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Report on a Limited Anopheline Survey at Ifakara, South-Eastern Tanzania

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I. Introduction

1. *The aim*

The aim of the survey, which is reported on in this paper, was primarily to gain wider knowledge on the epidemiology of malaria at Ifakara. It forms part of the scientific work carried out in connection with malaria and mosquito-borne diseases at the Field Laboratory of the Swiss Tropical Institute in former years (5, 8) as well as of the teaching activity taking place at the Rural Aid Centre since 1961 (3, 4, 9). There must be pointed out, that we were unable to perform any age-grouping of the mosquitoes collected. The resulting lack of information, naturally, has its bearing on the accuracy of the "apparent inoculation rate". Despite such disadvantage and although local control of the vectors would be of but limited value and a campaign on a larger scale presumably cannot be undertaken within the next decade, for some practical purposes, the data collected could be of sufficient interest to be made generally available.

The principal data to be obtained from an Anopheline survey are the six points to follow (15): 1. species density and frequency, 2. resting habitat behaviour, 3. sex distribution in resting places, 4. sporozoite rate, 5. oocyst rate, and 6. human blood ratio. According to the limited trained personnel, time and technical facilities available, we restricted ourselves mainly to points 1., 3., 4. and 6. With reference to point 2. we confined ourselves to collecting mosquitoes resting in houses.

2. *Topography*

As shown on the map (Fig. 1), Ifakara, a rural township of around 15 000 inhabitants, is situated nearly 8° 9′ S and 36° 40′ E, in the wide, open plain of the Kilombero Valley, about 4 miles north of the river and 180 miles from the Indian Ocean, at an altitude of some 230–260 meters (700–800 feet) (1, 6). The types of prevailing vegetation are of open grassland—including swampy areas along the main river—and of Brachystegia-bush ("Miombo"). In and around the township there are plenty of coconut-palms and mango-trees. Through the township, in North-South direction, flows the Rumemo (Lumemo), a tributary of the main river.

3. *Climatic conditions*

The climatic conditions were described elsewhere (6). The annual mean temperature is of about 26°C (79°F), the annual mean relative air humidity of 72%. The monthly variations are connected with the heavy rains, mainly in

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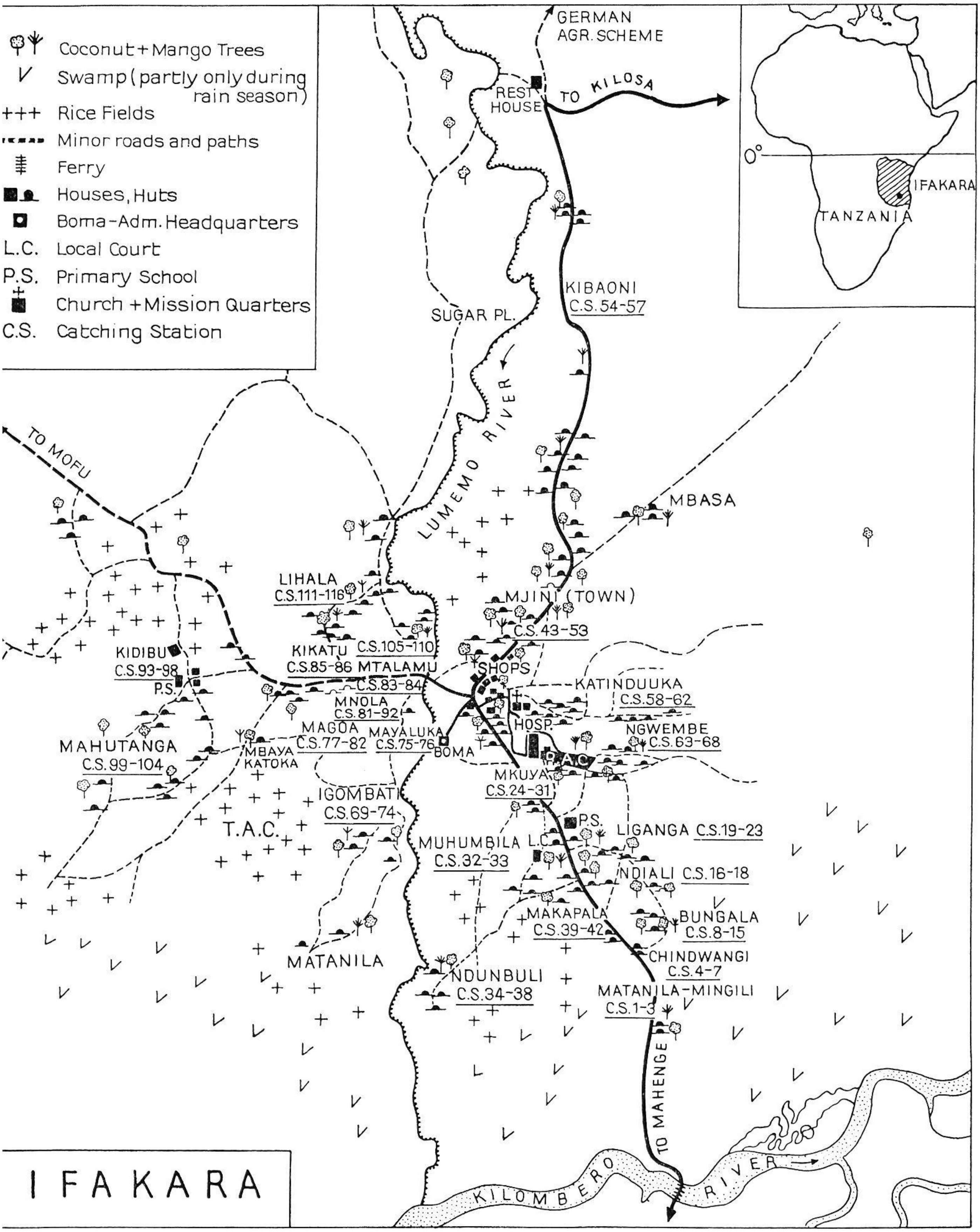

Fig. 1. Sketch map of Ifakara, 1965 (scale: 1 inch approx. 1 1/3 mile).

TABLE 1

Rainfall at Ifakara

	Mean rainfall 1931–1959 (mm)	Rainfall 1965 (mm)	Number of rain days 1965
January	185.2	175.6	10
February	168.9	324.6	9
March	263.6	246.8	9
April	339.3	436.4	17
May	127.5	45.4	3
June	23.4	0	0
July	7.1	0	0
August	4.4	29.6	6
September	6.8	8.2	1
October	12.1	23.0	2
November	46.8	17.0	1
December	118.6	260.0	9
Total	1286.4	1566.6	67

Average number of yearly rain days 1931–1959: 84.

March and April, as well as with lighter and less regular rains in December and January. The annual mean rainfall is of 1286.4 mm over an average of 84 rainy days. The average monthly amount of rain as well as the actual rains in 1965 are shown in Table 1, the latter also in Fig. 2. Except during thunderstorms at the onset of the rainy season wind velocity is slow. The most regular feature during dry season is a breeze from the sea, lasting from about 21 to 24 hours daily. It is important to mention, that during the heavy rain season large areas are flooded by the Kilombero river and its tributaries.

4. *Human factor*

For the human way of life at Ifakara the reader is referred to earlier descriptions (7, 10, 11). Admittedly, these are somewhat out of date. But, although the number of immigrants from other—and mostly more advanced—parts of the country is rapidly increasing and although the number of well educated people, e.g. teachers, Government officials and others, rises from one year to another, progress is slow and the bulk of the population still lives on subsistence agriculture. Beside some hundred goats, there are virtually no cattle at Ifakara, except some few heads at the Mission premises. The houses of the Africans usually consist of mudwalls and grassroofs. Most of them comprise two bedrooms and are of the type «mgongo wa tembo», i.e. where the length of the ridge is at least equal the longer side of the house.

II. Personnel Involved and Methods Applied

One of us, P. M. K. being a Senior Entomology Technician, took care of the work on the spot. For determination of mosquitoes and dissection we were assisted by a trained technician, for the daily catches we were helped by two locally recruited people.

As already mentioned, we limited ourselves to collecting mosquitoes in bedrooms inside houses. The selection of these was made at random, their distribution being shown in Figure 1. As a rule, every house was visited once in a month, the sequence of houses remaining the same throughout the year. We applied the spray-catch method, using 0.1% pyrethrum-kerosene solution to knock down all mosquitoes onto white sheets spread before. 15 to 20 min. after spraying the sheets were removed, the mosquitoes counted and transferred into tubes. With such proceedings, according to GILLIES (personal communication), we could expect to find about 75% of the mosquitoes actually present in a house.

Usually, determination and dissection of the mosquitoes were carried out the same day. When it had to be postponed onto the following day, the mosquitoes were kept in the refrigerator in the meantime.

III. Results

1. *Species density and frequency*

The species density and frequency for *Anopheles gambiae* and *A. funestus* are shown in Table 2 and Fig. 2. During the month of April only a very few specimens of other species were collected in houses, namely: *A. pharoensis* (2 specimens), *A. ziemanni* (2 spec.), *A. longipalpis* (1 spec.) and *A. welcomei* (1 spec.).

2. *Sporozoite rate*

The sporozoite rates for *A. gambiae* and *A. funestus* are indicated in Table 3 and Fig. 2. Females were dissected irrespective of their age and gravidity.

The few specimens belonging to other species were not examined for sporozoites, as it is unlikely that they are of any importance in the transmission of malaria (12).

3. *Human blood ratio*

For reasons unknown the results of the precipitin tests were very unsatisfactory. From a total of 710 blood samples from *A. gam-*

TABLE 2

The density of Anopheles gambiae and A. funestus (1965)

	Number of houses sprayed	Number of males		Number of females		Males % of total catch		Number of fem. per bedroom	
		A. g.	A. f.	A. g.	A. f.	A. g.	A. f.	A. g.	A. f.
January	25	97	0	849	1	10.3	0	(34)	(0.04)
February	61	80	12	811	8	9.0	60.0	13	0.1
March	90	254	3	2614	74	8.9	3.9	29	1
April	58	180	19	1924	318	8.6	5.6	33	5
May	85	35	70	740	494	4.5	12.4	9	6
June	90	11	73	286	446	3.7	14.1	3	5
July	91	40	94	475	429	7.8	18.0	5	5
August	97	105	190	421	331	20.0	36.5	4	3
September	96	44	78	369	161	10.7	32.6	4	2
October	85	23	15	595	91	3.7	14.2	7	1
November	102	9	0	177	36	4.8	0	2	0.4
December	97	88	0	1182	4	6.9	0	12	0.04

TABLE 3

The sporozoite rate in Anopheles gambiae and A. funestus (1965)

	Females dissected		Females positive		Sporozoite rate	
	A. g.	A. f.	A. g.	A. f.	A. g.	A. f.
January	225	0	2	0	0.9	0
February	451	0	4	0	0.9	0
March	906	3	16	0	1.8	0
April	633	69	6	0	0.9	0
May	429	137	19	2	4.4	1.5
June	233	342	2	5	0.9	1.5
July	350	332	4	6	1.1	1.8
August	76	58	1	1	1.3	1.7
September	305	88	1	1	0.3	1.1
October	429	55	3	0	0.7	0
November	154	31	1	0	0.6	0
December	569	1	0	0	0	0

biae 449 could not be identified at all. From the 261 samples remaining, 176 (67.4%) proved to be of human origin, whereas for 85 (32.6%) only the mammalian origin could be ascertained. With regard to *A. funestus* 85 samples were taken. 70 were unidentifiable. There remained 15 of which 9 were of human, 5 of mammalian and 1 of avian source.

As to the "mammalian" feeds, they simply were too weak for further identification. Presumably they, too, were of human origin. It is noticeable that—beside the one feed on a bird—not a single animal could be detected as blood donor. It may be assumed, therefore, that at Ifakara the vast majority of *A. gambiae* and probably also of *A. funestus* use to feed on man.

4. *Chance of infection for the human population*

The daily chance of infection for an individual is expressed as the "apparent inoculation rate" (15) and shown in Table 4. It was calculated first separately, for both vector species, and then combined to give the "total apparent inoculation rate". This indicates how frequently a single human being is likely to get infected. Thereby, index 1 means one infectious bite once a day, index 0.2 one infectious sting every fifth day, 0.1 every tenth day, 0.03 once

TABLE 4

Apparent inoculation rate, Ifakara, 1965

	Anopheles gambiae			*Anopheles funestus*		Total apparent inoculation rate
	Average number of positive females per bedroom	Inoculation rate Factor 2.6	Inoculation rate Factor 3.0	Average number of positive females per bedroom	Inoculation rate Factor 3.6	
January	0.3	0.12	0.10	0	0	(0.10–0.12)
February	0.1	0.04	0.03	0	0	0.03–0.04
March	0.5	0.19	0.16	0	0	0.16–0.19
April	0.3	0.12	0.10	0	0	0.10–0.12
May	0.4	0.15	0.13	0.09	0.03	0.16–0.18
June	0.03	0.01	0.01	0.08	0.02	0.03
July	0.06	0.02	0.02	0.09	0.03	0.05
August	0.05	0.02	0.02	0.05	0.01	0.03
September	0.01	0.004	0.003	0.02	0.005	0.008–0.009
October	0.05	0.02	0.02	0	0	0.02
November	0.01	0.004	0.003	0	0	0.003–0.004
December	0	0	0	0	0	0

in a month and 0.01 once in a hundred days (which, applied to a single month's period, means that there is a chance of 1 to 3 for the individual to get infected in the month concerned).

The apparent inoculation rate was evaluated on the assumption of an average of two people sharing one bedroom, the actual numbers varying from one to seven people in a house. As pointed out in the introduction no age-grading was carried out; according to GILLIES (13, 14, and personal communication) 66% of *Anopheles gambiae* resting in houses have fed during the previous (freshly fed females) and 33% in the night before (gravid females). Our own observations seem to indicate a relation nearer to 50%. Consequently we calculated the apparent inoculation rate applying the factors 2.6 and 3.0 respectively.

Factor 2.6 is obtained as follows:

66% mosquitoes fed within 1 day		0.66
33% mosquitoes fed within 2 days	0.33×2	0.66
		1.3
2 people sharing bedroom	2×1.3	2.6

Factor 3.0 is obtained as follows:

50% mosquitoes fed within 1 day		0.5
50% mosquitoes fed within 2 days	0.5×2	1,0
		1.5
2 people sharing bedroom	2×1.5	3.0

For *Anopheles funestus* a three-day gonotrophic cycle has been described (13, 14); the factor amounts to 3.6.

5. *Transmission of malaria in a selected area*

The Ifakara area as a whole is of rather homogeneous appearance. In order to get information about the transmission of the disease in part-areas we selected the village of Matanila-Chindwangi, consisting of two groups of about twelve houses in all of which six were sprayed at monthly intervals, on the southern outskirts of Ifakara (Fig. 1), where the Anopheles density is definitely higher than in other parts of Ifakara. The figures are summarized in Table 5, for which all calculations were carried out in the same way as for the whole of Ifakara. It clearly appears, that malaria transmission is reduced to nil during a longer period of the year than in the township as a whole; on the other hand, during the months following the rainy season, the apparent inoculation rate

TABLE 5

Malaria transmission at Matanila-Chindwangi-Village (6 houses)

	Anopheles gambiae			*Anopheles funestus*			Total apparent inoculation rate
	Females per bedroom	Sporozoite rate	Apparent inoculation rate (F 2.6)	Females per bedroom	Sporozoite rate	Apparent inoculation rate	
January	31	0	0	0	0	0	0
February	—	—	—	—	—	—	—
March	44	0	0	0	0	0	0
April	25	0	0	1	0	0	0
May	39	4.0	0.61	9	0	0	0.61
June	9	2.5	0.09	10	2.2	0.61	0.70
July	24	4.5	0.42	16	0	0	0.42
August	19	1.8	0.12	15	0	0	0.12
September	16	0	0	15	2.1	0.58	0.58
October	35	1.0	0.15	2	0	0	0.15
November	13	2.2	0.12	4	0	0	0.12
December	31	0	0	0	0	0	0

TABLE 6

Total number of patients and patients treated for malaria at the S. Francis Hospital Ifakara in 1965

	Out-Patients		In-Patients		Total		
	Total	Malaria	Total	Malaria	Total	Malaria	%
January	2982	550	625	43	3607	593	16.4
February	3957	769	625	24	4582	793	17.3
March	4546	737	704	42	5250	779	14.8
April	5241	1008	679	55	5920	1063	18.0
May	5220	999	607	73	5827	1072	18.4
June	5616	1277	657	71	6273	1348	21.5
July	6112	720	712	44	6824	764	11.2
August	5922	726	656	13	6578	739	11.2
September	6185	824	704	26	6889	850	12.3
October	6463	904	817	41	7280	945	13.0
November	5404	747	752	57	6156	804	13.1
December	5922	828	614	27	6536	855	13.1
Total	63570	10089	8152	516	71722	10605	14.8

is very much higher in Matanila-Chindwangi than in the rest of Ifakara.

6. *Incidence of malaria at the Ifakara Hospital*

The number of patients treated for malaria at St. Francis Hospital in the time of our survey is compiled in Table 6 and its percentage in relation to the total number of patients shown in Fig. 2. With regard to the Plasmodia concerned, here, we only want to mention that all four species pathogenic to man do occur. Due to the impossibility of checking the Hospital slides, we abstain from giving more detailed figures.

IV. Discussion and Conclusions

Reference is made to Fig. 2. Although it could not be established beyond all doubt that man is their only source of blood, the two most important vectors of malaria certainly are *Anopheles gambiae* and *A. funestus.*

The frequency of both species is clearly correlated to the two rainy seasons. However, the season has a slightly different bearing on the two species. *A. gambiae* very much increases in number while the rains are on, this being true for the long rains in February to April as well, though to a smaller extent, for the short rains towards the end of the year. Presumably, this is due mainly to the type of breeding site of this mosquito, consisting in part of very tiny pools such as foot marks of large animals and the like. As soon as the rains stop, many of these small holes dry out, and in consequence the number of *A. gambiae* is greatly reduced. As for *A. funestus,* their breeding sites being rather large swamps or lake-like waters, more rain is required until sufficiently abundant water is present. Therefore, it is not surprising to find that the largest numbers of *A. funestus* occur after the long rainy season, and that the short rains in October/November do not suffice to create new breeding places.

The sporozoite rate in *A. gambiae* appears to be rather constant in the months January to April and, again, from June to November. The well marked increase in May must be due primarily to a decrease in the number of young females and, accordingly, to an increase in the average age of the mosquito population. Similar conclusions can be drawn for *A. funestus.* From Fig. 2 it appears that *A. gambiae* would be able to transmit malaria alone through almost the whole year, although in the months from June to September *A. funestus* is at least of equal importance.

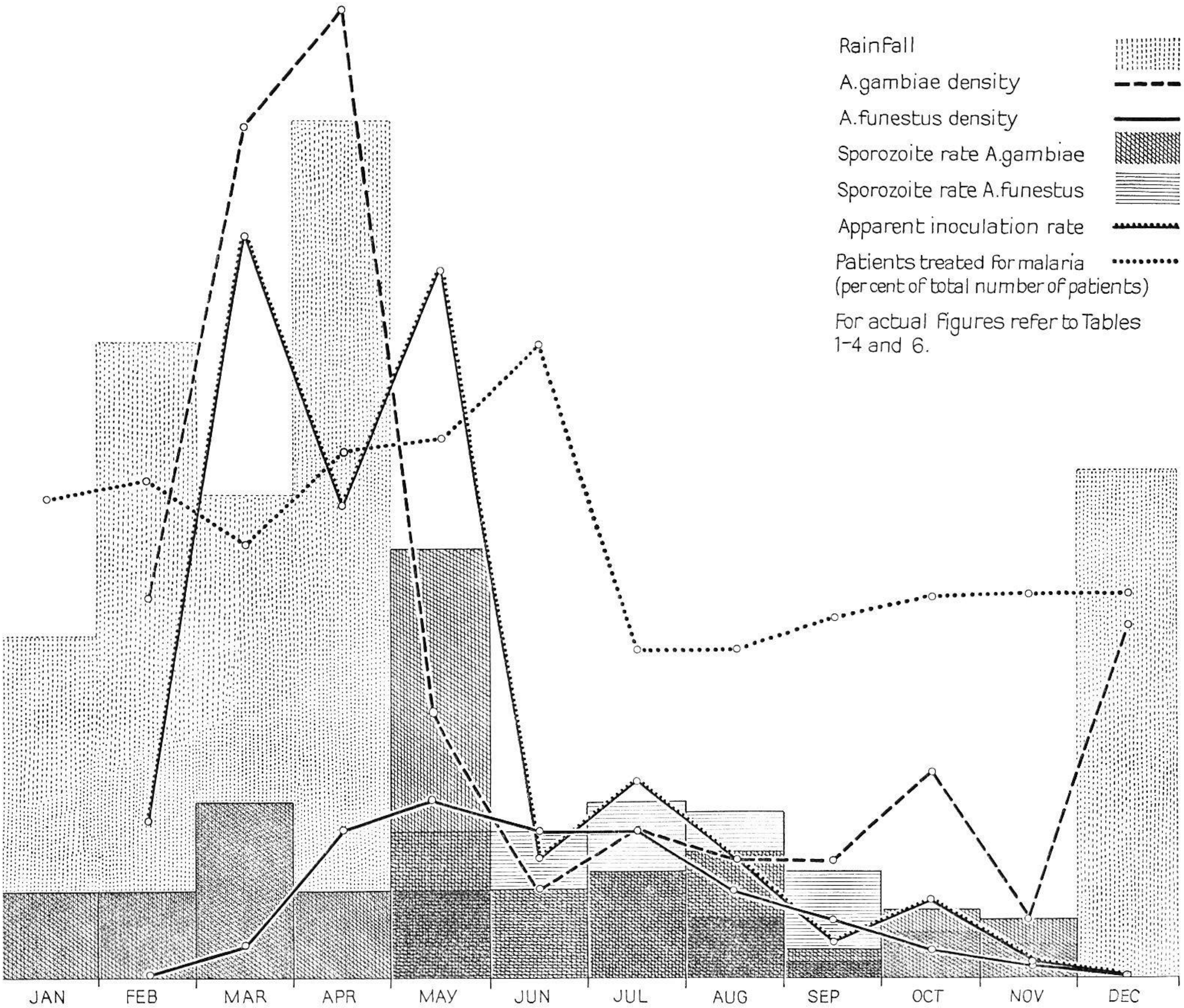

Fig. 2. Malaria transmission at Ifakara in 1965.

The apparent inoculation rate gives but a very rough idea as to the chances of infection for an individual person. For neither does it take into account the individual conditions of living (actual number of people per house, literacy, economic position, degree of personal hygiene and prophylaxis), nor the possibly existing selective feeding habits of mosquitoes amongst humans of different age and sex (2, 5), nor whether there are sporozoites in the ducts—as opposed to the cells—of salivary glands ready for injection. Still, being a combination of the total number of Anopheles females and their sporozoite rate, it shows the seasonal variations of malaria transmission for the community in its entity. It appears to be relatively high in March and in May, to remain rather constant from June to August and, then, to decline to almost nil in

December, when the transmission seems to be too low to be detected with the methods applied.

Although the corresponding figures give only a fraction of the true incidence of malaria at Ifakara (1), it is thought that its seasonal variations are reflected to some extent by the number of patients treated for the disease at the Hospital. There appears to be a clear coincidence between its increase from March to June and the March-to-May-peak of the apparent inoculation rate.

As to malaria transmission in a small selected area, the example chosen shows that the apparent inoculation rate may be quite different there from the one calculated for the whole area investigated. The main transmission period may also be shifted from one month to another and the seasonal variations may be much more emphasized.

Acknowledgements

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Zusammenfassung

In Ifakara, Sitz des «Rural Aid Centre», einer Lehr- und Forschungsstelle im holoendemischen Teil des südöstlichen Tanzania, wurde im Jahre 1965 eine Erhebung über Malaria-Mücken angestellt. Die Ergebnisse sind im wesentlichen in Fig. 2 zusammengefaßt.

Als Überträger der Krankheit sind einzig *Anopheles gambiae* und *A. funestus* von Bedeutung. Die jährlichen Regenfälle beeinflussen die Dichte beider Arten unmittelbar, wenngleich in etwas verschiedener Weise, was mit der Beschaffenheit der natürlichen Brutplätze erklärt wird.

Die Sporozoiten-Rate hängt ihrerseits eng mit den Schwankungen der Mükkenpopulationen zusammen; sie bewegt sich zwischen 0 und 4,4 bei *A. gambiae* und von 0 bis 1,8 bei *A. funestus.* Die durchschnittliche Infektionschance für die Bewohner Ifakaras erreicht ihre höchsten Werte im Verlaufe und in der Folge der großen Regenzeit, während sie im Dezember auf praktisch 0 absinkt. An der Malaria-Übertragung ist im ganzen gesehen *A. gambiae* in stärkerm Maße beteiligt; *A. funestus* erlangt aber in den Monaten Juni bis September ebenfalls erhebliche Bedeutung.

Die im Ifakara-Spital für Malaria behandelten Patienten sind im Juni am zahlreichsten, einen Monat also nach dem Abflauen der Infektionschance. An einem ausgewählten Beispiel wird gezeigt, daß das Muster der Malaria-Übertragung in einem begrenzten Teilgebiet von demjenigen Ifakaras als Ganzem etwas abweicht.

Résumé

Nous avons effectué en 1965 une enquête sur les Anophèles dans une région holoendémique au Sud-Est de la Tanzanie, plus précisément à Ifakara, siège du « Rural Aid Centre ». Voir fig. 2 pour les résultats principaux.

Anopheles gambiae et *Anopheles funestus* sont les seuls vecteurs d'une certaine importance dans cette région. Leur fréquence dépend largement des pluies annuelles, bien qu'elle soit quelque peu différente selon l'espèce. Ceci s'explique par les particularités des gîtes naturels.

L'indice sporozoïtique est en rapport étroit avec les fluctuations des populations d'Anophèles ; il varie de 0 à 4,4 chez *A. gambiae* et de 0 à 1,8 chez *A. funestus.* Le taux d'inoculation est le plus élevé pendant et après les grandes pluies ; il est, par contre, virtuellement nul en décembre. Ainsi à Ifakara, *A. gambiae* serait à lui seul capable d'assurer la transmission du paludisme, mais *A. funestus* acquiert une importance pour le moins aussi équivalente de juin à septembre.

Le nombre des malades traités pour le paludisme à l'hôpital d'Ifakara atteint son maximum au mois de juin, c'est-à-dire un mois après la diminution décisive du taux d'inoculation.

L'étude d'un quartier limité d'Ifakara démontre que la transmission locale ne correspond pas nécessairement à celle enregistrée dans la ville entière.