Zambesi Valley (hot, lowveld) indicated that, of 193 people examined, 89 percent were infected with S. mansoni while only

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20 percent showed signs of S. haematobium. Prior to the survey 11 deaths had occurred among children between 5 - 13 years of age and a further 16 children, all exhibiting similar symptoms of hepato-splenomegaly, were given treatment for S. mansoni.

As can be expected, with the more intense cycle of infection, people are now carrying increasingly heavier burdens of the adult schistosome worms. As a result of this an increased number of unusual symptoms and sequelae of bilharzia are being noticed. Bird (1965) in reporting on cases of spinal complications in bilharziasis mentions that up to 1963 literature on this subject reported a total of 26 cases of S. mansoni and 11 of S. haematobium. In 1964 Bird himself examined a total of eight cases, one of which was terminal. Later Zilberg (1967) noted a case of S. mansoni induced paraplegia in a child, while cerebral abnormalities were seen in three other cases, (Zilberg et al 1967). A further seven undocumented cases of paraplegia, presumed to be of bilharzial origin, were reported to the Rhodesian Ministry of Health in 1967. This indicated that in the last four years almost as many cases of spinal complications due to schistosomes have been reported in Southern Africa alone, as reported for the whole globe up to 1963 (excluding S. japonicum infections).

Future Outlook

With the rapid increase in population in central and southern Africa, development of agriculture will depend more and more on irrigation especially in the more dry parts of the country where rainfall is unreliable. In Rhodesia from 1964 until recently, the amount of irrigated land has increased by close on 100,000 acres. There are now 126 irrigation schemes ranging in area from 20 to 3,000 acres in rural areas reserved for Bantu settlement. These derive water from dams of various sizes, perennial rivers, or from subterranian sources. However, regardless of from where the water comes, the overall stabilisation of the aquatic biotope is occurring, and with it the increased problem of bilharziasis.

TABLE 1. Prevalence of Schistosoma haematobium infections in several communities in Rhodesia After Clarke (1966).

Community Number	Occupation	Altitude	Hydrology		Under 4	4-6	7-9	10-12	13-15	16-20	21-40	Ove[r] 40
1.	rural mineworkers	middle veld[A] 2 - 4000'	Well watered perennial [B]	No. Examined	25	49	58	46	26	15	68	41
				% +ve	16	61	78	80	88	80	24	5
2.	rural mineworkers	highveld over 4000'	well watered seasonal[B]	No. examined	32	62	74	54	52	33	45	52
				% +ve	3	16	34	63	69	52	29	8
3.	rural mineworkers	middleveld 2 - 4000'	well watered seasonal	No.examined	18	40	66	106	77	78	22	20
				% +ve	6	20	33	57	53	44	18	10
4.	rural mineworkers	highveld over 4000'	poorly watered seasonal	No. examined	18	25	100	76	13	15	114	102
				% +ve	Nil	12	13	13	39	29	13	1
5.	irrigation (old)	lowveld under 2000'	well watered perennial	No. examined	9	76	55	25	13	21	101	35
				% +ve	89	96	98	96	92	90	72	57
6.	irrigation new	lowveld under 2000'	well watered perennial	No. examined	30	87	66	38	42	106	237	116
				% +ve	30	30	54	74	67	55	33	7

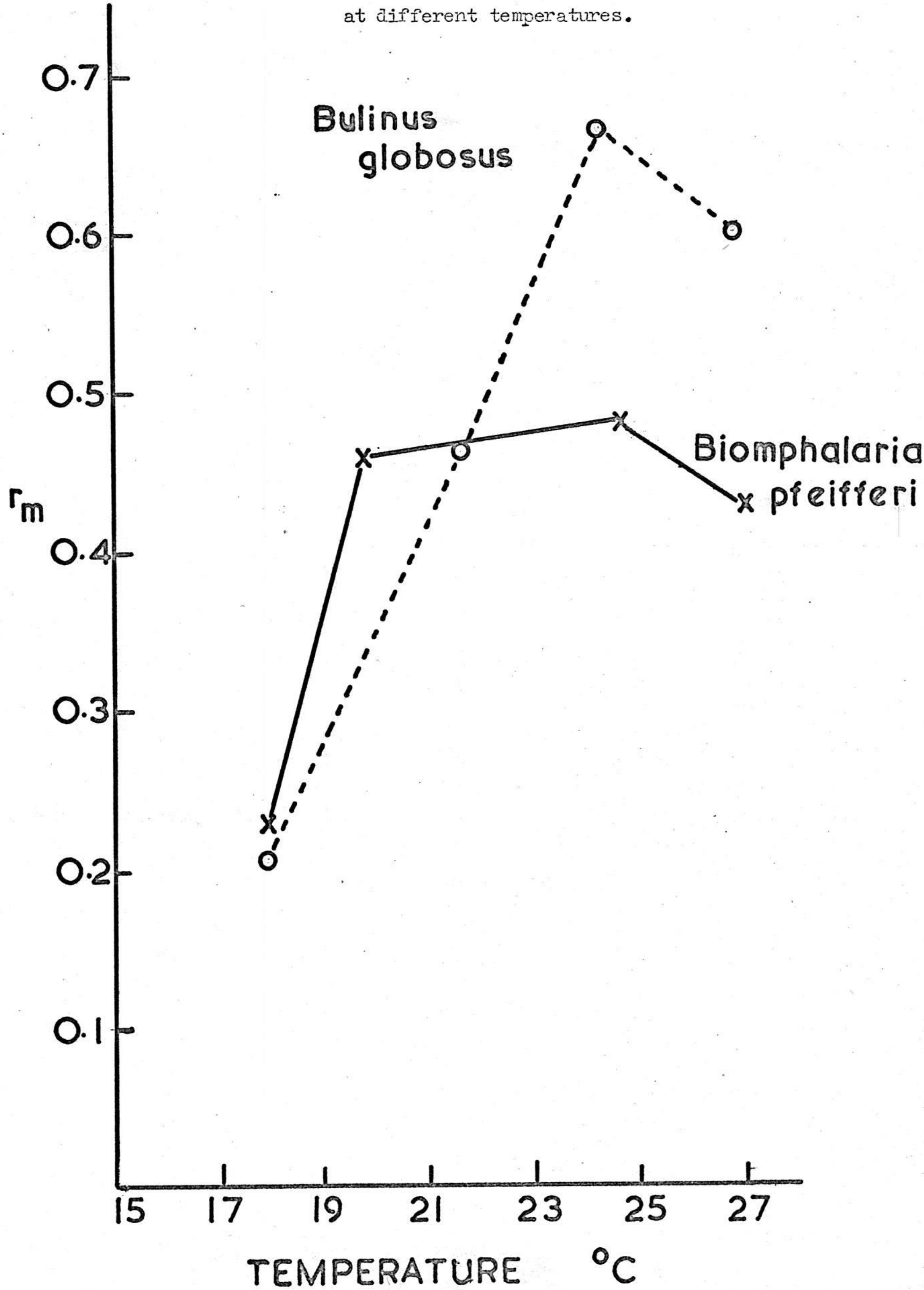
Footnotes A. As Rhodesia is a tropical country prevailing temperatures increase as altitude decreases

B. The distinction between perennial and seasonal is based on availability of water from permanent sources or temporary ponds filled by seasonal rains.

TABLE 2. Prevalence of Schistosoma mansoni infections in Rhodesia. Surveys made in the same communities as in Table 1 and at the same time. After Clarke (1966).

Community Number		Age Groups							
		Under 4	4-6	7-9	10-12	13-15	16-20	21-40	Over 40
1.	No. Examined	6	27	45	50	24	Not	29	11
	% +ve	Nil	41	78	58	58	done	38	18
2.	No. Examined	33	61	73	53	52	33	106	51
	% +ve	3	7	10	43	44	18	15	20
3.	No. Examined	20	37	60	84	67	59	21	20
	% +ve	5	3	5	6	3	12	14	5
4.	No. Examined	14	26	100	75	14	9	95	95
	% +ve	Nil	Nil	5	3	Nil	Nil	6	6
5.	No. Examined	8	70	51	23	15	24	95	32
	% +ve	50	83	92	87	67	50	59	50
6.	No. Examined	30	87	66	38	42	106	237	116
	% +ve	13	11	17	50	24	16	10	7

Fig. 1: Values for r_m obtained from snails cultured at different temperatures.



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2. THE EFFECTS OF MOLLUSCICIDES ON THE MICROFLORA AND MICROFAUNA OF AQUATIC SYSTEMS

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The situation outlined in the case histories on schistosomes and development requires immediate preventive action to avert the growing menace to public health. As there is yet no prophylaxis people cured by chemotherapy are immediately at risk again once treatment ceases. The best approach to achieve reduction of the problem is to reduce the infectivity of natural waterbodies which have been colonised by intermediate host snails of the schistosomes. Because snails once infected will produce cercariae for several months, and, at this stage in Africa, it is almost impossible to exclude human contact of the water, the strategy has been to attack the aquatic snail populations with chemical poisons.

Initial experiments were carried out in Rhodesia as early as 1950 (Clarke et al, 1961) using copper sulphate. They showed that it was feasible to reduce the snail populations by spraying the chemical into waterbodies at approximately 20 - 30 parts per million (ppm). However, the desirability of adding a stable biocide to water systems, particularly static waterbodies, was disputable, but when sodium pentachlorophenate (NaPCP) became available large-scale experiments were undertaken. Early reports indicated that this chemical was more selective, and being organic, it would not be as stable as copper sulphate (Hiatt et al., 1960); furthermore, it was to be applied to aquatic systems at the lower concentration of 5 ppm. At this stage experimental application of molluscicides to natural water systems in Rhodesia was expanding over four different geophaphical regions covering some 4,000 square miles of territory.

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A wide variety of waterbodies was treated with chemicals, particularly with sodium pentachlorophenate, and some of the results of this application gave rise to immediate concern. The effects were frequently noticeable in small lakes and ponds, particularly if there was an abundance of 'soft' aquatic vegetation such as Nymphaea, Otellia, Potamogeton and others. At the molluscicidal doses these plants were quickly killed by both sodium pentachlorophenate and copper sulphate, and in the hot weather soon commenced rotting. This decaying organic material increased the biological oxygen demand on the water, and, as there was no longer a source of transpiratory oxygen for the water system, there was a tendency for the system to become anoxic. At this stage numbers of fish and other aquatic fauna died, and their rotting bodies made the situation much worse, the ponds sometimes remaining almost sterile until rejuvenated by the next rains. The writer personally investigated nine such affected waterbodies - two as a result of using copper sulphate, and the rest as a result of sodium pentachlorophenate.

One of these waterbodies, the Karoi dam, contained approximately 100 million gallons of water and was used to supply the nearby village. In August 1962 the periphery was treated to a depth of approximately six feet using sodium pentachlorophenate: 50 lbs. (23 kg) of chemical was applied. Several days after spraying, power boats were used on the lake causing considerable disturbance. Over the next six days the oxygen status of the water decreased until large numbers of fish began to die. At this stage the water became anoxic

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and developed a strong odour of decay, and large quantities of rotting fish were evident in parts of the lake. The water was completely unpalatable and remained so, in spite of expensive filtration techniques, for four months until rejuvenated by heavy seasonal rains.

Experimental Evidence

Clearly it was important to study the effect of these chemicals in detail, and this was done along with a new molluscicidal product called Baylucid. Shiff and Garnett (1961) selected four trial ponds 4 x 4 m in area and 60 cm deep. They were normally interconnected by means of a water furrow, but for the duration of the experiment they were completely isolated from each other and any inflowing water. The ponds were essentially similar in macro-vegetation, containing growths of Potamogeton pusillus, Polygonum salicifolium and the alga Chara sp. The ponds were numbered 1 to 4; pond 1 was treated with copper sulphate at 20 ppm, pond 2 with sodium pentachlorophenate at 5 ppm, pond 3 with Bayluscid at 1 ppm and pond 4 was the untreated control. They were sampled for plankton just prior to treatment and then on day 2, day 11 and day 32, post treatment. It was possible to classify the plankton collected as follows: Cladocera; Insecta (larval Diptera, Tricoptera, Coleoptera, Neuroptera, Odonata, and Ephemeroptera; adult Gryinidae, Gerridae and Dytiscidae), and acarines; Copepoda; copepod nauplii; Ostracoda (Cypris sp. and others), and Spirogyra. A few Rotifera were seen, but as they appeared only sporadically their numbers were excluded; this was the case also with some diatoms.

The overall short-term effect is clearly demonstrated in Fig. 1 which records the population fluctuation of the total number of individuals in all groups. The immediate effect of both copper sulphate and sodium pentachlorophenate was to reduce the population very considerably, while only a slight reduction was apparent after treatment with Bayluscid. The Cladocera and copepods appear to be highly sensitive to the molluscicides, particularly the more stable chemicals. The phytotoxicity of these latter compounds is apparent from the Spirogyra data.

More recently a new molluscicidal chemical, Frescon, has been tested (Shiff, 1966)} and, together with Bayluscid, it appears to have very little effect on the plankton normally found in small ponds and dams in Rhodesia. The data are shown in Table 1 where it can be seen that even the sensitive forms, the Cladocera and Copepoda, remained relatively unchanged after treatment of a waterbody with Frescon.

It would thus appear that the two compounds Bayluscid and Frescon are selective snail poisons; however, most species of fish are sensitive to both compounds in varying degrees. Shiff, et al, (1967) have shown that bream, Tilapia mossambica, can tolerate a higher concentration of Frescon than the related T. melanopleura, while personal observation shows that Clarias sp. (barbel) are sensitive to all molluscicides.

The latter observations were carried out in small, static waterbodies. However, in an anti-bilharzia campaign, much of the

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water treated is flowing and application can either be to effect total coverage (blanket), or focal, i.e. only where snails are found. Harrison (1966) has studied the effects of blanket spraying two streams from source downwards with Bayluscid. One stream flowed with soft water over stony runnels and small pools, and after spraying retained chemical from 2 - 24 hours. The second stream, a somewhat larger one, carried hard water with a longer retention time up to three days. Blanket spraying produced concentrations of 0.2 - 0.4 ppm of Bayluscid. Harrison recorded the following effects:

" Immediate

1. Gastropod snails were virtually eliminated.
2. All fish were killed. Fish died more rapidly in soft (5-10 minutes) water than in harder water (2-6 hours).
3. The rest of the invertebrate fauna, especially insects was not seriously affected. In the soft water stream some were excited and others became moribund, but, at least in some cases, these effects were temporary and reversible. There was no reduction in density of invertebrate predators such as crabs and Odonata.

Subsequent effects

4. Recolonisation by snails which are hosts to schistosomes *Bulinus* (*Physopsis*) spp and *Biomphalaria pfeifferi*, was slow. In the stream with hard water they began to reappear after 10 months after treatment but in the

soft water none was found after 22 months after treatment. Other snails, specially smaller species, returned more rapidly.

5. There were local increases in density of insect larvae including mosquitoes during the first three months after treatment. "

The technique, evolved in Rhodesia, of applying molluscicides to aquatic systems, is based on snail surveillance. Essentially, when a stream or waterbody is brought into a bilharzia control scheme, it is initially blanket sprayed using a suspension of molluscicide applied by means of a stirrup pump or pressure sprayer. Subsequently waterbodies are inspected every 6 - 8 weeks by rangers trained to look for snails, and chemical is applied only to those foci where intermediate host snails are found to occur. No attempt is made to eradicate snails, but artificial pressure is maintained upon the population of those species which transmit schistosome parasites. As soon as they increase in density and become obvious within the biotope, the focus is dosed with chemical. Harrison and Mason (1967) studied two streams which had been under surveillance for two years and matched each stream with a similar untreated one nearby. The invertebrate fauna of all four was studied periodically over a year. They recorded the following results of the application of Bayluscid under the system of snail surveillance:

"1. No schistosome host snails were found in the treated streams until surveillance was discontinued. Other snail species were found.

2. The surveillance treatment appeared to have no significant effect on the invertebrate fauna, including those anthropods known to prey on snails.

3. Fish were not eliminated from the one treated stream which was sampled for them.

4. When surveillance treatment was discontinued, host snails returned within two or three months and, in one case, an abnormally high density was built up. "

The application of toxic chemicals to any water system should not be lightly considered as it must have some disrupting effects on the flora and fauna, although they have not been detectable in the studies reported here. However, in the face of severe public health problems some control must be achieved and it would appear that this has been done with minimum interference of the biotope. The reduction in populations of intermediate host snails produced by snail surveillance has been shown to reduce the incidence of urinary bilharzia (Schistosoma haematobium) in a rural population. Shiff and Clarke (1967) have published the results of surveys carried out in a rural population living in an area protected by snail surveillance over a period of seven years, 1960 - 1966. The data in Table 1 show an overall reduction in the prevalence in each age group during the period 1960 to 1962 and 1963 - 1966, together with the progressive absence of infection in the younger a age groups. This gives some indication of the real impact of the campaign as practiced in Rhodesia.

TABLE 1.

Results of Schistosoma haematobium surveys carried out in the Kyle Catchment Snail Control area from 1960 - 1966. Control originated in 1960. (After Shiff & Clarke, 1967)

Year of assessment		Age groups						
		-4	4-5	6-7	8-9	10-11	12-13	14-15
1960	No. examined	403	590	611	578	209	144	106
	percent positive	5	5	32.6	55.6	70.8	63.9	65.1
1962	No. examined	117	160	367	504	657	731	441
	percent positive	0	3.1	22	35	43.7	46.1	56.9
1966	No. examined	17	20	75	187	276	275	113
	percent positive	0	0	17.3	20.3	31.5	47.6	42.5

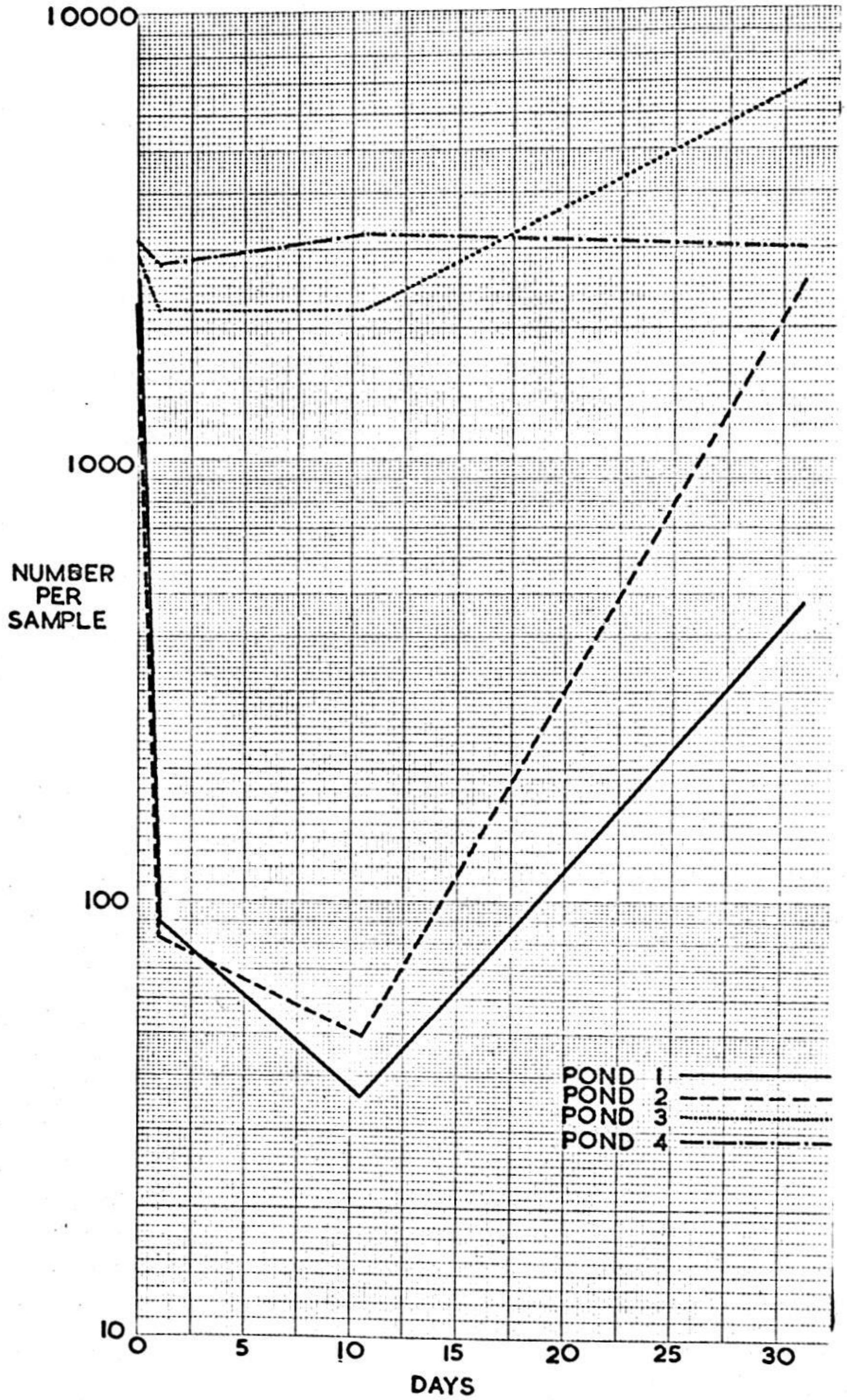

Figure 1. Showing the numerical fluctuations of the total number of individuals collected in each sample. Samples were made on Day 0, Day 4, Day 11 and Day 32. Pond I was treated with copper sulphate at 20 p.p.m., Pond II with sodium pentachlorophenate at 5 p.p.m., Pond III with Bayer at 1 p.p.m. Pond IV is the untreated control.

Figs. 1 - 7. After Shiff and Garnett (1961).

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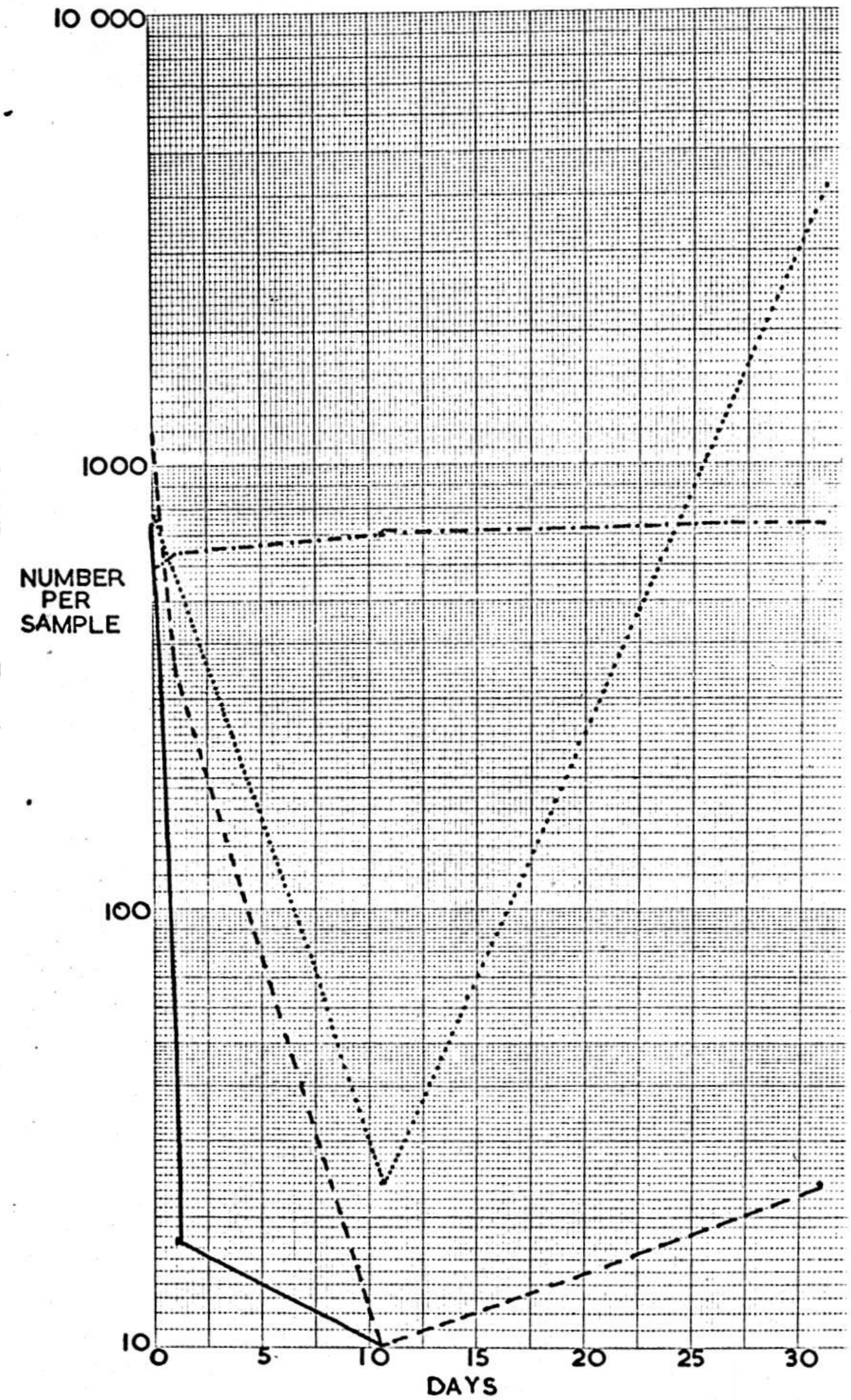

Figure 2. Showing numerical fluctuations of individuals of the order cladocera. Key as for Figure 1.

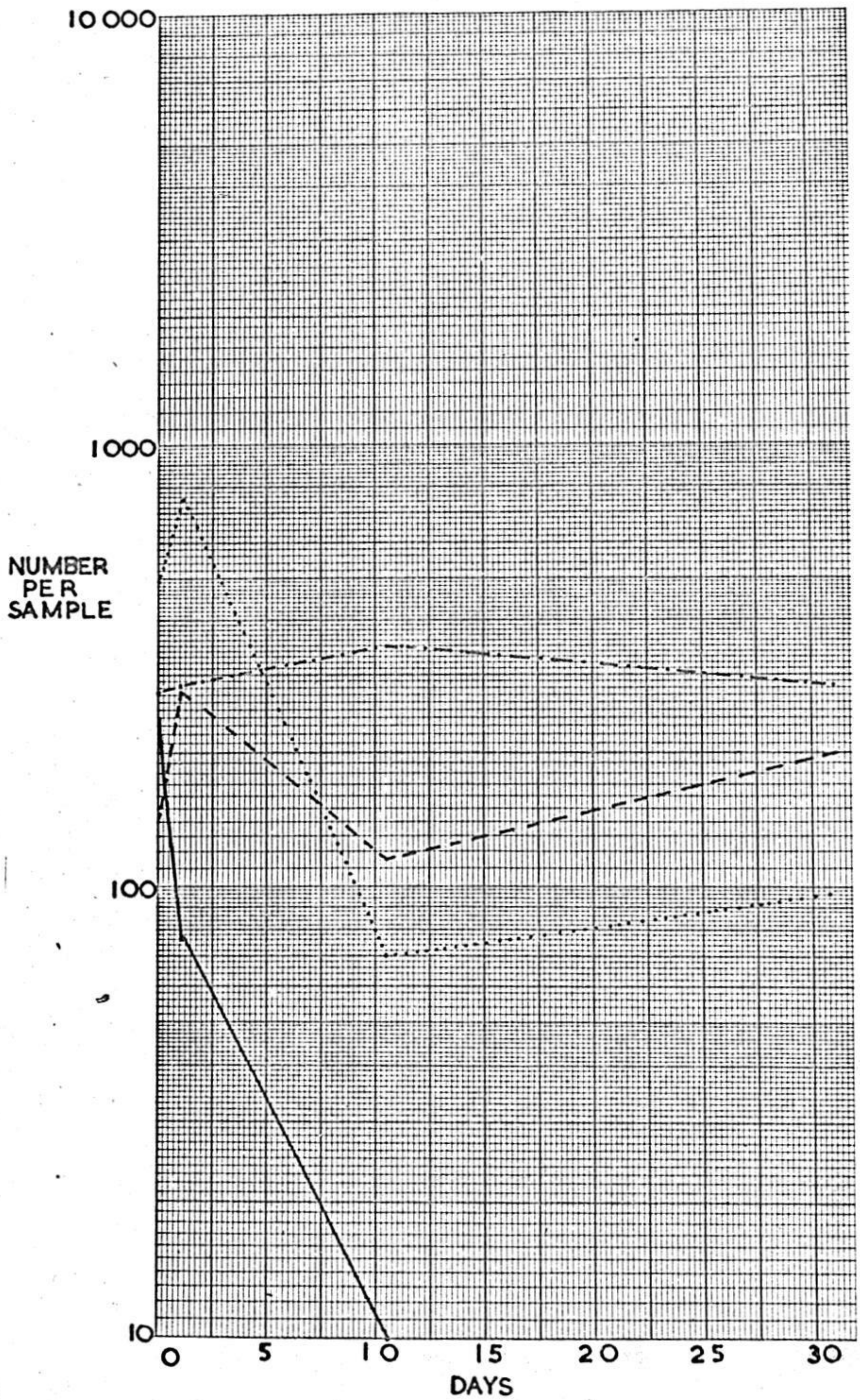

Figure 3. Showing numerical fluctuations of aquatic insect larvae. Key as for Figure 1.

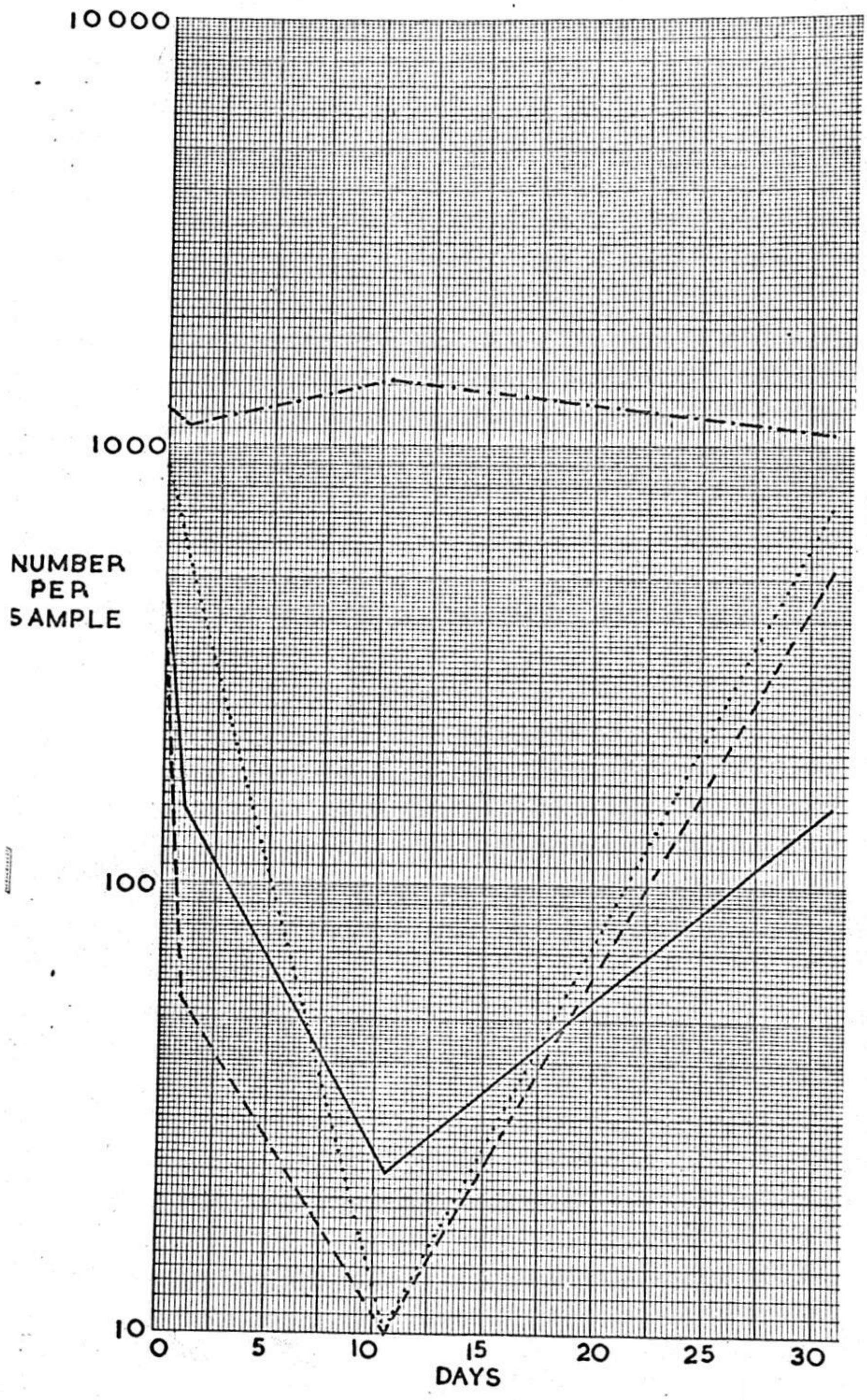

Figure 4. Showing numerical fluctuations of copepoda.

Key as for Figure 1.

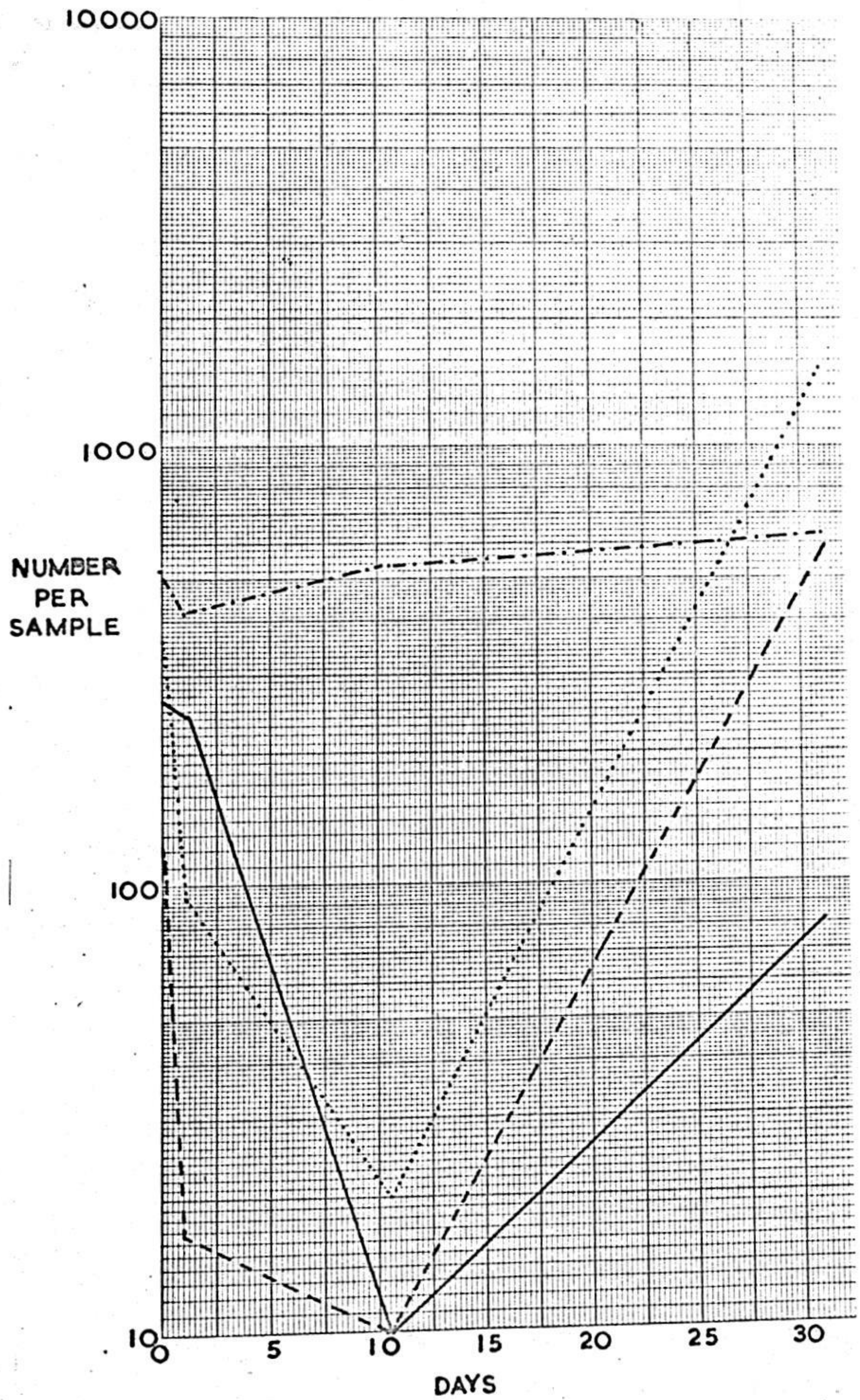

Figure 5. Showing the numerial fluctuations of copepod nauplii.

Key as for Figure 1.

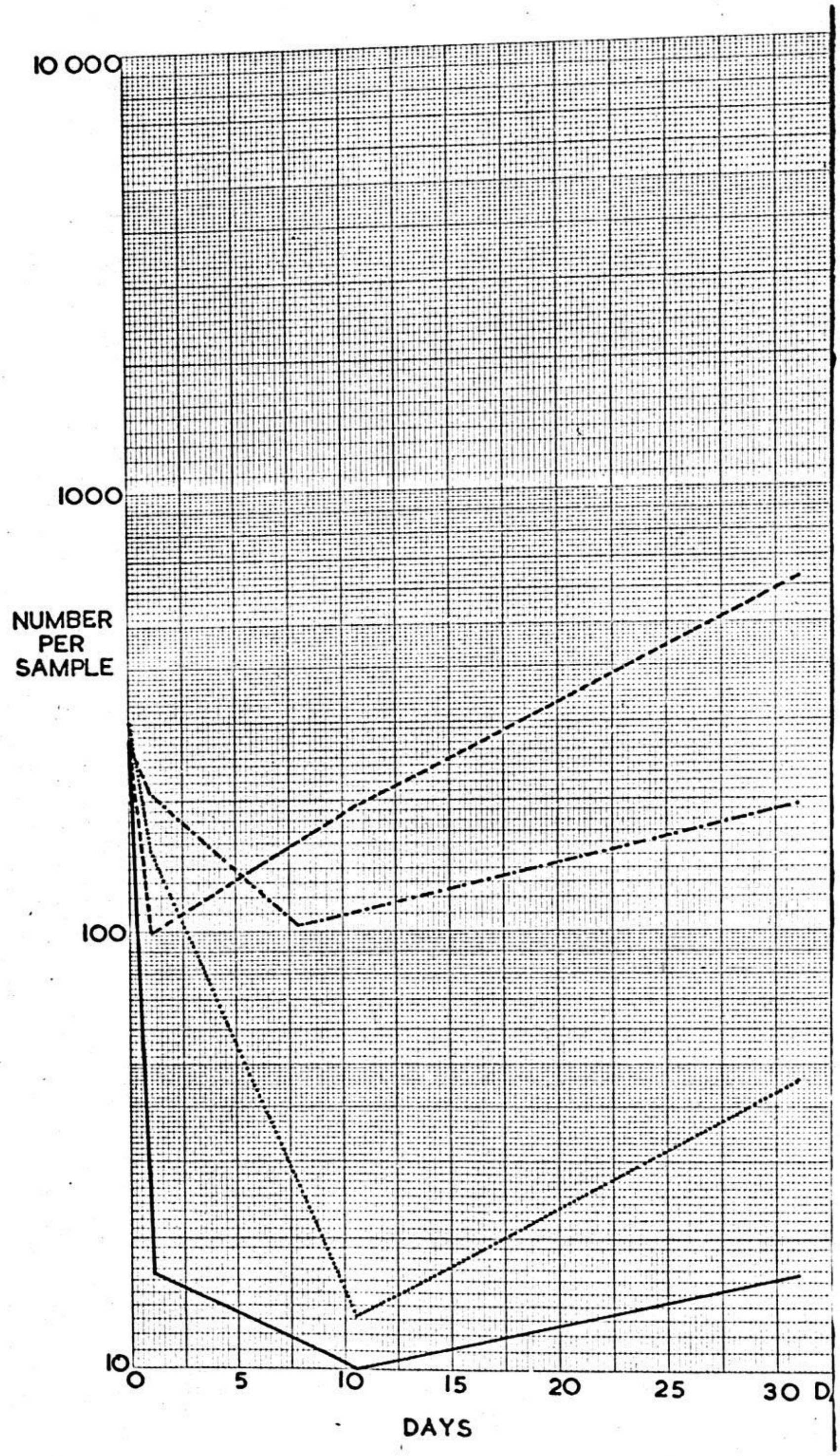

Figure 6. Showing numerical fluctuations of ostracoda.

Key as for Figure 1.

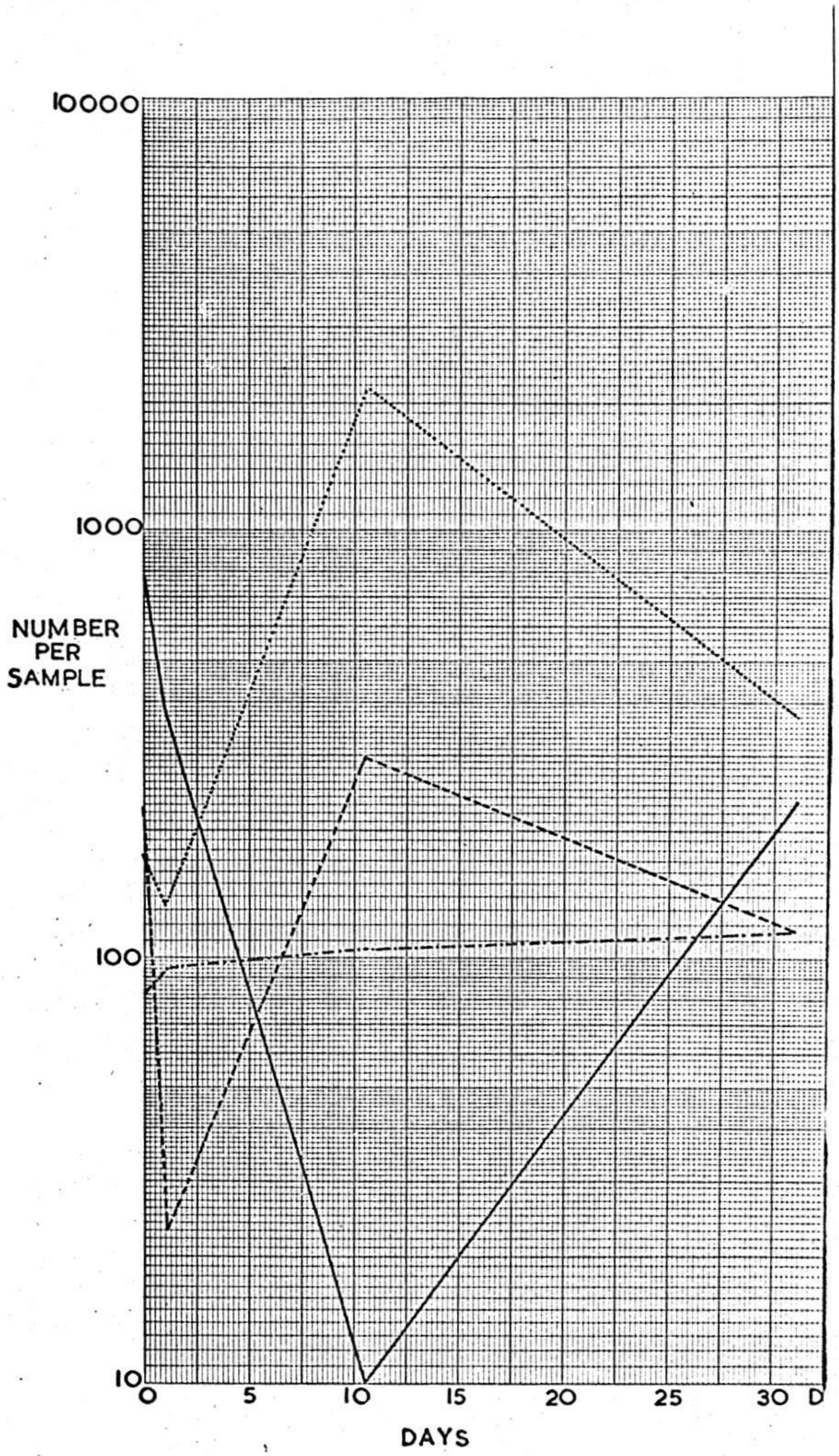

Figure 7. Showing numerical fluctuations of various spirogyra.

Key as for Figure 1.

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