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MALARIA IN THE PARE AREA OF TANZANIA. IV. MALARIA IN THE HUMAN POPULATION 11 YEARS AFTER THE SUSPENSION OF RESIDUAL INSECTICIDE SPRAYING, WITH SPECIAL REFERENCE TO THE SEROLOGICAL FINDINGS

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The South Pare area was one of two areas selected for special study within the Pare-Taveta Malaria Scheme, described by WILSON (1960). In this, spraying of houses with the residual insecticide dieldrin, at intervals of 8 months for 3 years from 1956 to 1959, caused a dramatic reduction in the transmission of malaria. Malaria in the South Pare area before, during, and after the spraying has been described in a series of previous papers by DRAPER and SMITH (1957 and 1960) and by PRINGLE (1967 and 1969). The last author recorded observations made during the period from the suspension of the spraying in 1959 until 1966. During this time there was a surprisingly slow return of *Anopheles gambiae*, with evidence of continuing reduced longevity, and an even greater delay in that of the other main vector in the area, *Anopheles funestus* type form which, unlike the former, had been completely eradicated by the spraying. Factors in this slow return were thought to have been a prolonged residual insecticide effect of the dieldrin and, particularly in the case of *A. funestus*, competition by replacement species. Hence, it was only by 1966 that densities of *A. gambiae* near to those found before the spraying were observed, while the *A. funestus* type form was only then beginning to reappear. The resurgence of malaria in the human population appeared to be similarly delayed; a contributory factor in this was thought to be an increase in the use of anti-malaria drugs.

This paper describes malaria in the human population as found in surveys done in February and March 1970, that is almost exactly 11 years after the last round of insecticide spraying. In addition to the standard malariometric methods, a serological survey was done to determine whether this would give any further information on human infections, and a repeat survey of haemoglobin levels was also done.

Entomological background

From 1968 onwards densities of *A. gambiae* and *A. funestus* were similar to those before spraying (WHITE and MAGAYUKA, 1968). The Human Blood Index (HBI) of re-established *A. funestus* females was about 90% indoors as in pre-spray years, while the HBI of *A. gambiae* had risen by about 25% in certain villages between 1955 and 1968,

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apparently in consequence of the reduction of the availability of cattle as alternative hosts (WHITE, 1971)*. Table I shows the theoretical annual human malaria inoculation rates based on entomological data, calculated by the standard methods (WHO, 1963). Throughout the series of papers describing malaria in the Pare area a distinction was made between the swamp and the roadside villages and this is continued here. Because of the technical and statistical inaccuracies inevitable when the vectors have a very low sporozoite rate (less than 1% both before spraying and subsequently) such calculations can be no more than approximate. They suggest, however, that by the start of 1970 the risk of malaria was approaching that before spraying.

TABLE I. Approximate theoretical human malaria inoculation rates (infective bites per individual per year) in the South Pare area, based on entomological data. Range and (means).

	Year	*A. gambiae*	*A. funestus*	Total
Swamps villages	1954–55*	10–15 (11·9)	26–40 (29·8)	27–53 (42)
	1967–68	1–20 (5·7)	2–35 (12·2)	3–55 (18)
	1968–69	2–11 (4·8)	3–24 (9·5)	5–35 (14)
	1969–70	10–34 (19·4)	15–54 (30·3)	25–88 (50)
Roadside villages	1954–55*	11–22 (20·3)	1–10 (4·6)	13–27 (25)
	1967–68	1–21 (5·9)	1–13 (4·4)	2–34 (10)
	1968–69	1– 8 (3·5)	1– 7 (2·9)	2–15 (6)
	1969–70	7–24 (13·9)	5–18 (10·1)	12–42 (24)

* before spraying

Malaria in the human population

An attempt was made to examine people from exactly the same villages and hamlets as had been examined during the main part of the scheme from 1954 to 1959. This was not altogether possible because of some rebuilding, in particular an extension of the rice growing areas in some parts having caused the abandonment of hamlets in the swamps and the migration of their people to the roadside villages. However, a differentiation between swamps and villages has been maintained and this is justified by differences in their malaria indices. These are shown in Table II while in Figure 1 the parasite rates for the swamp villages are compared with those before and at the suspension of spraying. For 1966 PRINGLE (1969) gave parasite rates for the swamp villages of 23% for the combined age groups under 2 years, of 39% for the 2 to 9 years combined groups, of 22% for the 10 to 19 years combined groups, and of 18% for the over 20 years groups. His figures for the roadside groups were 28, 23, 27 and 15% respectively. Despite the return of the vectors the indices for 1970 do not show more than a small increase over those for 1966 and are still considerably below those before spraying.

**Note:* Since the present survey was conducted in early 1970 an epidemic of East Coast Fever during mid 1970 has eliminated perhaps three-quarters of the cattle from South Pare, causing greater man dependence of anophelines and a striking rise in sporozoite-rates.

TABLE II. Spleen and parasite rates in S. Pare area February to March 1970.

Age groups		Swamp villages	Roadside villages
0–11 months	No. examined	68	33
	Spleen rate	16	9
	Parasite rate	24	6
12–23 months	No. examined	69	42
	Spleen rate	37	12
	Parasite rate	30	17
2– 4 years	No. examined	187	90
	Spleen rate	40	26
	Parasite rate	32	28
5– 9 years	No. examined	227	283
	Spleen rate	54	35
	Parasite rate	51	38
10–14 years	No. examined	106	291
	Spleen rate	46	23
	Parasite rate	47	28
15–19 years	No. examined	46	41
	Spleen rate	31	14
	Parasite rate	41	29
20–39 years	No. examined	159	33
	Spleen rate	38	24
	Parasite rate	24	33
Over 40 years	No. examined	111	23
	Spleen rate	38	30
	Parasite rate	9	0

89% of infections were with *Plasmodium falciparum,* 10·2% with *P. malariae,* and 0·8% with *P. ovale,* similar proportions to those before spraying. The mean densities of *P. falciparum* infections, when compared with those before spraying, showed a rise in those of the 5 to 9 years and 10 to 14 years of age groups, compatible with a delay in the acquisition of immunity. This can be seen also in Figure 1 where the peak prevalence of parasitaemia in 1970 has been shifted towards the older school age children. The peak prevalence rate of gametocytes (13% in 1970, compared with 30% in 1955 and 5% in 1959) still occurred in the 1 to 2 year age group.

Serological studies

While films were made blood was also collected into heparinized capillary tubes for serology as described by OTIENO et al. (1971). Several tubes were taken from each person and after separation the sera were stored frozen. One set of samples was examined for malaria antibodies in East Africa using the indirect fluorescent antibody test (IFAT) with *P. fieldi* in a thin film (OTIENO et al., 1971). Another set was examined in London by the IFAT with *P. falciparum* in a thick film following, with minor modifications, the method of SULZER et al. (1969). The prevalence of antibodies by age groups, as determined by these two methods, is shown in Figure 2, where swamp and roadside villages have been combined and the parasite and spleen rates are given for comparison. Figure 3 shows the geometric mean reciprocal titres (GMT) of the antibodies. The heterologous *P. fieldi* antigen is almost as sensitive as the *P. falciparum* in this community, the prevalence rates detected by the two methods being usually fairly close to each other. The greater sensitivity of the homologous *P. falciparum* antigen is, however, shown by a comparison of the GMT's of the antibodies detected by the two methods, those with *P. falciparum* being far higher.

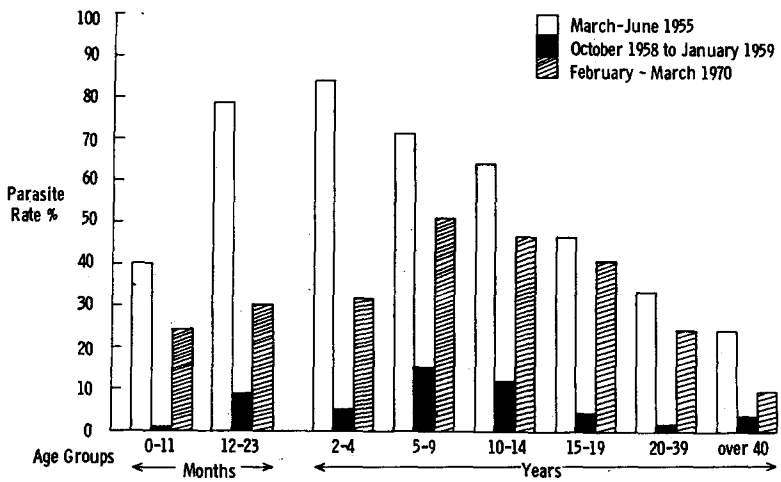

FIG. 1. Parasite rates in S. Pare swamp villages before and after spraying.

A large proportion of the antibodies detected in the infants under one year old would be congenitally transmitted. The falls in the prevalence rates, and more particularly in the GMT's, at the age of about one year suggests that these congenital antibodies have begun to decrease by this time, after which the prevalence begins to rise again following the acquisition of malaria infections. A similar picture in an area of hyperendemic malaria was originally reported by MCGREGOR et al. (1965).

The sharply rising curve of antibody prevalence rates in young children suggests that more malaria infection was occurring than might be deduced from the parasite rates alone. For example, of the 1 to 2 years age group 84% show antibodies to *P. falciparum* while only 24% show parasites, and in the 2 to 4 years age group the figures are 99 and 30% respectively. Omitting the figures for the age groups under one year with congenital antibodies, it has been possible to fit a curve to the figures for older children, by the method given by DRAPER et al. (1972), corresponding to an annual successful inoculation rate with malaria of 0·72 or 72% of the population (95% confidence limits from 65 to 78). This shows the usual discrepancy with the theoretical inoculation rate calculated from entomological data, which has been remarked by several authors (e.g., DRAPER and SMITH, 1957).

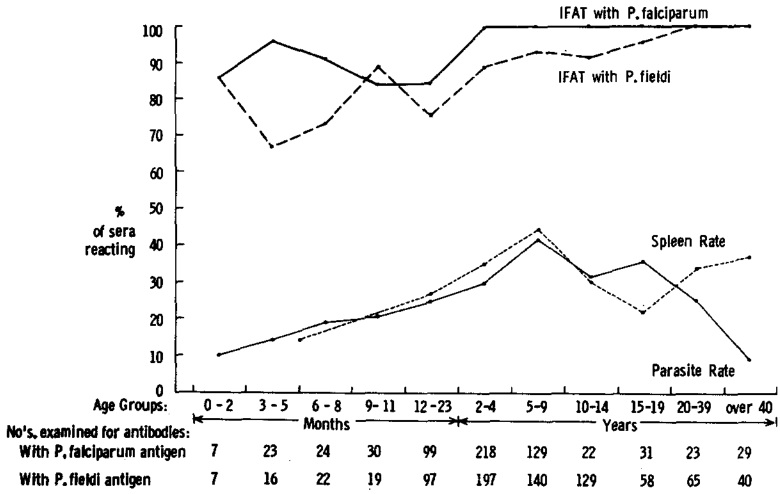

FIG. 2. Malaria antibodies and parasite and spleen rates for S. Pare swamp and roadside villages combined, 1970.

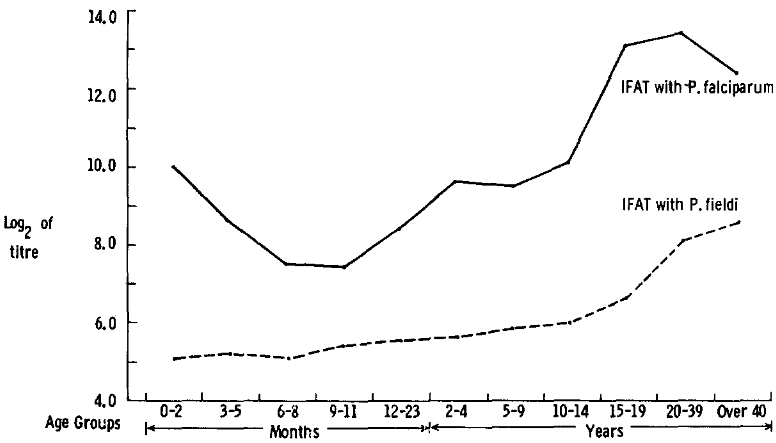

FIG. 3. Geometric mean positive titres of malaria antibodies for S. Pare swamp and roadside villages combined, 1970.

Measurement of haemoglobin levels

One of the few positive observations made during attempts to assess the effects of the successful 1954-1959 Scheme on the general health of the population was a rise in levels of haemoglobin. This occurred at all ages but there was a particular improvement amongst the younger age groups (DRAPER, 1960). In 1970 haemoglobin levels were again measured in the South Pare on a sample drawn from the same swamp and roadside areas as in 1954-1959, using the same method of estimation (the M.R.C. grey-wedge photometer). The results are given in Table III, together with those at the beginning and end of the Scheme. The latter included also measurements made on a sample of people from Taveta, who were not examined again in 1970, but their haemoglobin levels at previous times were similar to those in South Pare. With the resurgence of malaria there has been a general deterioration of haemoglobin levels although this is significant only in the younger age groups, but they are still above the levels found in 1955 before any malaria control.

TABLE III. Mean haemoglobin levels in g. per 100 ml.

Sex and age group	Feb–Mar 1970 No. ex.	Feb–Mar 1970 Mean	Aug. 1958–Feb. 1959 No. ex.	Aug. 1958–Feb. 1959 Mean	Feb.–June 1955 No. ex.	Feb.–June 1955 Mean
Both sexes:						
2–11 months	88	9·7 ± 1·4	106	10·9 ± 1·2	40	9·2 ± 1·6
12–23 months	104	9·9 ± 1·4	87	11·2 ± 1·1	40	8·9 ± 1·8
2– 4 years	226	11·6 ± 1·5	102	12·2 ± 1·4	108	10·4 ± 1·5
5– 9 years	227	12·1 ± 1·3	250	12·9 ± 1·1	245	11·6 ± 1·6
Males:						
10–14 years	83	12·5 ± 1·3	132	13·1 ± 1·2	156	12·0 ± 1·5
15–19 years	30	12·9 ± 1·7	63	14·8 ± 1·7	44	12·9 ± 1·5
20–39 years	58	13·8 ± 1·7	121	15·2 ± 1·5	182	13·5 ± 1·8
Over 40 years	56	13·2 ± 1·7	133	14·5 ± 1·5	163	12·6 ± 1·9
Females:						
10–14 years	90	12·6 ± 1·3	87	13·2 ± 1·1	104	12·3 ± 1·6
15–19 years	44	12·3 ± 1·7	57	13·0 ± 1·5	82	12·0 ± 1·9
20–39 years	99	11·8 ± 1·6	182	12·9 ± 1·4	215	11·6 ± 1·8
Over 40 years	47	12·4 ± 1·8	92	13·4 ± 1·4	130	11·6 ± 1·6

Discussion

Although the densities of the vectors and the theoretical malaria inoculation rates in the South Pare area have almost returned to the levels found before the insecticide spraying, there has not been a similar resurgence of overt malaria in the human population as judged by standard malaria indices. One factor in this is probably because the older members of the population, of 14 years and over, still possess immunity acquired before the relatively short period of malaria control. The high incidence of congenital antibodies in children born of mothers who were alive in the previously highly malarious era, has been pointed out. The serological findings, however, suggest that considerably more human infections may have been occurring and that many parasitaemias were being suppressed to submicroscopic levels. A dissociation between the parasite rates and the theoretical malaria inoculation rates was noted also by PRINGLE (1967 and 1969), who ascribed it to widespread use of small doses of antimalaria drugs. Following the cessation of spraying this was encouraged in the population, and additionally there has been in Tanzania in recent years considerable national propaganda, commercial and government, for the use of these drugs. During the visit in 1970 an enquiry was made of all shops and of the dispensary in the Gonja roadside area to discover how many antimalaria drugs had been sold and given out during the preceding year. A total of about 60,000 tablets of chloroquine, 2000 ml. of chloroquine solution for injection, and 400 ml. of quinine solution had been disbursed. This was for a total population of between 5,000 and 10,000. This amount, even if reduced to a *per caput* consumption, could be expected to have some effect on the prevalence of parasites in the blood. Other recent surveys elsewhere in Tanzania by OTIENO et al. (1971), and by VOLLER et al. (1971), have shown falling malaria indices in places where these were formerly high, with similar dissociation from the antibody prevalence rates. These findings have been ascribed also to the increasing use of antimalaria drugs. In such conditions the use of serological methods may give a more accurate measurement of the amount of transmission occurring.

The last two authors mentioned above used *P. fieldi* as their only antigen in the IFAT. As shown here, this is almost as sensitive as *P. falciparum* in communities which are exposed to a considerable weight of malaria transmission, and which could be expected to develop heterologous antibodies reacting with a simian parasite as well as with the homologous human parasite. However, in a less exposed community, with antibodies of lower titre and with less cross reaction, a greater proportion than recorded here might be missed by using *P. fieldi* alone. This might be significant if, for example, the IFAT was being used to search for small residual foci of transmission in a malaria control scheme.

Although pre-existing immunity and the use of drugs have helped to mitigate the full resurgence of malaria in the Pare area, this has already been sufficient to reverse the improvement in haemoglobin levels previously found with malaria control. PRINGLE (1969) has already noted the reversal of downward trends in the death rates of infants and young children. It is tempting to speculate what would have occurred if some degree of residual insecticide spraying had been maintained over the last 11 years, together with the increasing availability, awareness of, and use of antimalaria drugs. Such combined measures may provide the pattern for malaria control, as opposed to eradication, in many parts of rural tropical Africa in the future.

Summary

A parasitological and serological survey was made in the South Pare area in 1970, where a residual insecticide spraying campaign had previously caused a great reduction in the transmission of malaria. Although the densities of the vectors and the theoretical inoculation rates had almost returned to pre-spraying levels the prevalence of malaria parasites in the human population was still significantly less than formerly. Serological findings, however, suggested that more transmission was occurring than was shown by the parasite rates. As well as pre-existing immunity, an important factor in the delayed resurgence of malaria, and in the dissociation between parasite rates on the one hand and inoculation and antibody prevalence rates on the other, was the widespread use of antimalaria drugs. There was an indication of a fall in mean haemoglobin levels towards those of the period before malaria control.

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