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CONTENTS

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TERNIDENS DEMINUTUS (Railliet and Henry, 1909) AND HOOKWORM IN RHODESIA AND A REVIEW OF THE TREATMENT OF HUMAN INFECTIONS WITH *T, DEMINUTUS*

By

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Ternidens deminutus

(Railliet & Henry, 1909)

and hookworm in Rhodesia and a review of the treatment of human infections with *T. deminutus**

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SYNOPSIS

The position of hookworm infections in Rhodesia is not altogether clear, partly due to a lack of critical surveys and partly due to the fact that hookworm in Rhodesia co-exists with *Ternidens deminutus* — a fact which has been overlooked by workers in this country for the last 35 years. The aim of the present paper is to define more clearly the problem of human infection with hookworm and *T. deminutus* in Rhodesia and to compare the epidemiology of these species where possible in an attempt to gain greater insight into the importance and biology of the latter species — a species about which relatively little seems to be known. It appeared from the results obtained that while hookworm infection was fairly widespread in Rhodesia, it was largely introduced, being maintained at relatively low levels over most of the country. Hookworm disease here, seems to be rare but could develop if transmission is facilitated by increased irrigation in areas where low levels of hookworm infection already exist unless measures are taken to prevent infection.

Human infection with *Ternidens deminutus*, however, seems to be largely confined to Rhodesia, being widespread in the eastern part of the country and in some cases having an extremely high prevalence.

Introduction

While reports of human infection with *Ternidens deminutus*, Railliet & Henry, 1909, appear to be restricted to Central and Southern Africa and a few neighbouring islands, infections of other primates with this species are more widespread, being recorded from parts of Southern Asia and certain Pacific Islands as well.

* This paper comprises part of the work accepted for the degree of Doctor of Philosophy by the University of London.

However, with the development of an increasing awareness of this species, new records are coming to light and thus it has recently been found in Man in Tanzania (Kilala, 1971) and in Uganda (Anthony & McAdam (1972)).

Of all the regions from which *T. deminutus* has been recorded, the country in which it appears to be most prevalent is Rhodesia (Sandground, 1931, Blackie, 1932; Amberson and Schwarz, 1952; Goldsmid, 1968b and 1971a).

Hookworm infections are also fairly widespread in Rhodesia (Blackie, 1932; Gelfand, 1950; Gelfand and Garnett, 1965; Kennedy, 1956; Gelfand and Warburton, 1967; Goldsmid, 1965; 1968b; Roberts, 1970) although these infections have been confused with those caused by *T. deminutus* due to mis-identification of the eggs of the two groups as discussed by Goldsmid, 1967; 1968a and b; 1969; 1971a).

Materials and Methods

Eggs of hookworm and *T. deminutus* were recovered by centrifugation and NaCl Flotation of routine stool specimens and the hookworm eggs were separated from those of *T. deminutus* on the basis of egg volume as described by Goldsmid, 1968a or on the basis of the infective larvae reared by the Harada-Mori Test Tube Cultivation Technique of Sasa *et al* (1958), Hsieh (1963) and Goldsmid (1967). The latter technique and collection of adult worms also allowed the identification of hookworm species where required (Goldsmid, 1967; 1968b) although in the present investigation such infections were treated as "hookworm", Goldsmid (1968b) having already discussed the prevalence of *Ancylostoma duodenale* and *Necator americanus* in Rhodesia. In this paper he concluded that 80 per cent. of hookworm infections in Rhodesia were caused by *N. americanus* and 20 per cent. by *A. duodenale*.

T. deminutus infections in baboons were studied by means of autopsy studies on baboons poisoned to protect crops surrounding African settlements.

Results

(a) Studies on the prevalence and occurrence of *T. deminutus* and hookworm in Rhodesia.

The distribution of *T. deminutus* in Rhodesia was investigated by Sandground (1931) who extended his studies to Zambia, Mozambique and South Africa. Blackie (1932) also remarked that the species appeared to occur in a number of areas in Rhodesia.

By means of questioning patients admitted to Harari Central Hospital, Salisbury who were infected with *T. deminutus* and hookworm, these species still appeared to be widespread over the

country and consequently small surveys were undertaken in various parts of Rhodesia to compare the relative prevalence of *T. deminutus* and hookworm — a comparison of interest due to the *Ternidens*-hookworm confusion which has existed in Rhodesia for the last 35 years — the last record of *T. deminutus* infection in this country as reported by medical laboratories being that recorded in the Report on the Public Health for the year 1934 by Blackie (1935), although "hookworm" has been reported regularly during this period. The areas covered in the survey are shown in Fig. 1, from which it can be seen that these areas mostly lay in the East and South-East of the country.

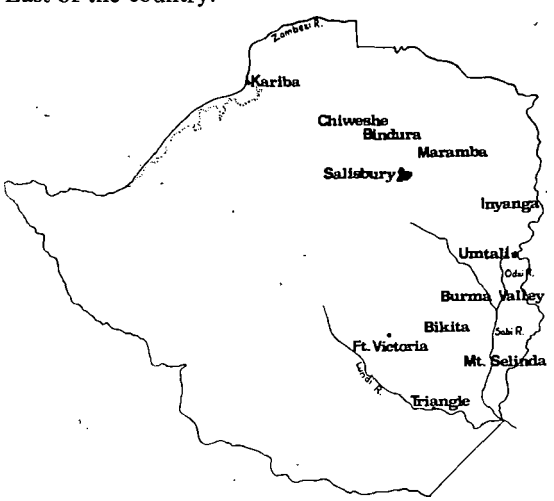

Fig. 1.—Rhodesia showing areas covered in the survey.

The results of these surveys are shown in Table I, where the prevalence of *T. deminutus* and hookworm in Man is compared and the prevalence the former species in baboons (*Papio ursinus griseipes* Pocock) is shown. Of 57 stool specimens containing "hookworm" eggs sent from Kariba District Hospital, all were found to be eggs of hookworm but of these, four mixed *T. deminutus* -hookworm infections were found, i.e. 7 per cent. of the patients were also infected with *T. deminutus.* Examination of the histories of these *Ternidens*-infected patients, however, revealed that they had all recently arrived at Kariba from areas where the *T. deminutus* prevalence was known to be high (Victoria, Chiweshe) and it is thus seen that in the Zambesi Valley, *T. deminutus* does not appear to occur to any great extent, if it occurs at all — a conclusion supported by examination of specimens collected in the Zambesi Valley at the Hunyani-Angwa River junction where only hookworm was found.

From investigations on the domicile of patients suffering from *T. deminutus* and/or hookworm infections, some interesting facts emerged, suggesting that, while *T. deminutus* infections were almost exclusively local (i.e. acquired in Rhodesia), hookworm infections were largely introduced from neighbouring territories to the north (Zambia, Mozambique and Malawi mostly). These preliminary results were reported by Goldsmid (1968b) who found that of 50 Africans infected with hookworm, 24 (48 per cent.) were of foreign origin, 19 (38 per cent.) being from Malawi, 4 (8 per cent.) from Mozambique and 1 (2 per cent.) being from Zambia. As opposed to this, of 50 patients infected with *T. deminutus* only 2 were of foreign origin (Malawi), and both of these had lived in Rhodesia for more than 10 years. These figures suggested, as Askins (1932) and Blackie (1932) had inferred, that many hookworm infections were brought into Rhodesia from neighbouring territories, while the figures on *T. deminutus* infections suggested that this was an almost exclusively local problem, even the 2 infected Malawians having lived here sufficiently long to have acquired their infections locally rather than to have retained them from their country of origin. Studies on this problem were extended, and 301 consecutive inpatient stools were examined in the laboratory at Harari Hospital, and details of the patients taken as to their country of origin; length of residence in Rhodesia and whether they had ever returned home and if so, when. Stoll dilution egg counts

Table I

PREVALENCE OF HOOKWORM AND *T. deminutus* IN VARIOUS REGIONS OF RHODESIA.

DISTRICT	HUMAN			BABOON	
	T. deminutus (%)	Hookworm (%)	Total Examined	*T. deminutus* (%)	Total Examined
Bikita	87,0	0	46	70,5	17
Bindura	69,2	0	52	—	—
Burma Valley	16,6	47,6	84	—	—
Chiweshe	6,9	20,9	43	—	—
Fort Victoria	40,5	6,1	296	—	—
Inyanga	13,9	14,8	108	—	—
Lundi	1,0	0	100	—	—
Maramba	11,5	1,9	52	73,7	15
Mt. Selinda	0	29,0	100	—	—
Sabi Valley	0	2,7	37	—	—
Salisbury (local)	17,1	2,9	35	—	—
Salisbury (mixed)	3,8	5,8	5 545	—	—
Triangle	0,5*	26,5*	32 000	—	—
Umtali	2,3*	7,0*	3 730	—	—
Zambesi Valley	0	60,0	25	—	—

* These figures were derived by extrapolation from Hospital Laboratory Reports after examination of samples of "hookworm" eggs.

were carried out on all patients positive for hookworm in order to get an assessment of the worm load carried.

It was found that of the 301 patients examined, 26 (8,6 per cent.) were positive for hookworm. Of these, 17 (5,6 per cent.) were from Malawi and 2 (0,7 per cent) from Mozambique although of the 301 examined, only a total of 33 (11 per cent.) were from Malawi and 9 (3 per cent.) from Mozambique, i.e. of the 33 from Malawi, 17 (51,5 per cent.) were infected with hookworm and of the nine from Mozambique, 2 (22,2 per cent) were infected with hookworm. All of the remaining 259 Africans were born in Rhodesia, but only 7 (2,7 per cent) of these were infected with hookworm. This later work then, confirmed the earlier suspicions that many of the hookworm infections were being introduced from neighbouring territories as, of the 26 cases positive for hookworm, 19 (73 per cent.) were of foreign origin.

Confirming the theory that *T. deminutus* infections are largely local, of 127 consecutive patients found infected with this helminth in Harari Hospital over a number of months, 124 had been born and bred in Rhodesia (and had never left the country as far as could be ascertained) and the remaining three, while born in Malawi, had lived for more than 12 years in Rhodesia — suggesting that infection had in fact occurred in their country of adoption. Of the 301 patients examined in the consecutive series above, 22 (7,3 per cent.) were found to be infected with *T. deminutus* and all of these had been born and bred in Rhodesia, further confirming the theory that for some reason this infection is largely peculiar to Rhodesia.

It should be noted, however, that these histories were gathered by questioning the patients and relied on trusting to their accuracy and understanding of what was required. It was often extremely difficult to get accurate details of when the immigrant Africans had left their homelands and if and when they had last visited these territories, and it was also difficult to ascertain with absolute certainty whether indigenous Rhodesian Africans had ever visited neighbouring territories to the North — although this latter event was unlikely in most cases as, if there was any tendency for Rhodesian Africans to seek work outside Rhodesia, it would be to the industrialised Republic of South Africa rather than to the more underdeveloped countries to the North.

The effect of length of stay in Rhodesia on the percentage of immigrant Africans infected with hookworm was also studied. Of 11 immigrant Africans who had lived in Rhodesia for less than five years, 9 (82 per cent.) were infected with hookworm. Of 14 who had been here for 6-10 years, 7 (50 per cent.) were infected and of the

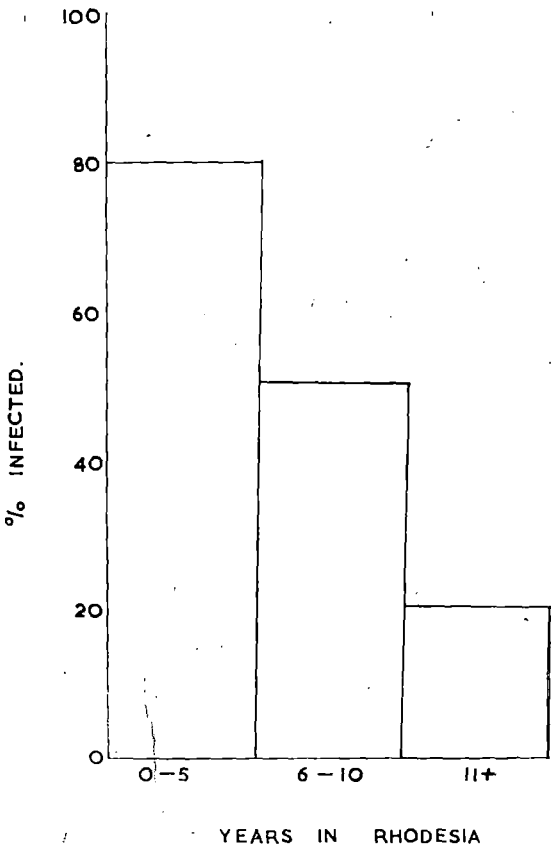

Fig. 2.—Prevalence of hookworm infection in immigrant Africans who had lived for varying periods in Rhodesia.

20 who had lived in Rhodesia for more than 10 years, 4 (20 per cent.) were infected. This progressive decline in the number of immigrant Africans infected with hookworm can be seen in Fig. 2. The effect of length of residence in Rhodesia on the worm load of patients was studied using length of domicile and carrying out Stoll dilution egg counts on subjects. The mean egg output per gram stool was then calculated for each group. It was found that in a group of 34 Africans examined, the mean egg output per gram fell with length of domicile in Rhodesia as can be seen in Fig. 3. It thus appears that the worm load decreases with length of stay in Rhodesia although low loads are retained even for periods exceeding 10 years of residence — suggesting that a low level of hookworm infection occurs over most of Rhodesia (with localities of high incidence, e.g. Mt. Selinda, Triangle). Also, probably infected people mix largely with people of their own country or tribe thus to some extent maintaining a reservoir of infection by contamination of the environment.

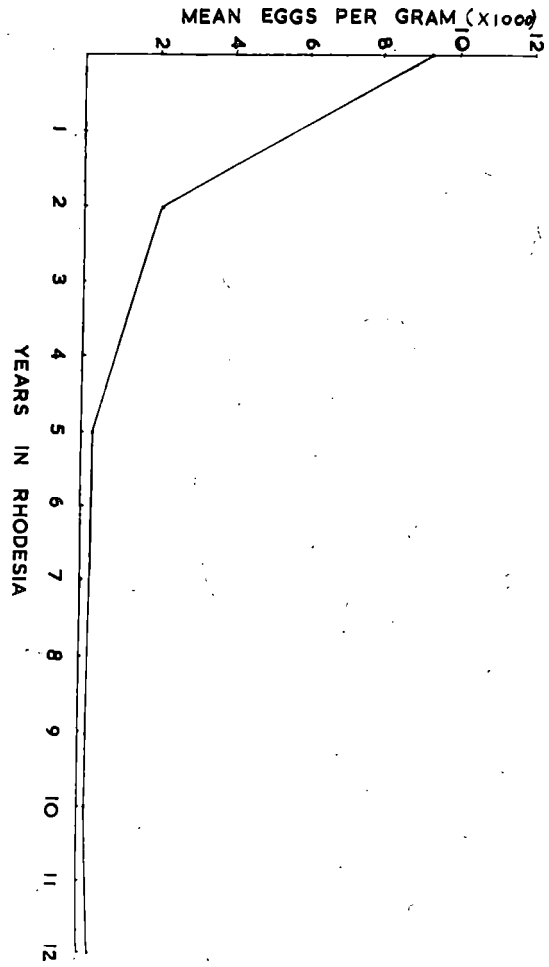

Fig. 3.—Load of hookworm as measured by eggs per gram faeces of immigrant Africans who had lived for varying periods in Rhodesia.

If mean loads of hookworm harboured by Rhodesian Africans are compared with those harboured by non-Rhodesian Africans, it can be seen that the mean load for Rhodesian Africans was 157 ±35,5 eggs per gram (for 30 subjects examined) while that of the non-Rhodesian Africans was 1 534 ±633 eggs per gram (for 55 subjects examined). Examined statistically, using χ^2 as indicated in Table II, the hookworm loads carried by Rhodesian and non-Rhodesian Africans differed significantly (p=between 0,02 and 0,05). It is worth noting that this figure for non-Rhodesian Africans is for all infected Africans of foreign origin, irrespective of their length of domicile in Rhodesia — and some of those included had lived here for over 10 years. It is also interesting to note that after about 10 years of residence in Rhodesia, the load of worms in immigrant Africans had dropped to a figure comparable to the mean recorded for local Rhodesian Africans. It should also be pointed out, however, that no medical histories were available for any past treatments, etc. which subjects might have had during previous admissions, at earlier outpatient consultations or at other centres, etc. The effect of urbanization in some of the cases should also be borne in mind. All this again suggests that hookworm is largely an introduced problem but that it can be and is maintained at low levels over much of Rhodesia (with the exception of the Zambesi Valley, the south-eastern border and the irrigated Lowveld areas where infection rates appear to be high). Infected Africans entering the country lose part of their load but may maintain a low grade infection for a number of years. *T. deminutus,* however, poses quite a different problem. Here infections appear to be limited largely to Africans of Rhodesian origin or ones who have lived in this country for long periods. Another interesting point is that, while whites are sometimes found infected with hookworm, cases of *T. deminutus* infection among this racial group are extremely rare and of the 10 whites found passing 'hookworm-like' eggs who were available for study during the present investigation, all were found infected with hookworm and none with *T. deminutus.* This is a point of great interest as in all the literature studies, only one white subject has ever been found to be infected with *T. deminutus* — an eight year old child recorded by Sandground (1931). These comparisons between hookworm and *T. deminutus* infection point to basic differences in the natural history of the two infections as has been discussed by Goldsmid (1969; 1971a).

(b) Baboon-Man relationships in *T. deminutus* infections

The high rate of *T. deminutus* infection amongst baboons destroyed because of their raiding activities on African villages and the corresponding high rate of infection amongst Africans in the villages exposed to these raids suggests that the

Table II

EGG OUTPUT IN RHODESIAN AND NON-RHODESIAN AFRICANS INFECTED WITH HOOKWORM

Hookworm eggs/g.faeces	Value	Non-Rhodesian	Rhodesian	Total
<100	Observed	17	13	30
	Expected	19,4	10,6	
100-500	Observed	24	16	40
	Expected	25,9	14,1	
>500	Observed	14	1	15
	Expected	9,7	5,3	
Total		55	30	85

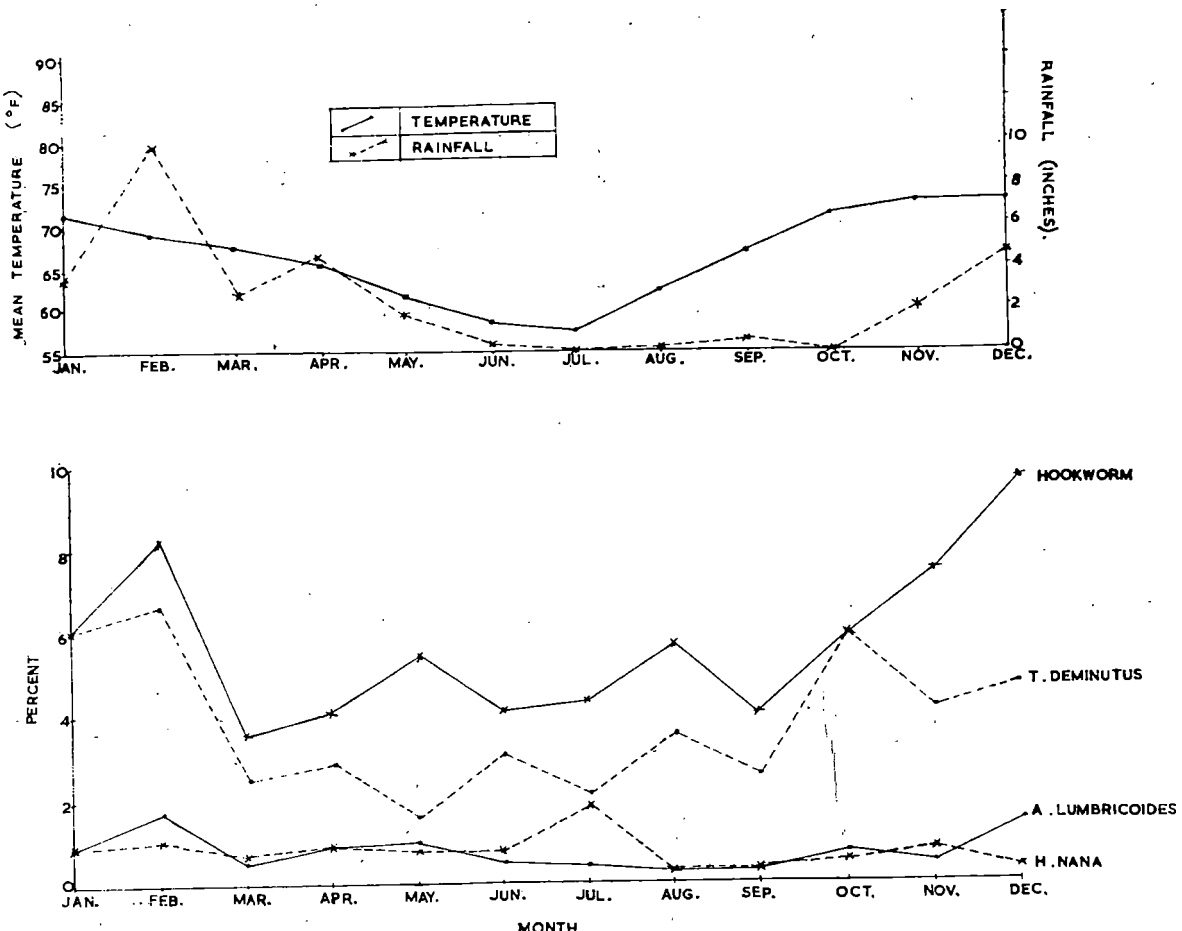

Fig. 4.—Seasonal prevalence of hookworm, *Ternidens deminutus, Ascaris lumbricoides* and *Hymenolepis nana* as recorded in Salisbury.

infection is a zoonosis, infection being from baboon to Man as discussed in detail by Goldsmid (1969; 1971a) who found 73,7 per cent. of baboons infected near one village with a human frequency of infection of 16 per cent., and 70,5 per cent. of baboons infected in the vicinity of villages where the African infection rate was 87 per cent. It would be of interest to see if a negative correlation could be established in areas where the baboon infection rate is low.

(c) Seasonal variation in infection with *T. deminutus* and hookworm

An analysis of 5 545 African inpatient stool specimens at Harari Central Hospital on a month by month basis was found to give results shown in Fig. 4. From these figures it can be seen that there is a tendency for both hookworm and *T. deminutus* infections to increase in the warm wet summer months and to decrease during the cold dry winter months. This trend is not seen in the cases of *Ascaris lumbricoides* and *Hymenolepis nana* infections presumably because the former has thick-shelled relatively resistant eggs and the latter has a person to person type of transmission.

(d) *T. deminutus* and hookworm infection rates in different sexes.

The prevalence of *T. deminutus* and hookworm infections in 6 123 African males and females was examined and is shown in Table III while the mean worm egg counts from males and females infected with these helminths is given in Table IV.

Table III

PREVALENCE OF HOOKWORM AND *T. deminutus* IN AFRICAN MALES AND FEMALES.

Species	Sex					
	MALE			FEMALE		
	No.+	%+	Total Examined	No.+	%+	Total Examined
Hookworm	237	6,1	3892	107	4,8	2231
T. deminutus	113	2,9		79	3,5	

Table IV
MEAN EGG COUNTS OF AFRICAN MALES AND FEMALES INFECTED WITH HOOKWORM AND *T. deminutus.*

Species	Sex			
	MALE		FEMALE	
	Mean eggs/ g.	Total Examined	Mean eggs/ g.	Total Examined
Hookworm	457±131	84	2003±1015	26
T. deminutus	435±102	89	296±61,1	68

(e) *T. deminutus* and hookworm infection rates in different age groups.

Studies were then made on the prevalence of hookworm and *T. deminutus* in various age groups of Africans. An attempt was made to group the subjects "naturally" in terms of biology and behaviour of the groups, i.e. 0-2 years old — babies, not getting around outside by themselves and not eating a fully adult diet, etc.; 3-6 years — young but on a more or less full diet and moving about outside by themselves; 7-12 years — full adult diet, very active outside, etc. The results are shown in Fig. 5 It can be seen that in the 345 subjects examined, the highest prevalence of hookworm infection occurred in the 13-35 year old age group and for *T. deminutus* in the 7-12 year old age group. For the latter species, a fairly high prevalence continues through the 13-35 year old age group and for hookworm through the 36-45 years old age group. An interesting point is that *T. deminutus* infection increases dramatically after the age of seven years, while hookworm was recorded in a child as young as six months of age.

Worm loads in the different age groups were adjudged by means of Stoll dilution egg counts and the results are shown in Tables V and VI.

DISCUSSION

The records of *T. deminutus* from Man appear to be limited to Central and Southern Africa and certain neighbouring islands (Leiper, 1908; Sant 'Anna, 1909; Sandground, 1929 & 1931; Blackie, 1932; Amberson & Schwarz, 1952, Goldsmid, 1967, 1968a and b; 1969, 1971a) although the species has recently been recorded from Tanzania (Kilala, 1971) and Uganda (Anthony & McAdam, 1972). From primates other than Man, however, it has been recorded from further afield including

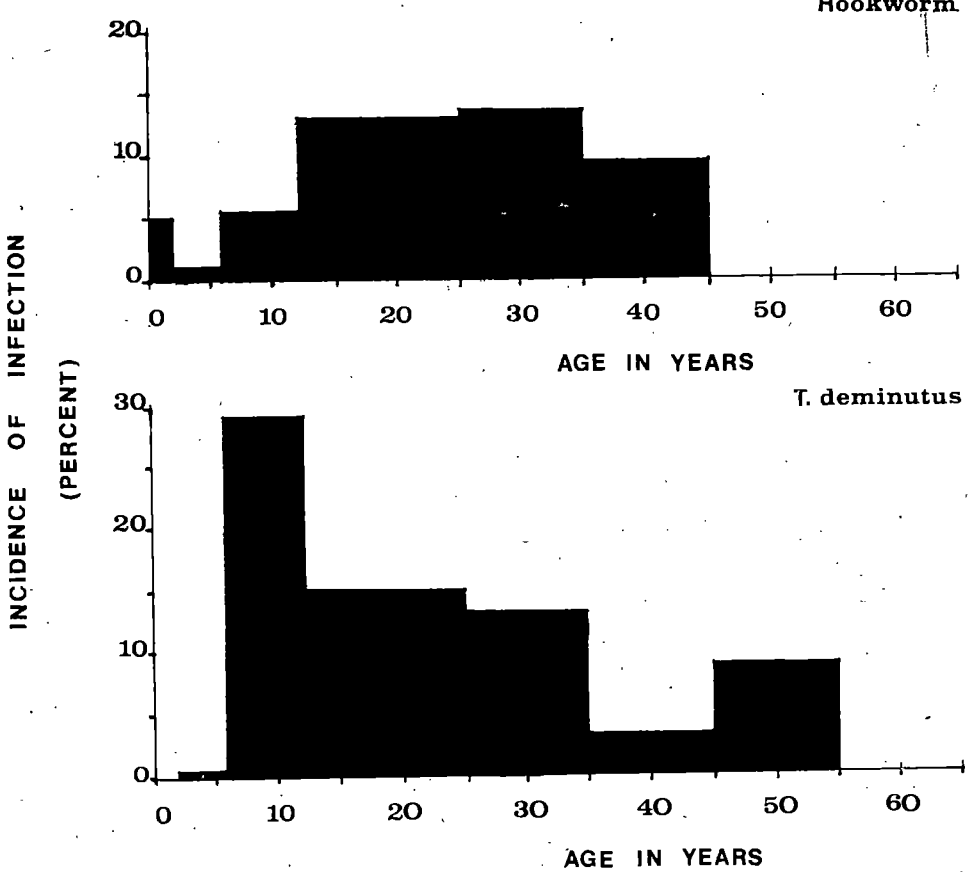

Fig. 5—Prevalence of infection with hookworm and *Ternidens deminutus* amongst Africans of different ages.

Table V

EGG OUTPUT PER GRAM FAECES IN VARIOUS AGE GROUPS OF AFRICANS INFECTED WITH *T. deminutus*.

	Age group (years)								
	0-2	3-6	7-12	13-25	26-35	36-45	46-55	56-65	>65
Total Eggs	—	690	5294	3999	4230	2650	2010	1646	5620
No subjects	—	4	15	31	25	7	8	9	4
Mean eggs/g. faeces	—	172,5	353	129	169,2	378,5	251,3	183	1405
Range	—	50-530	30-1117	30-650	30-850	50-720	50-420	50-660	30-5090

Table VI

EGG OUTPUT PER GRAM FAECES IN VARIOUS AGE GROUPS OF AFRICANS INFECTED WITH HOOKWORM

	Age Group (years)								
	0-2	3-6	7-12	13-25	26-35	36-45	46-55	56-65	>65
Total eggs	60	100	1190	4510	27 730	15 531	310	2190	8100
No. subjects	1	1	4	20	23	11	2	3	3
Mean eggs/g. faeces	60	100	297,5	225,5	1205,7	1412	155	730	2700
Range	60	100	100-450	30-1030	50-23 900	50-10 001	120-180	30-1960	50-7720

a number of countries in Southern Asia (Amberson & Schwarz, 1952; Nelson, 1965, Goldsmid, 1969, 1971a).

The main focus of infection, however, especially for human cases, seems to be Rhodesia. Sandground (1931) & Blackie (1932) reported on investigations into the prevalence of the helminth and their results are compared in Table VII with those of the present investigation.

It can be seen that today, as was the case more than 30 years ago, *T. deminutus* is widespread in Rhodesia, although with a rather patchy distribution. The present investigation has shown that in many places *T. deminutus* infections are much commoner than hookworm infections, while in other areas the opposite appears to be true. In the light of the fact that it is 35 years since *T. deminutus* was reported from a public health or medical laboratory in Rhodesia (Report on the Public Health for the year 1934), the comparative figures for hookworm and *T. deminutus* are of interest. This lack of reports of *T. deminutus* was also commented upon by Nelson (1965). The results of the present survey have shown that the lack of reports of *T. deminutus* for this period is due to mis-identification on the part of laboratory staff, not due to the disappearance of the species from humans since 1934. This was subsequently confirmed by the questioning of laboratory staff, both professional and technical, not one of whom was found to have ever heard of *T. deminutus*. The changes in prevalence between the present investigation and the earlier ones are discussed by Goldsmid (1968b).

As regards hookworm, the two main species in Man, *Ancylostoma duodenale* and *Necator americanus*, are more or less world-wide in the tropics and subtropics and Blackie (1932) and Goldsmid

Table VII

COMPARISON OF THE PREVALENCE OF HOOKWORM AND *T. deminutus* RECORDED FROM VARIOUS PARTS OF RHODESIA BY SANDGROUND (1931), BLACKIE (1932) AND IN THE PRESENT INVESTIGATION.

AREA		Salisbury	Bindura	Maramba	Umtali	Melsetter	Darwin	Selukwe	Bikita	Mt. Selinda	Chikore	Lundi	Wankie	Chiweshe	Ft. Victoria	Inyanga	Burma Valley	Triangle	Zambesi Valley
Author	Species																		
Sandground (1931)	Hookworm	—	—	—	—	—	—	—	—	54,7	37	—	—	—	—	—	—	—	—
	T. deminutus	—	—	—	—	—	—	—	—	58,4	65	—	—	—	—	—	—	—	—
Blackie (1932)	Hookworm	23,2	—	—	19,8	9,1	0	4,4	2,5	—	—	—	3,6	—	*	—	**	—	—
	T. deminutus	5,3	—	—	12,8	10,2	0	0	16,0	—	—	—	0	—	*	—	**	—	—
Present investigation	Hookworm	5,8	0	1,9	2,3	—	—	—	0	29	—	0	—	20,9	6,1	14,8	47,6	26,5	60
	T. deminutus	3,8	69,2	11,5	7,0	—	—	—	87	.0	—	1	—	6,9	40,5	13,9	16,6	0,5	0

* Included in figures for Bikita.

** Probably included in figures for Umtali

(1968b) have shown that in Rhodesia, *N. americanus* is the commonest species — a finding similar to that of Buckley (1946) in Northern Rhodesia (Zambia). The report of *Ancylostoma duodenale* by Friis-Hansen and McCullough (1961) is peculiar in the light of Buckley's work (*loc.cit*) as the former authors only mention "stool and urine samples . . . collected from most of the children and examined for parasites" and does not make it clear whether they collected eggs or adults or even used culture methods to allow a species identification to be made.

Askins (1932) and Blackie (1932) both believed that Africans entering Rhodesia from neighbouring territories (Zambia, Malawi and Mozambique) had a higher prevalence of infection with hookworm than local Africans and suspected that these foreign Africans lost a proportion of their hookworms on entering and residing in Rhodesia. The comments by Askins, the Medical Director at the time, in the Report on the Public Health for 1931 were based on the work at that time being undertaken by Blackie, although the latter never really investigated this problem in any detail. However, this suspicion that hookworm was introduced was first mentioned in the Report on the Public Health for the year 1914, when Orpen (1915) found that all 29 "hookworm" cases (i.e. undifferentiated from *T. deminutus*) he examined had come from Malawi and Mozambique and had been in Rhodesia for less than two years. From these results, he tentatively suggested that this infection was probably imported but that it might readily be spread by infected persons. After his investigation, not much work was carried out on hookworm in Rhodesia until 10 years later, although Eaton (1916) stated that "ancylostomiasis occurs particularly amongst native mine labourers from north of the Zambezi".

The next report on ancylostomiasis was that of Fleming (1926) who reported on an "outbreak" in the Melsetter area which was investigated by Orpen (1926). He decided that the infection was localised to the south Melsetter area where Lawrence of the American Board Mission had reported an incidence of 82 per cent. in 250 stool specimens (for subjects of all races) examined. Fleming (1929) remarked that "Ancylostomiasis . . . is not yet prevalent in Southern Rhodesia, though it is said to be spreading in certain parts of the Union of South Africa, notably amongst labourers on mines. Only four cases were reported last year compared with an equal number in the previous year". Then, in 1930, Fleming again drew attention to the possibility of hookworm being imported, stating "attention has been drawn to the extent to which alien natives from North-Eastern Rhodesia and Nyasaland coming into this colony seeking work are affected with hookworm". Ninety-two specimens from alien Africans were examined and 82,6 per cent were found to be positive for "hookworm". It was then shown that the percentage of positives grew less with each year of residence in Rhodesia, eventually disappearing in about three years. He stated that of the indigenous Africans, the only definite knowledge available at that time was that "in parts of the South Melsetter area bordering on the Sabi River this disease is endemic, but the figures so far do not show it to be widespread or to be very serious".

In 1931, the Medical Director, Askins, again commented on the hookworm problem saying "Ancylostoma (Hookworm) . . . is found not uncommonly as an indigenous disease amongst natives in Southern Rhodesia. The comparatively cool and dry climate of the Colony is not favourable to this worm, which is probably the reason why severe cases of ancylostomiasis are rarely seen amongst indigenous natives. More severe cases are found in native labourers immigrating from northern areas where climatic conditions favour heavy infestations". He then went on to state "With a view to alleviating this debilitating disease amongst imported labourers, mass treatment has been applied at the frontier stations of the Colony 1 cc of oil chenopodium with 2 cc of Carbon Tetrachloride being the mixture at present employed. Altogether 50 000 doses have been issued to the stations during the last nine months, and no untoward results have been reported from them. The parasite is not often found amongst Europeans in Southern Rhodesia". No further reference to this problem of hookworm being imported could be found, although Public Health Reports were examined up to 1971. However, in 1931, Askins did comment on Blackie's work (*loc. cit.*) referring for a last time to this problem.

No reference could be found in the literature available regarding the withdrawal of the act providing for compulsory hookworm treatment of Africans entering Rhodesia from the north, but the practice seems to have fallen into abeyance with the passage of time.

Blackie (1932) never investigated the problem of introduced hookworm in great detail, but examining newly-arrived Africans from Northern Rhodesia, Nyasaland and Portuguese East Africa, found a prevalence rate of 13,8 per cent., 16 per cent. and 6,3 per cent. respectively. He stated that "the question of hookworm loss in regard to natives of Southern Rhodesia could not be studied in detail in the time available".

It should be pointed out that the whole question of hookworm in Rhodesia prior to the work of Sandground (1931) and Blackie (1932) was based largely upon the finding of eggs, and all reports prior to these papers were complicated by the

fact that it was not realised that *T. deminutus* accounted for a percentage of the so-called "hookworm infections" — although all available work suggests that *T. deminutus* is not common in neighbouring territories. In fact it was only in 1930, after almost all of the above work on the problem of introduced hookworm had been carried out, that the first report of the occurrence of *T. deminutus* in Rhodesia appeared, when Askins (1931) commented on Blackie's results, saying that *T. deminutus* occurred "not infrequently amongst natives in Southern Rhodesia".

We thus see that the investigations to that date were not strictly accurate due to the possible mis-identification of some eggs at least and the fact that Blackie never dealt with the problem in detail, only examining newly entered Africans and not studying the effect of length of stay on either load or incidence. Thus all work prior to that of Sandground (1931) and Blackie (1932) which was based on identification by egg appearance only, really refers to the "hookworm-*Ternidens* complex" and one cannot really be sure of the extent to which each may have been involved at that time. Subsequent to Blackie's paper in 1932, all trace of *T. deminutus* was again lost in Rhodesia, the last report of it being in 1935 (Report on the Public Health for the year 1934). Also, little work was carried out on hookworm in the following years and what was done, was again based largely on the so-called "hookworm ova" (Gelfand, 1945a and b; Gelfand & Garnett, 1965). In fact, since the Report on the Public Health for the year 1934, the first report of *T. deminutus* occurring in Rhodesia is that of Goldsmid (1967). The work of Gelfand (1950) on hookworm was based on autopsy studies and he reported only the presence of *A. duodenale* and *N. americanus* being interested in hookworm and thus presumably examining only the small intestine. It is, however, surprising that no *T. deminutus* infections were revealed in 31 consecutive "hookworm" patients at Harari Central Hospital examined by the Harada-Mori Test Tube Cultivation Technique by Gelfand & Warburton (1967). This whole problem of the confusion existing in Rhodesia in the past as regards the hookworm-*Ternidens*" complex, has been discussed in detail by Goldsmid (1968 a & b).

Thus while hookworm seems to be a largely imported disease, it appears to be maintained at a low level in alien Africans after they enter Rhodesia. So, while the percentage of these immigrants infected drops, and while the load decreases, it never really disappears completely. This is in contrast to the report of Fleming (1930) who claimed that "hookworm" infection usually disappeared "in about three years". The present results would suggest that hookworm can be maintained at a low level over much of Rhodesia but that in some areas it is endemic. It is further obvious that the area in which immigrant Africans settle in Rhodesia would also have an effect, and the present survey considers alien Africans in general rather than in local situations. In local Africans, hookworm is found, but the loads as judged on egg counts are usually low. In this general context, the high hookworm prevalence found at Mt. Selinda which is an area of high rainfall and that of 27 per cent recorded at the irrigated Lowfeld sugar estates by Saunders (1969) is of interest, showing that in the hot moister areas of the country the prevalence can be high and, when irrigation is introduced, the prevalence can build up to a significant level. Load studies in these areas would be of interest.

In contrast to these findings on hookworm, *T. deminutus* appears to be an almost purely local Rhodesian problem, almost all infected Africans being born and bred Rhodesians. Those few alien Africans found infected had lived in Rhodesia long enough to almost preclude the possibility of infection having occurred in their countries of origin. Of investigations carried out in neighbouring territories on *T. deminutus*, Sandground (1931) found infected Africans working in the mines in Johannesburg, South Africa, who had originated from Portuguese East Africa (Mozambique). He also found a 27 per cent. prevalence at Gogoyo in Mozambique, 40 miles from Mount Selinda. However, in Lourenco Marques, he only found one case in 323 examined and this infected subject had lived until a year previously in Rhodesia near Mt. Selinda and Chikore. In his work on intestinal helminthiasis in the Portuguese Territories, de Azevedo (1964), discussing *T. deminutus*, merely comments that he "presumed that this parasite still exists" following its report by Sant'Anna (1909). Amberson and Schwarz (1952) received specimens from the Medical Laboratory in Lourenco Marques in Mozambique, but no details are given of the histories of the patients. Sandground (1931) also found infected Africans working in the mines in Johannesburg, South Africa, who had originated from the Transkei and Pondoland in the Republic of South Africa, suggesting that the infection occurred as far south as these areas. However, the survey carried out by Elsdon-Dew and Freedman (1952) in Durban, although reporting a hookworm prevalence of 16,09 per cent, makes no mention of *T. deminutus* and discussions with the Government Pathologist at East London, South Africa, the central laboratory dealing with the territories of the Transkei and Pondoland, again revealed that they were unaware of *T. deminutus* as a parasite of Man.

Surveys carried out in Zambia too, indicate that *T. deminutus* is uncommon there. Sandground (1931) found no cases of this species

at Livingstone and Blackie (1932) records only one case from Northern Rhodesia. Buckley (1946) reports finding no human cases of *T. deminutus* during his survey of Northern Rhodesia, although one infected monkey was found. Blackie (*loc. cit.*) remarking on his positive cases from Zambia, Malawi and Mozambique, felt that they had all been resident in Rhodesia "sufficiently long to render infestation within the Colony a possibility". Mahmud-Durrani, Desai and Tembo (1970) discuss the prevalence of "hookworm" amongst surgical patients in the Kitwe Central Hospital but do not make it clear whether they made any attempt to differentiate against the possibility of the occurence of *T. deminutus* infection in their patients.

The prevalence of *T. deminutus* amongst baboons (*Papio ursinus griseipes*) examined at autopsy by Goldsmid (1971a) also proved to be high, 72,1 per cent. being found to be infected with this helminth. The results recorded by this author are in general agreement with those of Blackie (1932) who found that of 29 baboons (*Papio porcarius Geoffroy* (?*P.. ursinus griseipes*)), 22 (75,9 per cent.) were infected with *T. deminutus* while 3 (60 per cent.) of five vervet monkeys *Cercopithecus pygerethrus* (=*C. aethiops cynsuros*)) were also found to be infected. The present author has also found *T. deminutus* in the latter species of monkey in Rhodesia. However, Sandground (1931) failed to find *T. deminutus* in any of six baboons, four *C. leucampyx nyasae* Schwarz, 1928 (*C. metis stevonsoni* Roberts 1948) and one *C. pygerethrus* he examined. The difference might, however, have been due to the fact that the animals were from different regions in Rhodesia.

The high prevalence of infection amongst non-human primates would suggest that *T. deminutus* infection is a zoonosis (Blackie, 1932; Watson, 1960; Fiennes, 1967; Bisseru, 1967; Goldsmid, 1969; 1971a), although Sandground (1931) felt that "in the region of Mount Selinda, at least, monkeys do not serve as a reservoir for Ternidens", and Witenburg (1964) comments that "it is not certain whether *man* or other animals are the main host of this species". Blackie (1932) however, states "the incidence of *T. deminutus* amongst the natives of a district is associated with a correspondingly high incidence of the parasite amongst the monkeys and baboons of the district, and it is possible that these animals constitute important reservoir hosts" and Goldsmid (1971a) inclines to agree with him.

The seasonal variation of *T. deminutus* appears similar to that of hookworm, prevalence being highest in the wet summer months as discussed by Goldsmid (1971a). The drop in prevalence during the cold dry months is probably related to the responses of the free-living larval stages of both species to desiccation and low temperatures — laboratory studies on which have been carried out by Sandground (1931), Blackie (1932) and Goldsmid (1971b).

For hookworm, the present results would correspond with the conclusions drawn at the CCTA/WHO African Conference on Ancylostomiasis (1963) where it was stated that "in tropical regions where there is a clear-cut rainy season, it is generally considered that the most favourable transmission periods are those at the beginning and end of the rains". An examination of the prevalence of hookworm and *T. deminutus* infection amongst males and females showed that, while 6,1 per cent of the males examined and 4,8 per cent of the females examined were infected with hookworm, the mean load of the females appeared to be higher as calculated on the basis of egg counts. For subjects infected with *T. deminutus*, 3.5 per cent. of the females examined proved to be infected as opposed to 2,9 per cent. of the males. Here, however, the loads of the males as adjudged on egg output, proved slightly higher. Analysed statistically by χ^2, however, there was no significant difference in the number of males and females infected with either *T. deminutus* or hookworm (p=between 0,1 and 0,2 for both species) and for the loads carried too, no significant difference could be detected for *T. deminutus* using χ^2 as indicated in Table VIII (p=between 0,3 and 0,5). For hookworm, however, the females carried significantly higher loads when tested by χ^2 as in Table IX (p=between 0,01 and 0,02). Blackie (1932) found that of 717 males he examined, 173 (24,1 per cent.) were infected with hookworm and 40 (5,6 per cent.) with *T. deminutus*. Of the 41 females he studied, 3 (7,3 per cent.) were infected with hookworm and 2 (4,9 per cent.) with *T. deminutus*. Analysed statistically by χ^2, his results showed that no significant differences existed between the number of males and females infected with *T. deminutus* (p= between 0,8 *and*

Table VIII

LOADS OF *T. deminutus* IN AFRICAN MALES AND FEMALES AS JUDGED BY EGG OUTPUT/G. FAECES.

T. deminutus eggs/g. faeces	Value	Male	Female	Total
<100	Observed Expected	26 27,8	23 21,2	49
100-500	Observed Expected	53 48,8	33 37,2	86
>500	Observed Expected	10 12,5	12 9,5	22
Total		89	68	157

Table IX

LOADS OF HOOKWORM IN AFRICAN MALES AND FEMALES AS JUDGED BY EGG OUTPUT/G. FAECES.

Hookworm eggs/g. faeces	Value	Male	Female	Total
<100	Observed Expected	31 25,2	2 7,8	33
100-500	Observed Expected	39 42,0	16 13,0	55
>500	Observed Expected	14 16,8	8 5,2	22
Total		84	26	110

0,9) thus agreeing with the present work but he did find significantly more females than males infected with hookworm (p=between 0,02 and 0,05). Blackie made no comparative study on the possible difference in loads carried by males and females.

Gilles, Williams and Ball (1964) working in Nigeria examined 183 African villagers and found no significant difference in prevalence of infection between the sexes, 90 per cent. of the males and 83 per cent. of the females examined proving to be infected with hookworm (in this case *N. americanus*). They found that the males tended to have a mean egg output of 43 000 eggs per gram of faeces as opposed to a female mean of 39 000 eggs per gram of faeces. The male range ran a bit higher, being 22 000 to 96 000 eggs per gram faeces, while the female range was 28 000 to 58 000 eggs per gram. The conclusions of Belding (1965) also agree that the overall prevalence in males and females is more or less equal and a recent report on soil transmitted helminths states, for hookworm, that "most surveys indicate that there is little difference between the prevalence in males and females, unless there are behavioural or occupational differences", (W.H.O. Expert Committee on Helminthiases, 1964).

Thus for hookworm, the present survey is in general agreement with the conclusions of Gilles *et al* (1964) and Belding (1965), no significant difference being found in the prevalence of infection between males and females. For *T. deminutus* the present investigation also revealed no significant difference in infection rates between males and females, thus agreeing with the findings of Blackie (1932). An analysis of the prevalence of hookworm and *T. deminutus* infection among different age groups was also made. The results indicate that with *T. deminutus* infections, among the 345 Africans investigated, the greatest prevalence of infection occurred in the 7-12 year old age group. However, in hookworm infections, the highest prevalence was noted in the 12-25 and 26-35 year old age groups (Fig. 5). These hookworm results too are in general agreement with those given in the W.H.O. Expert Committee on Helminthiasis (1964), where it was stated that the maximum prevalence with hookworm occurs somewhere between the ages of 15 and 25 years. Figures published in the CCTA/WHO African Conference on Ancylostomiasis (1963) show that hookworm infection increases rapidly after the age of six years, with maximum infection in the 11-20 year old range. Hookworm infection, however, extended even to the 0-2 year old group as it did in the present survey. Gilles *et al* (1964) in Nigeria found that with *N. americanus*, maximum prevalence of infection occurred in the 30-59 year old age groups, but that infection was common even in the people over 60 years of age.

McGregor and Smith (1952) found a maximum hookworm infection in Gambia between the ages of 6 and 10 years, with a slight drop after 17 years of age. They found none in the two year old children. In Georgia, U.S.A. Scott (1946) recorded an increasing prevalence up to the age of 5-19 years and thereafter a slowly decreasing prevalence, but Tang (1949) found the prevalence of hookworm was maintained up to the age of fifty and over. Gelfand (1961) made the general observation that in his experience (in Rhodesia), hookworm infection was uncommon in young children, although the present survey shows it does occur in this group in Rhodesia.

No comparative figures are available for the prevalence of infection at various ages for *T. deminutus*, but in the present survey it was found that after a maximum prevalence between the ages of 7-12 years, a sharp drop occurred and that this level remained steady between the ages of 13 and 35 years after which it fell off rapidly.

As regards the loads carried by the various age groups, no clear-cut pattern emerged in the present investigation, although an increase in load was indicated by egg counts up to the age of 36-45 years in both *T. deminutus* and hookworm infections, thereafter mean counts from small numbers of subjects are influenced by individual high counts. McGregor and Smith (1952) found an increase in hookworm load as indicated by egg counts up to the age of 6-16 years and thereafter a fall. However, they did not give details in the 17 years and over age groups due to difficulties in obtaining adult stool specimens.

Figures given in the CCTA/WHO African Conference on Ancylostomiasis (1963) show an increasing rate of infection in the older age groups, but the data on worm loads in the different age groups does not seem to show any clear cut increase in load with age, except for males over 15 years, where 25 per cent, gave egg counts of more than 10 000 eggs per gram of faeces.

The effect of hookworm on the human host is largely dependent upon the load of worms, but may manifest itself as an iron deficiency anaemia or, when loads are very high, as a hypoproteinaemia with oedema. Nausea, vomiting and diarrhoea are also recorded (Foy & Kondi, 1961; Gelfand, 1961; Goldsmid, 1965).

The effects of *T. deminutus* on Man are not well understood, but have been discussed by Goldsmid, 1971a. It is possible that when loads are high the worm may be associated with anaemia but even single worms can cause lesions of the large intestine or may enter the wall of the small intestine causing nodules which might necessitate surgical intervention (Anthony & McAdam, 1972). These infections do therefore require treatment as has been discussed by Goldsmid (1968a). While much work has been published on the treatment of hookworm infections, relatively little has been published on the treatment of human infections with *T. deminutus*. Table X gives a comparison of the results of various trials that have been carried out to test the efficacy of various drugs on *T. deminutus*.

Table X

COMPARISON OF VARIOUS DRUGS IN THE TREATMENT OF HUMAN INFECTIONS WITH *Ternidens deminutus*.

Drug	Evaluation	Reference
Carbon tetrachloride	Ineffectual	Sandground (1931) Webb (1937)
Tetrachlorethylene	Ineffectual	Sandground (1931)
Oil of Chenopodium	Ineffectual	Sandground (1931)
Phenylene diisothiocyanate	22,2% cure	Goldsmid & MacCabe (1972)
Bephenium hydroxynaphthoate	87,5% cure	Goldsmid (1971c)
Thiabendazole	90,5% cure	Goldsmid (1972)
Pyrantel pamoate	91,7% cure	Goldsmid & Saunders (1972)

As can be seen from Table X, Thiabendazole and Pyrantel pamoate gave very high rates of cure but the unpleasant and frequent side effects of Thiabendazole probably preclude its being considered the drug of choice when compared to the equally effective and relatively side-effect free Pyrantel pamoate — a conclusion endorsed by Desowitz (1971) who wrote of Thiabendazole "it probably will not become the drug of choice for many intestinal helminthiases when less toxic anthelmintics are available".

SUMMARY

Studies on the epidemiology of *Ternidens deminutus* and hookworm infection in Rhodesia have shown that the former infection is still widespread in this country in both human and monkey hosts. The loads, however, tend in Man to be relatively low. Hookworm infection is also fairly widespread but seems largely to be an introduced infection with a high prevalence among immigrant Africans. The prevalence in these immigrant Africans drops as does the load with lengthening stay in Rhodesia although in areas of high rainfall or with overhead irrigation, the prevalence in Rhodesia may be high. Loads of hookworm in Rhodesian Africans seem to be usually low.

Both hookworm and *T. deminutus* appear to increase in the warm rainy season (October to March) and to drop during the cold dry months.

It was also found that the prevalence of hookworm and *T. deminutus* in males and females was about the same, although females carried significantly higher loads of hookworm than did males.

As regards infection of different age groups with these helminths there seemed to be a tendency for the younger age groups to be infected with *T. deminutus* (but not very young children under two years of age) while hookworm was commoner in young adults.

A review of the treatment of human infections with *T. deminutus* is included in the paper.

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REFERENCES

AMBERSON, J. M. & SCHWARZ, E. (1952) *Ann. trop. Med. Parasit.* **46,** 227.
ANTHONY, P. P. & MCADAM, I. W. J. (1972) Gut. **13,** 8.
ASKINS, R. A. (1931) *Report on the Public Health for the year 1930.* Govt. Printer, Salisbury, Rhodesia.
ASKINS, R. A. (1932) *Report on the Public Health for the year 1931.* Govt. Printer, Salisbury, Rhodesia.
BELDING, D. L. (1965) *Textbook of Parasitology, 3rd ed.* N.Y. Appleton-Century-Crofts.
BISSERU, B. (1967) *Diseases of Man acquired from his Pets.* London, Heinemann.
BLACKIE, W. K. (1932) *A Helminthological survey of Southern Rhodesia. Memoir Ser. Lond. Sch. Hyg. trop. Med. No.5.*
BLACKIE, W. K. (1935) *Report on the Public Health for the year 1934.* Govt. Printer, Salisbury, Rhodesia.
BUCKLEY, J. J. C. (1946) *J. Helminth,* **2,** 111.
CCTA/WHO (1963) *African Conference on Ancylostomiasis Wld. Hlth. Org. tech. Rep. Ser.* 255.
DE AZEVEDO, J. FRAGA (1964) *Anais de Instituto de Medicina Tropical* **21,** 273.
DESOWITZ, R. S. (1971) *Ann. Rev. Pharmacol.* **11,** 351.
EATON, W. M. (1916) *Report on the Public Health for the year 1915* Govt. Printer, Salisbury, Rhodesia.
ELSDON-DEW, R. & FREEDMAN, L. (1952) *S. Afr. J. clin. Sci.* **3,** 59.
FIENNES, R. (1967) *Zoonoses of Primates.* London. Weidenfeld and Nicolson.
FLEMING, A. M. (1926) *Report on the Public Health for the year 1925* Govt. Printer, Salisbury, Rhodesia.
FLEMING, A. M. (1929) *Report on the Public Health for the year 1928.* Govt. Printer, Salisbury, Rhodesia.
FLEMING, A. M. (1930) *Report on the Public Health for the year 1929.* Govt. Printer, Salisbury, Rhodesia.
FRIIS-HANSEN, B. & MCCULLOUGH, F. (1961) *J. trop. Med. Hyg.* **64,** 243.
FOY, M. & KONDI, A. (1961) *Trans. R. Soc. trop. Med. Hyg.* **54,** 419.
GELFAND, M. (1945a) *Clin. Proc.* **4,** 21.
GELFAND, M. (1945b) *E. Afr. med. J.* **22,** 98.
GELFAND, M. (1950) *Schistosomiasis in South Central Africa.* C.T. Juta.
GELFAND, M. (1961) *Medicine in Tropical Africa,* Edinburgh, Livingstone.
GELFAND, M. & GARNETT, P. A. (1965) *J. trop. Med. Hyg.* **68,** 157.
GELFAND, M. & WARBURTON, B. (1967) *Trans. R. Soc. trop. Med. Hyg.* **61,** 538.
GILLES, H. M., WILLIAMS, E. J. W. AND BALL, P. A. J. (1964) *Quart, J. Med.* **33,** 1.
GOLDSMID, J. M. (1965) *C. Afr. J. Med.* **11,** 160.
GOLDSMID, J. M. (1967) *C. Afr. J. Med.* **13,** 54.
GOLDSMID, J. M. (1968a) *Trans. R. Soc. trop. Med. Hyg.* **62,** 109.
GOLDSMID, J. M. (1968b) *Trans. R. Soc. trop. Med. Hyg.* **62,** 619.
GOLDSMID, J. M. (1969) *Studies on Ternidens deminutus Railliet & Henry* 1909, *a nematode parasite of Man and other Primates in Rhodesia. Ph.D. Thesis, University of London.*
GOLDSMID, J. M. (1971a) *Ternidens deminutus — A Parasitological Enigma in Rhodesia. Fac. Med. Res. Lect. Ser.* No. 4, University of Rhodesia.
GOLDSMID, J. M. (1971b) *J. Helminth.* **45,** 341.
GOLDSMID, J. M. (1971c) *J. trop. Med. Hyg.* **74,** 19.
GOLDSMID, J. M. (1972) *S. Afr. med. J.* **46,** 1046.
GOLDSMID, J. M. & MACCABE, R. J. (1972) *C. Afr. J. Med.* **18** (in press).
GOLDSMID, J. M. & SAUNDERS C. R. (1972) *Trans. R. Soc. trop. Med. Hyg.* **66,** 375.
HSIEH, H. C. (1963) *CCTA/WHO African Conference on Ancylostomiasis Wld. Hlth. Org. tech. Rep. Ser.* **255,**
KENNEDY, A. F. (1956) *C. Afr. J. Med. 2,* 104.
KILALA, C. P. (1971) *E. Afr. med. J.* **48,** 636.
LEIPER, R. T. (1908) *J. trop. Med. Hyg.* **11,** 181.
MAHMUD-DURRANI, A., DESAI, M. H. & TEMBO, D. (1970) *Med. J. Zambia.* **4,** 121.
MCGREGOR, I. A. & SMITH, D. A. (1952) *Trans. R. Soc. trop. Med. Hyg.* **46,** 403.
NELSON, G. S. (1965) *The Baboon in Medical Research, Proc. 1st Int. Symp. on the Baboon and its use as an Experimental Animal* ed. Vagtborg, H. Austin, Univ. Texas Press.
ORPEN, L. J. J. (1915) *Report on the Public Health for the year 1914* Govt. Printer, Salisbury, Rhodesia.
ORPEN, L. J. J. (1926) *Report on the Public Health for the year 1925* Govt. Printer, Salisbury, Rhodesia.
ROBERTS, C. J. (1970) *C. Afr. J. Med.* **16,** 12.
SANDGROUND, J. H. (1929) *Ann. trop. Med. Parasit.* **23,** 23.
SANDGROUND, J. H. (1931) *Ann. trop. Med. Parasit.* **25,** 147.
SANT 'ANNA, J. F. (1909) *Arch. Hyg. Path. exót.* **2,** 58.
SASA, M., HAYASHI, S., TANAKA, H. & SHIRASAKA, R. (1958) *Japan J. exp. Med.* **28,** 129.
SAUNDERS, C. R. (1969) *Rhod. Sci. News.* **3,** 174.
SCOTT, J. A. (1946) *Amer. J. trop. Med.* **26,** 331.
TANG, C. C. (1949) *Amer. J. Hyg.* **50,** 236.
WATSON, J. M. (1960) *Medical Helminthology,* London, Bailliere, Tindall & Cox.
WEBB, J. L. (1937) *Parasitology* **29,** 469.
WITENBERG, G. G. (1964) *Zoonoses. ed.* Van der Hoeden, J. Amsterdam Elsevier.
W.H.O./Expert Committee on Helminthiases (1964) *Soil-transmitted helminths. Wld. Hlth. Org. tech. Ser.* 277.