STUDIES ON *ANOPHELES GAMBIAE* GILES AND MALARIA TRANSMISSION IN THE UMBUGWE AREA OF TANGANYIKA

By A. Smith

Tropical Pesticides Research Institute, Arusha, Tanganyika

(*Received 19th September 1963*)

Field trials of insecticides against *Anopheles gambiae* Giles entering experimental huts are made by this Institute in the untreated Umbugwe area of Tanganyika as part of a World Health Organization programme of insecticide testing. The habits of the mosquitos greatly affect the extent to which they come into contact with the insecticide in the experimental huts, and therefore also the assessment of toxicity of the insecticide. Specific studies on domestic habits of *A. gambiae* have been made (Smith, 1962*a*, *c*) but a general appreciation of the bionomics of *A. gambiae* in the Umbugwe area was desirable for a fuller interpretation of the data from experimental huts, particularly in comparison with results from parts of Africa where the habits of *A. gambiae* are somewhat different. The present paper describes the results, from 1960 to 1962, of long-term studies on *A. gambiae* and *A. funestus* Giles. Dissections were also made for sporozoite infections, and the degree of exposure of the inhabitants to malaria infection was estimated from the entomological data.

The country and its people

The Umbugwe area (fig. 1) lies in the Mbulu District of the Northern Region of Tanganyika, at latitude 3° 55′ South and longitude 35° 45′ East, and 3,500 ft. above sea-level. The area is about 20 miles long and eight miles wide; it is bounded by the rift wall of the Mbulu Mountains on the west, and by the sparsely inhabited Masai country on the east. A large river, called the Cau River, whose source is in the Mbulu Mountains, flows north to Lake Manyara and is the chief supply of water to the irrigation furrows of the Umbugwe area.

The indigenous people are the Wambugwe, a Bantu-speaking tribe of about 7,500 individuals whose tribal area, Bugwe, is at the south end of the salt-water Lake Manyara. Some 2,000 flat-roofed huts, called ' tembe ', are spread fairly widely and evenly over a barren alkaline plain that extends southwards to the hill called Besi. There are many diffuse villages, which lie in six larger geographical units. Crops, chiefly red millet, are grown on both sides of the Great North Road. Cattle play an important part in the economic and social life of the Wambugwe, and are taken in herds each day to graze on the plains and bushland that lie beyond the cultivated zone. At night, domestic animals, whose numbers per tembe are in the order of 10 cattle, 20 sheep and smaller numbers of donkeys and goats, are stalled indoors to conform with the tradition of protecting them from hyaenas and lions, although these animals are not now a serious problem.

South of Besi and extending to the hills of Kiru and Dudumera is an area, broadly called Magugu (fig. 1), which, with the exception of the large village of Matufa (3) *, is thinly populated by Mbugwe, but is inhabited by some 2,000

* The positions of all villages mentioned in the text and the tables are indicated on fig. 1 by numbers, to which a key is included in the legend to that fig. For convenience, whenever a village is mentioned in the text or tables its name is followed by the relevant number, in parentheses.

immigrants who grow cash crops such as maize and castor-oil plants in the fertile ground and swamps that lie between the Great North Road and the Mbulu Mountains. Peoples in this area include Mbugwe, Rangi, Nyaturu, Nyaramba, Sukuma, Nyamwezi and Jaluo. Most houses in this area conform to the ' banda ' or ' msonge ' type (see below for description) and the villages are situated where irrigation is at hand so that virtually all the villages are near

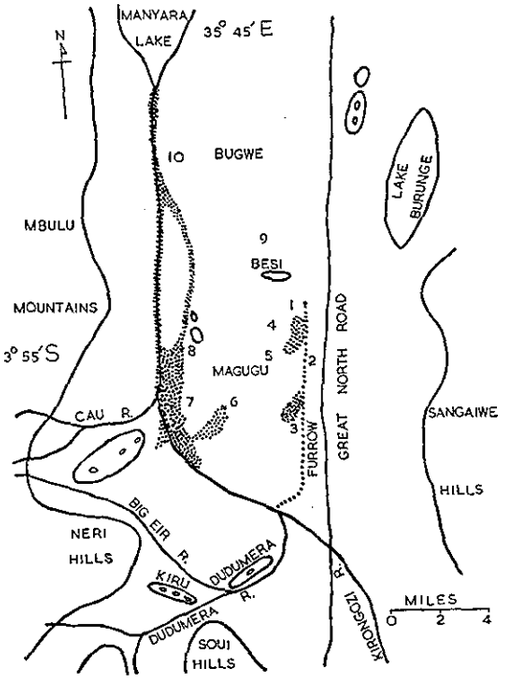

Fig. 1.—Map of Umbugwe area. Swamps and irrigated areas are shown by stippling. Villages indicated by numbers are: 1, Mbuyuni; 2, Kibaoni; 3, Matufa; 4, Mapeya; 5, Vibau vitatu; 6, Msimbazi; 7, Migungani; 8, Kinyume; 9, Talambwe; 10, Sanjirioi.

highly seasonal rice swamps; Migungani (7) and Kinyume (8) are probably the largest of them. The immigrant tribes restrict their domestic animals almost entirely to a few goats kept indoors at night. The Wambugwe keep cattle in Matufa (3), and in a few other villages. Most are stalled indoors, but a few are penned outdoors in unroofed enclosures at night. There are, in addition to the immigrant tribes, a number of European farmers growing coffee, papaws, sisal, maize and beans, and who employ a number of the immigrant tribesmen as well as some thousand labourers from their own camps.

Climate

Meteorological data are from the Institute Outstation in the Magugu Area. The main rains are generally in March and April and the short rains between November and January. The coolest months are typically from June to August

and the hottest from November to March. Table I shows the rainfall for 1960 and 1961, and Table II temperature and humidity data, from maximum and minimum thermometers and a hygrograph in a Stevenson Screen. Temperature and humidities indoors were similar to those outdoors but with less diurnal variation.

TABLE I. *Monthly rainfall in inches at Magugu Outstation, for 1960 and 1961*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1960	2·20	1·44	8·11	7·33	0·58	0·19	0	0	0·08	0·20	2·10	2·38	24·61
1961	1·74	3·48	2·89	3·77	1·16	0·03	0·20	0	0·05	2·17	12·13	3·99	31·61

Description of huts

The three types of huts encountered in the Umbugwe area are the tembe, banda and msonge. The tembe is a large, nearly square-shaped hut with a low, flat roof; the average measurements are length 32 ft., width 29 ft. and height 5 ft. The walls are constructed of wooden stakes, closely set together and daubed with a mixture of mud and cow dung. The undersurface of the roof is composed of the stalks of red millet (sorghum) placed across wooden beams. The outer surface of the roof is made of pieces of turf placed upside-down and covered with a layer of earth. There are usually five rooms for accommodation of cattle and sheep and the millet harvest in addition to the people. Walls between rooms are usually incomplete at the top. The internal plan of a traditional tembe is complicated, owing to historical influences and superstitious beliefs. The most important room is the kitchen and millet store, which is usually situated at the back of the tembe and is reached at the end of a maze of rooms and passages. The banda is a rectangular building with mud walls and a thatched roof of the gable or hip type, with the following average measurements, length 18 ft., width 10 ft. and ridge-height 10 ft. The msonge is uncommon and is a circular building with mud walls and a thatched roof and with an average diameter of 15 ft. and 10 ft. high at the apex of the roof. In both the latter types of hut there are usually no more than two rooms, a kitchen and a bedroom, and the walls dividing the rooms are usually incomplete at the top.

Densities of mosquitos in houses

Monthly catches were made in 90 selected houses, distributed in ten villages in the Bugwe and Magugu areas (fig. 1), by means of a standardised technique using floor sheets and a spray containing 0·1 per cent. pyrethrum in kerosene. The great differences in size and internal design of the different types of houses in the area presented a problem in sampling mosquito densities. Preliminary trials were made with floor sheets of unbleached calico (americani), each sheet being 10 ft. long and a yard wide. It was found by covering the whole floor space with sheets that, on average, ten sheets caught half the resting mosquitos in a banda and msonge and one-third in a tembe (*i.e.*, in the villages of Talambwe (9), Sanjirioi (10) and Matufa (3)). There was no simple relationship between the size of sheet and area of floor space covered in the banda and msonge houses, due to several factors, the principal one being that it was unusual to have enough uninterrupted floor space to lay a sheet down flat. These fractions were applied to the catches in the different types of houses. The estimated average number of *A. gambiae* and *A. funestus* per house per day, from catches done once or

TABLE II. *Monthly temperature and humidity data from a Stevenson screen at Magugu Outstation, for 1961*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean max. temp. (°C.)	34·4	31·7	32·8	30·1	30·7	29·9	27·7	28·2	29·3	31·2	29·3	27·9
Mean min. temp. (°C.)	18·1	18·4	19·5	19·0	19·1	16·4	16·3	17·0	17·7	18·8	18·7	19·1
Mean of max. and min. temp. (°C.)	26·2	25·0	26·2	24·5	24·9	23·1	22·0	22·6	23·5	25·0	24·0	23·5
Mean max. rel. humidity (%)	81	87	87	91	90	93	94	78	82	87	94	95
Mean. min. rel. humidity (%)	31	44	32	31	44	35	43	45	43	51	55	54
Mean of max. and min. rel. humidity (%)	56	65	59	71	67	64	68	61	62	69	74	74

twice a month in several houses in each village, and for each of the two years of observation, are shown in Table III.

TABLE III. *Estimated numbers of* A. gambiae *and* A. funestus (*complex*) *per house per day in Umbugwe villages, from spray catches carried out once a month*

	Map ref. no.	1960–61		1961–62	
		A. gambiae	*A. funestus*	*A. gambiae*	*A. funestus*
Mbuyuni	1	101	1	114	3
Kibaoni	2	28	0·4	45	1
Matufa	3	175	4	201	1
Mapeya and	4	62	3	85	1
Vibau vitatu ..	5				
Msimbazi	6	93	8	101	2
Migungani	7	77	10	95	2
Kinyume	8	61	3	107	0·4
Talambwe	9	33	2	64	0·3
Sanjirioi	10	—	—	87	0·3

The villages of Talambwe (9) (Madukani) and Kibaoni (2), which are the chief villages with shops in the area and are further away from swamps than the other catching stations, had the lowest densities of *A. gambiae*. Mosquito densities in Talambwe (9) are probably more representative than those of Sanjirioi (10) of mosquito numbers in tembe in the Wambugwe tribal area. Matufa (3) had the highest densities of *A. gambiae*, explainable by its situation near a rice-growing area with the additional attractive feature that the huts are tembe, housing cattle as well as people. The other villages in the Magugu area have densities of *A. gambiae* similar one to another, but lower than those at Matufa (3), which may be explained by the fact that although they were also situated near seasonal rice-growing areas, they had houses conforming to the banda or msonge types with only a few goats in addition to the human

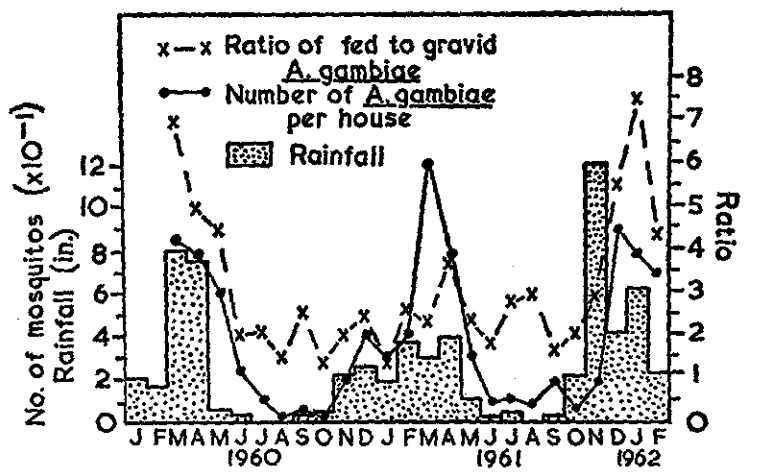

Fig. 2.—Seasonal incidence of *A. gambiae* in 90 houses in the Umbugwe area, as shown by spray catches, and ratio of fed to gravid mosquitos captured.

occupants. Apart from the presence of cattle, there is no indication of any other factor contributing towards high densities of *A. gambiae* in tembe compared with banda and msonge types.

The incidence of *A. gambiae* is highly seasonal in all villages, and the average densities in catching stations (90 houses in 10 villages) in the Umbugwe area, shown in fig. 2, indicate the sharp seasonal increase that coincides with the rains, when the rice seedlings are planted out. The rice-swamps quickly dry up, and after the crops have been harvested in June there are very few breeding places near houses that are suitable for *A. gambiae* and so its densities decline until it becomes scarce from August to October. The scarcity of the *funestus* complex in houses, shown in Table III, may be attributed largely to the rapidity with which the rice-swamps dry up before the rice is full-grown and suitable conditions develop for the members of the *funestus* complex to breed.

The results of a larval survey from May to July 1962 are summarised in Table IV and indicate that, despite the scarcity of members of the *funestus* complex in houses, *A. funestus* type form was the predominant species. Numerous breeding places were examined, ranging in kind from habitats of typical *A. funestus* to those of *A. confusus* Evans & Leeson, and of 833 larvae identified, 94 per cent. were *A. funestus* type form, 5 per cent. *A. rivulorum* Leeson and 1 per cent. *A. confusus*.

TABLE IV. *Numbers of larvae of the complex of* A. funestus *collected in the Umbugwe area from May to July 1962*

Breeding places	*A. funestus* var. *confusus*	*A. rivulorum*	*A. funestus sens. str.*
Irrigation furrows with grass	0	25	268
Pools with grass	0	4	116
Rice-fields	0	1	328
Swamps with reeds (*Typha* sp.)	9	9	73

The gonotrophic cycle and egress of mosquitos from houses after feeding

If it is assumed that the gonotrophic cycle in the majority of *A. gambiae* is complete in 48 hours when the mean temperature in a hut reached, or exceeded, 23·3°C. (as observed by Gillies (1953) near the Tanganyika coast), the temperature records in Table II would seem to suggest that *A. gambiae* had a 48-hour cycle for the nine hottest months of 1961.

TABLE V. *Ratio of fed to gravid examples of* A. gambiae *caught in houses in morning spray catches*

	1960–61			1961–62		
	Fed	Gravid	Ratio	Fed	Gravid	Ratio
Bugwe	805	212	3·8 : 1	3434	729	4·7 : 1
Magugu	18860	5707	3·3 : 1	21449	5859	3·7 : 1
Umbugwe	19665	5919	3·3 : 1	24883	6588	3·8 : 1

An indication of survival and of behaviour of *A. gambiae* was given by classifying mosquitos caught in pyrethrum spray catches into the abdominal conditions of unfed, fed and gravid, in conjunction with studies on egress, using experimental huts. Table V shows that the average ratio of fed to gravid mosquitos, caught in houses, was 3·3:1 in the first year and 3·8:1 in the second

year of observations. The average monthly ratios of fed to gravid examples of *A. gambiae* are shown in fig. 2. There was a long period from June 1960 to November 1961 when the average ratio of fed to gravid mosquitos was 2·3:1, and two peaks in March 1960 and January 1962, respectively, when the ratio exceeded 7:1. The high ratios of fed to gravid individuals of *A. gambiae* in both parts of the Umbugwe area, and in both years, indicated that a young population of *A. gambiae* infested houses in the area.

Studies with experimental huts (Rapley, 1961) indicated that the high proportion of individuals of *A. gambiae* that fed indoors remained within the huts until they were at least half-gravid. Of 797 blood-fed examples of *A. gambiae* caught in two huts during December 1960, only 13 per cent. were found in the exit window trap, having attempted to leave the huts on the night of feeding.

Distribution and host choice of mosquitos resting in houses

The great differences in size and internal design of different types of houses also presented a problem in determining the host choice of mosquitos resting in houses. Blood-fed mosquitos collected by routine pyrethrum spray catches in banda and msonge were a good random sample because in these types of small huts mosquitos are more or less evenly dispersed by the pyrethrum spray before they fall to the floor (unpublished results from the Pare-Taveta Scheme). Spray catches in tembe showed, however, that although the walls separating rooms were incomplete at the top as in banda and msonge, mosquitos tended to fall to the floor within the room in which they had been resting because of the large size of the rooms.

The distribution and host choice of mosquitos in houses was therefore determined as follows: resting mosquitos were collected by means of sucking tubes and the numbers in each room were counted, and the blood-fed ones of good quality subjected to precipitin tests. The distribution of unfed, blood-fed and gravid mosquitos, based on numbers caught in 14 tembe, 11 msonge and 17 banda, are shown in Table VI. The results show that in tembe most

TABLE VI. *The distribution between rooms put to different uses of different abdominal stages of* A. gambiae *resting in different types of houses, as shown by hand catches from December 1959 to February 1960*

	Percentage distribution								
	Tembe			Msonge			Banda		
	Unfed	Fed	Gravid	Unfed	Fed	Gravid	Unfed	Fed	Gravid
Bedrooms	19 (29)	28 (424)	31 (247)	87 (238)	95 (596)	87 (92)	76 (291)	89 (1074)	72 (201)
Cattle-rooms	59 (89)	64 (962)	52 (424)	— —	— —	— —	— —	— —	— —
Unoccupied rooms	21 (32)	7 (100)	18 (144)	14 (38)	5 (30)	13 (14)	23 (88)	11 (143)	29 (79)

Figures in parentheses are numbers caught.

blood-fed individuals of *A. gambiae* are found resting in rooms occupied by cattle and in msonge and banda they are found in bedrooms. A low proportion of blood-fed mosquitos rests in unoccupied rooms in all types of huts and the distributions of all stages of abdominal conditions in these rooms are rather similar.

Host choice, shown in Table VII, is based on a nearly complete collection of blood-fed mosquitos in tembe, and about half in banda, and shows that cattle are the principal hosts of *A. gambiae* entering tembe, and man the principal host in banda. Table VIII shows an average distribution of blood-fed individuals of *A. gambiae* in a tembe, determined by a more detailed study

TABLE VII. *Host choice of* A. gambiae *resting in houses, as shown by precipitin tests*

	Numbers of smears	Percentage positive				Negative
		Man	Cattle	Dog	Others	
Tembe	1221	20	65	5	0·1	9
Banda	623	77	0·3	1·8	0·2	21

of host choice in 14 tembe, in which the hand-collections from different rooms were subjected separately to precipitin tests, and indicates that about one-third of females of *A. gambiae* move out of the bedrooms into other rooms after feeding on man. The results which are in Table VIII also show that about a quarter of the females of *A. gambiae* that have fed on cattle move to other parts of the tembe after feeding.

TABLE VIII. *Dispersal of* A. gambiae *in a tembe after feeding, based on estimated numbers of man- and cattle-fed mosquitos in different parts of the house*

	% distribution of blood-fed examples of *A. gambiae*		
	Man-fed	Cattle-fed	Total
Bedrooms	16	12	28
Cattle-rooms	7	57	64
Unoccupied rooms	2	5	7
Total	25	74	99

Dissection for sporozoites

A total of 55 gland-positive individuals of *A. gambiae* were found among 3,746 specimens dissected from March 1960 to February 1962 (Table IX), giving an average sporozoite rate of 1·47 for the whole area. Most mosquitos were dissected during the wet seasons when the sporozoite rate (excluding February 1962) was 0·25 compared with 1·0 for the dry seasons. February

TABLE IX. *Results of dissection of salivary glands for sporozoites of* A. gambiae *taken in spray catches in houses from March 1960 to February 1962*

	No. dissected	No. positive	% positive
During dry seasons (June to October)	993	10	1·0
During wet seasons (November to May) (excluding February 1962) ..	2329	6	0·25
February 1962	424	39	9·2
Total	3746	55	1·47
(Total excluding February 1962) ..	3322	16	0·48

1962 was, however, an exceptional month, for 39 gland-positive specimens were found among 424 mosquitos dissected, thereby indicating that an unusually high rate of malaria transmission occurred during the early part of 1962. No gland-positive example of *A. funestus* was found among 94 specimens examined. Theoretical malaria inoculation rates, based on the method of Smith & Draper (1959*a*) are set out in Table X. Estimates for 1961–62 are given, as well as

TABLE X. *Approximate annual malaria inoculation rates * per individual in different parts of the Umbugwe area, calculated from entomological data*

	1961–62	Normal year
Indigenous tribal area (Sanjirioi (10) and Talambwe (9)) ..	11–14	3–5
Swamp villages (Mbuyuni (1) and Migungani (7))	29–75	19–25

* The approximate annual malaria inoculation rate is calculated by multiplying the sporozoite rate by the estimated numbers of mosquitos biting one person per annum and dividing the product by one hundred.

estimates for a more normal year based on a sporozoite rate of 0·48 obtained by omitting the very high infection rates of February 1962.

It would seem from the spray catches and dissection results that *A. funestus* plays virtually no part in malaria transmission in the Umbugwe area.

Malaria in the human population

As Magugu is a focus for sleeping sickness, more than usual dispensary care is given to the taking of blood-slides and microscopy. Of 9,249 slides examined in the Government dispensary between January 1961 and June 1962, 5,519, *i.e.*, about 60 per cent., were positive for malaria parasites. The data from June 1961 to May 1962, grouped for dry and wet seasons (Table XI), show that the parasite rates, from those persons attending the dispensary, were higher in

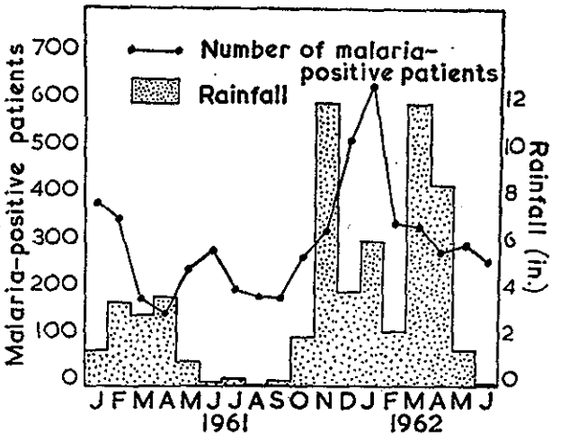

Fig. 3.—Number of malaria-positive patients attending the Government dispensary at Magugu each month, from January 1961 to June 1962.

the rainy seasons. The greatest number of malaria-positive patients came to the dispensary during the rainy seasons, and there were unusually many in December 1961 and January 1962 (fig. 3).

TABLE XI. *Results of examination of blood-slides at the Government dispensary at Magugu*

	1961–62	
	Dry season (June–October)	Wet season (November–May)
Number of slides examined	1958	3835
Number positive for malaria	1144	2795
Per cent. positive for malaria	58	73

Discussion

The results indicate that, in respect to gonotrophic cycle, egress from houses and facultative feeding habits, the bionomics of *A. gambiae* in the Umbugwe area are intrinsically the same as those of *A. gambiae* in other parts of East Africa such as the Taveta area of Kenya (Kauntze & Symes, 1933; Smith & Draper, 1959*a*) and the South Pare area of Tanganyika (Draper & Smith, 1960). Nevertheless, the ratios recorded here of fed:gravid mosquitos resting in houses are higher than in other parts of East Africa, which could be explained by a difference in the composition of the feeding section of the mosquito population and may be attributed to the more seasonal breeding, in which the ratio might be dominated by a high proportion of newly emerged individuals at the time of the rapid acceleration in production of adults during the rains. There are also differences in choice of host when these are equally available in houses as well as when they are not. Thus, in tembe, where man and cattle are housed together, most females of *A. gambiae* feed on cattle, whereas in the beehive-shaped houses of Taveta Forest, where man and cattle are also housed together, man is the chief host (Kauntze & Symes, 1933; Smith & Draper, 1959*a*); on the other hand, in the banda-type houses in the village of Mata, in the Taveta area of Kenya, which are occupied by man alone but provide the only shelter by day, 83 per cent. of the mosquitos taken indoors had fed on cattle, the blood-meal having been taken earlier outdoors from the exceptionally large herds of cattle (Smith, 1958).

The ratios of fed to gravid *A. gambiae* of 3·3:1 and 3·8:1 for the Umbugwe area (Table V) may be compared with 1·5:1 for the Taveta area (Smith & Draper, 1959*b*). The high average ratios in Umbugwe houses are consistent with the mosquitos being mostly young specimens, and this view is supported by slightly higher than average ratios for *A. gambiae* caught in houses in the more seasonally extreme Bugwe half of the Umbugwe area.

There appear to be two factors responsible for the low average age of the mosquitos. The first factor is the very rapid production of adults, during the limited period of the rainy seasons, leading to an increasing proportion of the population being newly emerged and consequently an increase in ratio of fed to gravid mosquitos. For example, fig. 2 shows that with sharp rises in mosquito production, following the heavy rain in November 1961, the ratio of fed to gravid mosquitos rose sharply to as much as 7·5:1. The second factor would appear to be the short duration of life of the mosquitos in the dry season so that a significant proportion of mosquitos that feed do not survive to become gravid. For example, fig. 2 shows that in the dry seasons of 1960 and 1961 the ratio of fed to gravid mosquitos was usually greater than 2:1, and Table V indicates that there was a higher ratio of fed to gravid

individuals of *A. gambiae* in the drier, desert-like Bugwe area than in the more shaded and irrigated Magugu area. A practical application of the high and irregular ratios of fed to gravid mosquitos in the Umbugwe area would be that it might be imprudent to use this ratio, when derived from spray catches in insecticide-treated huts, as a measure of insecticidal effectiveness in an area such as Umbugwe, though this was found a useful technique in other areas, where a high ratio in treated houses was found to be associated with effectiveness of residual deposits of insecticide (Smith, 1962*b*).

A. gambiae in Umbugwe is highly domestic in its feeding habits because its chief hosts sleep indoors. There is also little ' deliberate ' exophily (Gillies, 1955) as shown by the small proportion of recently fed individuals of *A. gambiae* in exit window traps of experimental huts. The egress of 13 per cent. at Magugu would suggest that there is no great difference in ' deliberate ' exophily between Umbugwe and other inland areas of East Africa (Smith & Draper, 1959*a*). The only studies on outdoor resting places that have been made in Umbugwe are a limited number of unpublished observations in pit shelters near experimental huts at Magugu, which indicated that there were virtually no recently fed individuals of *A. gambiae* resting outdoors that had fed on some outdoor host. No observations have been made on outdoor resting at Bugwe, but the barren, desert-like terrain is likely to be devoid of suitable resting places. The facultative feeding habits of *A. gambiae* are admirably illustrated by comparison of host choice in tembe and banda (as given in Table VIII). In tembe where cattle are more numerous than human occupants, cattle are the chief host; and in banda where people are nearly the sole occupants, man is the chief host. Present knowledge thus indicates that where cattle greatly outnumber people in houses *A. gambiae* prefers the former, but when equal numbers of people and cattle occupy the same houses, *A. gambiae* prefers to feed on man (Kauntze & Symes, 1933; Smith, 1955). The principal outdoor feeding is likely to be on an unassessed proportion of people sleeping outdoors on the roofs of tembe, or under the verandas of banda-type houses during the short dry season when it is uncomfortably hot and humid.

There is negligible transmission by *A. funestus* in Umbugwe because it is scarce in the area. Transmission by *A. gambiae* is highly seasonal, for, although the percentage of positive glands in *A. gambiae* (Table IX) is slightly higher in the long dry seasons than in the normal rainy seasons, the much larger mosquito population in the latter will lead to a higher number of infective bites during the rainy seasons. The seasonal transmission by *A. gambiae* is reflected in the results of examination of blood-films at the Government dispensary. The blood-films show that the highest percentage positive for malaria occurs in the rainy seasons (Table XI) and furthermore the highest number of malaria-positive patients is also detected in the rainy seasons. Malaria endemicity would seem to fall into Group II type described by Wilson (1949), *i.e.*, malaria is endemic with an epidemic element added. The epidemic element was revealed following the unusual weather of 1961 when the long rains, which were poor, were followed by extremely heavy rain in November. This weather was widespread in East Africa and led to near-famine conditions in many places including Bugwe area, and devastation of roads and railways. Its repercussions on malaria transmission were also great as shown by the greatest number of malaria-positive patients (fig. 3) and the highest proportion (94 per cent.) of malaria-positive blood-slides that were recorded over a period of 18 months, which occurred in January 1962. There were also high densities of Anophelines for three months and remarkably high sporozoite infection rates in the beginning of 1962.

The low sporozoite rate of less than one per cent. that is normal would seem to be due largely to the low average age of mosquitos in the wet season,

and to the low infectivity to the mosquito of the human population in the dry season. The number of dissections was too few to indicate to what extent zoophily contributes towards the low sporozoite rate in Umbugwe, but it would be expected to be a factor of some importance in Bugwe where some 65 per cent. of *A. gambiae* feed on cattle (Table VII) in tembe in that area. Finally, the domestic habits of *A. gambiae* that exist under present conditions indicate that malaria transmission in the Umbugwe area could be broken by the treatment of houses with residual insecticide.

Summary

The paper includes a description of studies on *Anopheles gambiae* Giles in the insecticide-free Umbugwe area of Tanganyika, and the results of dissections of *A. gambiae* and *A. funestus* Giles for sporozoite infections.

The densities of *A. gambiae* and *A. funestus* were assessed in houses by pyrethrum spray catches in 90 houses distributed in ten villages in the Umbugwe area between March 1960 and February 1962. *A. gambiae* was seasonally abundant, a sharp increase in density being associated with periods of rain. *A. funestus* type form was scarce in houses throughout the year, although a larval survey showed it to be the most common member of the complex of *A. funestus* in the area.

The average ratio of fed to gravid individuals of *A. gambiae* was 2·3:1 from June 1960 to November 1961, with peaks reaching 7:1 in March 1960 and 7·5:1 in January 1962. The peaks were attributed to rapid increase in production of adults during the limited period of the rainy seasons that followed very dry conditions.

Thirteen per cent. of recently fed individuals of *A. gambiae* were found in the exit window traps of experimental huts, having attempted to leave the huts on the night of feeding.

Two distinct types of huts are commonly found in the area, the tembe, which is large, divided into an average of five rooms by walls that are usually incomplete at the top, and accommodates large numbers of cattle as well as humans; and the banda, which is smaller, divided only into two rooms and seldom housing any domestic animals. Precipitin tests showed that whereas only 20 per cent. of individuals of *A. gambiae* taken in tembe had fed on man, in banda huts the percentage was 77. It was also shown that there was a dispersal of *A. gambiae* within a hut shortly after feeding. In a tembe, one-third of the individuals positive for man, and one-quarter of those positive for cattle had moved to rooms other than those in which they had fed.

A sporozoite rate of 1·47 per cent. was found among 3,746 specimens of *A. gambiae* dissected. Of the total number of 55 sporozoite-positive females of *A. gambiae*, 39 were found among the 424 individuals dissected in February 1962, thereby indicating unusually heavy transmission during the early part of 1962. *A. funestus* type form appeared to be of virtually no importance in malaria transmission in the Umbugwe area. Transmission by *A. gambiae* was highly seasonal, for although the percentage of gland-positive specimens was slightly higher in the long dry season than in the rainy season, the much larger mosquito population in the latter led to a higher number of infective bites in the rainy seasons. The highly seasonal transmission by *A. gambiae* was reflected in the results of examination of blood-films of people attending the Government dispensary.

Acknowledgements

I owe thanks to Mr. S. Esozed for the conscientious supervision of mosquito collections. Grateful thanks are also due to Dr. B. Weitz, of the Lister

Institute of Preventive Medicine, for the results of precipitin tests, and to Dr. L. Delaney, Regional Medical Officer, for the results of examination of blood-slides done in the Government dispensary at Magugu. I am also indebted to the Area Secretary, Mr. W. Brooks, for geographical information and for checking the manuscript for factual errors. Thanks are also due to Mr. K. S. Hocking, Director, Tropical Pesticides Research Institute, to Dr. D. Clyde, the Government Malariologist, and to Dr. G. Pringle, Director of the East African Institute of Malaria and Vector-borne Diseases, for valuable comments and criticism.

References

DRAPER, C. C. & SMITH, A. (1960). Malaria in the Pare area of Tanganyika. Part II. Effects of three years' spraying of huts with dieldrin.—*Trans. R. Soc. trop. Med. Hyg.* **54** pp. 342–357.

GILLIES, M. T. (1953). The duration of the gonotrophic cycle in *Anopheles gambiae* and *Anopheles funestus*, with a note on the efficiency of hand catching.—*E. Afr. med. J.* **30** pp. 129–135.

GILLIES, M. T. (1956). The problem of exophily in *Anopheles gambiae*.—*Bull. World Hlth Org.* **15** pp. 437–449.

KAUNTZE, R. E. & SYMES, C. B. (1933). Anophelines and malaria at Taveta.—*Rec. med. Res. Lab. Nairobi* (no. 5), 26 pp.

RAPLEY, R. E. (1961). Notes on the construction of experimental huts.—*Bull. World Hlth Org.* **24** pp. 659–663.

SMITH, A. (1955). The distribution and host-choice of resting *A. gambiae* Giles and *A. funestus* Giles in cone huts on Ukara Island, Tanganyika.—*E. Afr. med. J.* **32** pp. 7–13.

SMITH, A. (1958). Outdoor cattle feeding and resting of *A. gambiae* Giles and *A. pharoensis* Theo. in the Pare-Taveta area of East Africa.—*E. Afr. med. J.* **35** pp. 559–567.

SMITH, A. (1962*a*). Studies on domestic habits of *A. gambiae* that affect its vulnerability to insecticides. Part I. Resting places in huts.—*E. Afr. med. J.* **39** pp. 15–24.

SMITH, A. (1962*b*). Malaria in the Taveta area of Kenya and Tanganyika. Part III. Entomological findings three years after the spraying period.—*E. Afr. med. J.* **39** pp. 553–564.

SMITH, A. (1962*c*). The preferential indoor resting habits of *Anopheles gambiae* in the Umbugwe area of Tanganyika.—*E. Afr. med. J.* **39** pp. 631–635.

SMITH, A. & DRAPER, C. C. (1959*a*). Malaria in the Taveta area of Kenya and Tanganyika. Part I. Epidemiology.—*E. Afr. med. J.* **36** pp. 99–113.

SMITH, A. & DRAPER, C. C. (1959*b*). Malaria in the Taveta area of Kenya and Tanganyika. Part II. Results after three and a half years' treatment of huts with dieldrin.—*E. Afr. med. J.* **36** pp. 629–643.

WILSON, D. B. (1949). Malaria incidence in central and south Africa.—*In* Boyd, M. F., Ed. Malariology II pp. 800–809. Philadelphia, Saunders.