WORLD HEALTH ORGANIZATION

REGIONAL OFFICE FOR THE EASTERN MEDITERRANEAN

ORGANISATION MONDIALE DE LA SANTÉ

BUREAU RÉGIONAL DE LA MÉDITERRANÉE ORIENTALE

SECOND REGIONAL CONFERENCE ON MALARIA ERADICATION

ADDIS ABABA, 16 - 21 NOVEMBER 1959

EM/ME-Tech.2/21

23 October 1959
ENGLISH ONLY.

ANOPHELINE MALARIA VECTORS IN THE SOUTHERN BLUE NILE PROVINCE - REPUBLIC OF SUDAN

Part I : Some habits of A. gambiae

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Part II: Further Entomological Data on A. gambiae

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P A R T I

Some Habits of Anopheles gambiae Giles

Contents

Introduction

Certain observations made as Entomologist of the Malaria Control Pilot Project, Sudan, during the years 1957-59 form the subject matter of this paper.

General Description of the area

The Sudan (formerly Anglo-Egyptian Sudan) is a vast plain of about a million square miles isolated on the north by a desert through which the Nile flows and on the east by the elevated tract bounding the Red Sea. The peculiar and low water-shed of the Sudan makes a vast triangular clayey depression in the basin of the Blue and White Nile rivers. The middle of this plain is occupied by the swampy 'sudd' region. (Map I)

Pilot Project area

The Malaria Control Pilot Project in Sudan, as per the basic agreement between the Government of Sudan, World Health Organization and the UNICEF started working in the Blue Nile Province in 1956 which is the most densely populated area in the country. For malaria control the entire area of the Sennar District and Northern and Southern Fung District have been included, covering a population of 453,400. The area east of the Dinder and south of the railway line and extending upto the boundaries of the Province on the eastern side and upto the National Park and Game preserve in the south has been left as an Check area. (Map II)

Climate

The meteorological data furnished in table I in respect of three recording stations Sennar, Roseires and Kurmuk, all within the Project area and over hundred miles distance from each other and the average conditions at Sennar (Graph I), give a clear picture of the meteorological conditions in the area.

The Project area lying south of latitude 19° N has a typical tropical continental type of climate. In general the climate must be considered hot with a mean daily temperature usually never below 24°C.

It is very much dominated by the annual movements of the boundary between the dry northerly wind and the moist southerlies. Rain is associated with the latter, and particularly with the zone extending about 500 miles south from the boundary. Most of the rain is convectional and occurs in the afternoon and evening.

> "In winter the Saharan high-pressure system dominates the circulation and the northerlies are mainly of a cool dry continental nature from the North African source-region, though

> occasionally the Arabian high intensifies and brings a rather warmer air mass to the eastern part of the country. In Spring and autumn the Arabian high is more dominant in the east and the effect of the Mediterranean depression is rarely felt in the Sudan. From both the North African and the Arabian sources the air is in these seasons considerably warmer than in the winter. In summer the Arabian high disappears completely and the Saharan high is dominant bringing hot dry air. All the northerly air-masses are extremely dry. The southerlies, coming from the seas bring rain."

Thus there is a short rainy season in the north and a long rainy season in the south, with a progressively greater rain as one proceeds from north to the south.

The relative humidity is very low except during the rainy months, when it may go for varying periods of time over 60%. Very low humidities, even 25%, are recorded even at 8am.

The direction of the wind is mainly towards the north except during the winter months when the [illegible]

Population

The country is generally thinly populated although the Blue Nile Province, in which about 1/5 of the population of the country live, is the most thickly populated province in the Sudan (Table II)

The population may be considered under two heads:

1) Settled population
2) Moving population

Settled population: This may perhaps also be described as the nomad, who has settled. In fact various grades of this attempt at settlement may be seen in the area.

Moving populations: Two broad distinct types can be observed:

1) The nomads
2) Seasonal and migratory

The Nomads: The history of Nomadism dates from very early times. Nomadism is a particular way of life suited to the adverse environment. The pattern of life amongst the nomads is just the same from very early times. There is, however,

evidence that slowly the nomadism is being left in favour of a settlement mode of life.

The nomadic tribes in the Project area are given as a typical example of the type of Nomadism found in the Sudan.

Three main tribes or rather administrations are found in the Project area:

1) Rufa'a el Sherig
2) Rufa'a el Hoi
3) Kawatil Kenana

Some of these people are seen amongst the settled population in Abu Hagar, Dar Agil, Wad en Nail etc.

The Rufa'a el Sherig is mainly camel owning and of late the number of camels seem to decrease while that of the sheep and oxen seem to increase. These people graze as far south as the National game preserve on the Abyssinian frontier in the Dinder and as far south as Sowleil on the east bank of the Blue Nile. The other two tribes are mainly cattle and sheep owning and their movement extends from Managil to beyond Khor Yabbus in the South of the Province. The Kawanla Kenana keep to the East of the Blue Nile, while the Rufa'a el Hoi keep to the Western side. A bigger fragment of the Rufa'a move as far south as Khor Yabbus, while a smaller fragment remain distributed round about Roseires.

Further the Rufa'a el Hoi camping round about Roseires send their cattle to the eastern side of the Blue Nile and their cattle graze along with those of Kenana tribe by mutual consent. Usually the herdsmen go. The families live on the western side. There may be rare exceptions to this agreed delimitation.

During the rainy period they concentrate in certain areas as shown in Map III though some few scattered nomads exist in the other areas as well.

Seasonal migration of population consists of:

1) Nomads: The nomads themselves get employed as gum and cotton pickers during the months of November to March. Very often you will see the tents of the Nomads in a cotton plantation 'guthikas' and the ordinary 'tukuls'.

2) Labourers recruited from villages for cotton picking come and settle in specially constructed temporary structures in the plantations, leaving their former houses.

3) Temporary stay of owner-cultivators or hired labourers at varying distances from their native villages usually for short periods.

4) Labour from Abyssinia employed as herdsman by the nomads.

5) Fallata: These are the pilgrims from Nigeria who while crossing the Sudan to go to the holy city Mecca tend to stay for varying periods, some even as permanent settlers.

Habits of Anopheles gambiae, Giles

Against the background presented above let us now consider the behaviour of the malaria vector Anopheles gambiae.

Seasonal prevalence: Seasonal prevalence of the species was studied by the following methods of collection in the unsprayed check area.

1. Routine and random daytime collection from field stations during the years 1957 to 1959 (average)

2. Daytime collection by Pyrethrium spray in routine collection villages but at random selection of houses (average 1957-1958).

3. Night time collection by Pyrethrium spray at 9 p.m. and 4 a.m. Three houses were usually selected at random and sprayed at 9 p.m. and three others also at random at 4 a.m. (1958 and 1959 average)

The number and frequency of collections by methods two and three were comparatively less than one, nonetheless they help to confirm the seasonal curve vide Table III and Graph II.

From the Table and Graph shown the prevalence of adults, it might be easily made out that there are generally two peaks of prevalence one that may be called a general peak found all over the area occurring during one or other months of August to October and a second which may be called a local peak depending upon the extent of favourable conditions available for the species.

A high index of prevalence of larvae is also observed during the months of August to October. At other seasons the number of

breeding places and intensity of breeding varies. (Table IV)

Mention may also be made here that in at least some places like Bebinga in the creek area where breeding facilities existed in the earlier months of 1959 A. gambiae continued to be captured till the end of March. The same places did not show similar condition in 1958. This is stated as an example of the conditions which create a second peak.

Temperature Mosquitoes like other insects or even all animals are considerably affected by temperature. Probably no other single factor has a greater effect upon the distribution on the earth and upon their seasonal activity. Within the limits of temperature in which they are active, the rate of their metabolism and consequently their rate of growth and the resultant population are controlled. Temperature affects nearly all of the other physical features of the environment. Let us now study the seasonal curve of A. gambiae as obtained and certain other observations made on its life habits in relation to this very important environmental factor.

A. gambiae is captured throughout the year, though the trough in the temperature curve during the months of July, August and September seems to support a high prevalence of A. gambiae and its numbers are greatly reduced when the average mean temperature exceeds 30° C. It will be seen on a perusal of the mean temperature figures furnished that this hottest period falls in different months of the year in the three different areas under consideration (Table V).

This period of high mean temperature is earlier in the south, and later in the north but for a longer period.

A study of the prevalence of A. gambiae in relation to this factor during 1956 seemed to confirm that a mean temperature over 30° C is adverse for its longevity and therefore its prevalence (Table VI).

Further during the hottest months of the year the data given in Table VII will indicate that among the few A. gambiae dissected there are many beyond Ovarian group III Christophers and some in V too. The condition of the abdomen on dissection also indicates quite a number having fresh blood.

The ratio of the species in the catches made during the period furnished indicates a good proportion of males (Table VIII).

Summing up the summer behaviour it might be said that hottest period seem to effectively check the population of the species. The following additional points may perhaps also be stated.

1) a large number of larvae of all instars together with the [illegible] collected suitable breeding places [illegible] the high temperature.

2) males have been captured

3) but no high catch of either sex could be made during the period by any method known

Perhaps it may be stated that during the adverse season the species maintains itself at the expense of the individual and as stated by Russel and Rao the adult A. gambiae like A. culicifacies probably lays only one batch of eggs during the season and dies after a short period of existence.

Rainfall: Rainfall affects the adults in their longevity, and also provides better facilities for breeding, by the formation of pools. Formation of pools depends upon the initial rainfall and subsequent frequency of occurrence.

Seasonal A. gambiae curve and rainfall, if studied, would indicate:

i) that there is increased prevalence after the start of rains
ii) that the general peak is reached only during the rainy months.

The observance of Sporozoites during this period indicates that the mosquitoes are able to live sufficiently long to complete the sporogony cycle.

Pools are very necessary for A. gambiae to breed. These pools are formed by the rains. To form pools a certain amount of initial rainfall is necessary, first to soak the soil and then to form the pool. About 150mm of rainfall would create favourable conditions for pool formation. Another point to be considered is the interval between any two rains. If the interval is too long then the pool formed would tend to dry up. Along with such drying larvae and eggs would dessicate. All these factors would adversely affect prevalence.

The daily rainfall, and collection of adults and larvae indicates that the extent of Anopheles gambiae in the Nomads' tents is governed by the presence of rain pools during the rainy months of July, August and September. During this period a long interval such as the one that occurred between the 6th and 16th and again 16th and 30th of September 1957 tend to dry up the pools and consequent reduction in the output of the adults and hence their lower prevalence in the tents.

It was already stated that the rainfall extends over a much longer period in the south and is gradually lessened as one proceeds north. Hence favourable conditions for the breeding of

A. gambiae occurs earlier in the season in the South. The 150mm rainfall threshold is reached earlier in the south (Vide Map IV).

A larval survey carried out in the Roseires area in June 1958 indicated the presence of A. gambiae larvae in a stagnant pool with hoof marks of cattle and foot prints of man, when the 150mm threshold of rainfall was crossed, but similar surveys carried out in the same area in 1959 yielded neither larvae nor adults confirming perhaps, the observation of previous year that as the required threshold of 150mm rainfall was not crossed in 1959 no mosquito collections could be made.

At about the same time however mosquitoes both adults and larvae could be captured in the Bonj area 200 miles south on the fringe of the 'Sudd' region.

Relative humidity: A high relative humidity is observed only during the rainy period.

A higher humidity favours longevity of the mosquito and also favourable conditions for transmission. Observation of sporozoites during this period confirm this point.

A careful perusal of the figures recorded at 2 p.m. indicates that while in Sennar the average relative humidity never went over 60%, it did go over 60% for two months in the Roseires area and for four months in the Kurmuk area.

Evaporation: The Piche figures indicate a comparatively low rate of evaporation only during the months of rainfall. Further a perusal of the figures furnished for the three places in the project area indicate that while in the Kurmuk area the figure is less than 10mm during the months of rainfall, in the other two places the earlier period of showers i.e. April, May and June do show an evaporation rate higher than 10mm. This indicates the high drying capacity that exists in the area inspite of the rain, during this period.

This explains in part that while anopheline breeding in rain pools may occur it does not continue in Sennar and Roseires area during the earlier months as it does in the more southern Kurmuk area.

Wind direction: From November to March the direction of the wind is mainly southwards, while from April to October it is directed towards the north. The wind speed is low during the months of August and September and highest during the month of June.

The prevailing south to North wind may be of significance in the passive transportation of A. gambiae.

The Nile: The hydrology of the Nile is interesting in the study of the bionomics of A. gambiae. There are two seasons, the flood and the rest. The peak flow is in August and September. This flow is about 16 times that of its lowest stage. Over half the total volume for the year passes in the 2½ months mid-July to September.

During the flood the Blue Nile discharge may rise upto sixty times that at low river. The White Nile on the other hand is much more steady in that its discharge during flood bein only three times that at low season.

Large low-lying areas near the Blue Nile river, get flooded during the peak flow and remain flooded until the river falls low. During the peak time and subsequent times when pools are left by the receding river ample facilities are created for the breeding of A. gambiae.

During the period of observations reported in this paper the Down stream levels recorded near the Sennar dam shows wide variations between the year 1957 and '58.

The flood remaining for a longer time in 1958 delayed the formation of the pools and thus affected the breeding and prevalence of A. gambiae.

2. RESTING PLACES.

[illegible] the mosquitoes gambiae captured were from human dwellings either in the villages or in the tents of the nomads in the bush or in the seasonal crop huts in cotton plantation or other cultivated areas. A few were also captured from cattlesheds, which are relatively fewer in number also.(vide chart I). The Eaves, in the village 'tukul' or house furnish the best resting spot of the species. The cotton plantation summer huts gave a very high prevalence of the species. The nomadic tents were made either of coarse wool or palm leaf mats. Collections in this type of shelter are usually nearly cent per cent. Besides the roof of the tent forming good resting places for A. gambiae many other spots for resting are found in the large or small utensils, leather bags, woollen rugs used as curtains etc.

Besides what is stated above other resting spots are household articles, utensils, furniture and the 'zeer' a mud pot used for keeping drinking water.

In one instance during the month of March about noon adults were captured from the floor of a 'tukul' (there is usually no made-out-floor in a Sudanese 'tukul' and so the floor in many cases looks just like any other cracked clayey soil outside the house).

3. MAN-BITING HABITS.

The precipitin tests of Anopheles gambiae reals indicate that only twenty-three out of seventy-nine or twenty-eight per cent were positive for human blood out of those collected from the nomads' tents. The collections from the village had 75% (250 out of 333) positive for human blood. In the cotton pickers camp 89% (forty-three out of forty-eight) contained human blood, while in certain villages in the months of October and December the percent positive for human blood was very low four out of sixteen or twenty-five per cent and five out of forty-eight or ten percent.

4. HOUSE FREQUENTING. Anopheles gambiae was collected, dusted with printers' gold dust and released in the area captured. The next day attempts were made to recapture them (Table IX).

As with a very few exception all the human dwellings were searched with Pyrethrum spray the 14% recapture represents the extent that return to the house.

It is also noteworthy that mosquitoes were also recaptured in houses other than that in which they were released.

5. MORTALITY RATE.

The results of the gold dusting experiments indicate that only 14 or 15% of the mosquitoes return to the village of release. Does the remaining 85 or 86% represent mortality? Russel concluded so in the case of A. culicifacies in India.

Also our repeated failures to obtain dead mosquitoes in sprayed premises may confirm this point, that mortality occurs more in the outside than inside the house. This perhaps can also be concluded from the comparative absence of larvae in the area under Dieldrin as also from the satisfactory control of malaria attained in the area.

6. POSSIBLE INVASION OF THE SPECIES FROM THE SOUTH.

It was stated that the 'Sudd' region is in the central Sudan, where the area is swampy.

The rainfall starts early in the south and lasts for a longer period. So as rain occurs in the north progressively from the south, the threshold of rainfall of 150mm is reached at various times; so, when conditions favourable for A. gambiae exist in Roseires, similar condition may not exist at all at Sennar.

Concurrent surveys made at roughly 50 miles distant from Sennar southwards showed that no adult could be captured by

Pyrethrum Spray at 9 p.m. and 4 a.m. in all the places except Bong, where adult and larvae could be captured. Bong is in the fringe of the 'Sudd' region.

This might perhaps indicate that suitable conditions exist for the breeding of A. gambiae in the pools near about the swamp about the 'Sudd' region, but with the occurrence of the rain there is an 'invasion' of this species to more favourable areas created by the rain proceeding and increasing in intensity from south-northwards. This might progressively increase the output of adults in the area invaded.

Further the movement of the nomads from south-northwards pitching their tents at short distance during the season of early rains possibly gives a chance for the A. gambiae to live also a highly nomadic life to go to and fro with them. I mean there is an 'ebb' in its area of prevalence and a 'fall' backwards.

Such 'ebbing' and 'falling' may also take place from the riverian tracts especially from such rivers that go into pools during summer affording ideal conditions for A. gambiae output.

The wind direction from south to north at this time may also help in the dispersion of the species.

7. SUSCEPTIBILITY OF THE SPECIES TO DIELDRIN AND DDT

High susceptibility has been observed to Dieldrin and also DDT. The MLC for Dieldrin is 0.08 and 0.11 as recorded in Wad El Ageili and Kurmuk respectively. It is 0.27 for DDT as recorded from specimens collected from the former place.

8. FACTORS THAT FACILITATE MALARIA TRANSMISSION BY A. GAMBIAE IN THE AREA.

1) The clayey soil in the central part of Sudan, as represented in the Blue Nile Province being highly impermeable to water, creates pools even with a low rainfall. Nevertheless pools lasting for the necessary period of aquatic stages of A. gambiae are generally available only after an initial rainfall of 150mm.

2) Formation of pools give rise to a high output of A. gambiae, not perhaps necessarily higher than that which happens under summer conditions and the higher humidity present at this time favours longevity sufficient for malaria transmission.

3) A high anthropophilic index (75% of feeds examined were on man) has been recorded in the area. The comparatively lower percent of feeds in the nomads may be largely facultative in view of the very large number of cattle population that exist with the nomads, usually outnumbering the human population.

4) Nomads scatter themselves in the bush near settled villages within flight range of A. gambiae.

5) The higher proportion of cattle always promote a reservoir of food for A. gambiae, which has the dual facility of feeding on man or the cattle and to the extent it gets the repeated contact on man required for successful transmission of malaria, malaria transmission may occur from nil to a high degree.

6) Sporozoites have been observed in A. gambiae during the months of August to November. In both nomadic settlement and settled village, Oocysts have been seen in February in a cotton plantation.

7) With favourable conditions for breeding and longevity provided during the rainy season coupled with high man-biting rate, and a higher humidity, transmission becomes possible only during the rainy period.

At other seasons transmission is very unlikely although a high prevalence may be witnessed in conditions favourable for breeding and output, but not for longevity.

Summary

Certain habits of A. gambiae observed in the Sennar and Fung Districts of the Blue Nile Province of the Republic of Sudan is given. The environmental factors that go to make the species a good vector in the area is detailed to the extent observed. It is concluded that A. gambiae transmits mostly during the period of rainfall, and that high numbers present during the summer months are not epidemiologically significant. The species is highly susceptible to Dieldrin and DDT at present.

Acknowledgement

I am greatly indebted to Dr. M.A. Farid, Senior Regional Malaria Advisor, Eastern Mediterranean Region, for first suggesting the writing of this paper and to Dr Roy Chowdhury the WHO Senior Advisor and Team leader of the Pilot Project, Sennar, Sudan for the excellent conditions afforded for work both in the field and laboratory, for making the analysis possible, as also to all members of the Team both National and International and in particular to the able assistance rendered by Usman Eff Abdur Nur, the National counterpart to the Entomologist and his field and laboratory staff.

Table I
Meteorological Data
Sennar

Month	Mean Temperature Average	1958	Rainfall Average	1958	Relative humidity 8 AM Average	2 PM	1958	Evaporation (Piche) Average	1958
Jan	25.0	25.5	-	-	46	34	16	15.4	16:7
Feb	26.1	24.7	-	-	41	28	14	17.7	18:6
Mar	29:1	30:0	-	-	33	30	23	20.3	22:2
Apr	32:0	33.7	3	6	34	35	-	20:2	24:6
May	32:4	33.9	24	Tr	45	35	23	17:0	22:9
Jun	31:2	30:9	60	7	70	49	33	14:2	16:9
Jul	28:4	27:8	119	250	76	71	54	8.5	8:6
Aug	27:4	27:1	160	313	81	74	54	5:6	6:3
Sep	28:2	28:5	70	37	75	70	45	6:5	7:7
Oct	29:9	30:5	17	2	58	51	26	10:5	13:1
Nov	28:4	29.9	1	-	46	39	20	15:1	17:1
Dec	26.0	27.1	-	-	48	39	20	15.0	16.4
Total	28.7		454	685	54			13.8	

Roseires

Jan	26:2	28:3	-	-	41	41	35	12.2	12:4
Feb	27:5	26:3	1	-	[illegible]			[illegible]	
Mar	29:8	31:1	2	-	27	24	11	16:6	17:6
[illegible]			[illegible]		31	39	21	16:2	15:3
May	31:0	31:4	62	61	48	48	26	12:9	12:5
Jun	28:6	27:6	128	53	66	77	50	8.5	5:5
Jul	26:8	26:7	186	199	79	84	61	5:2	3:8
Aug	26:4	25:8	222	108	83	89	65	4:2	3:0
Sep	26:9	27:2	155	62	80	82	51	4:6	4:6
Oct	28:0	28.7	31	35	70	74	37	6.8	6.5
Nov	27:8	29:1	5	-	49	52	24	10:9	10.3
Dec	26 5	27.8		Tr	42	45	21	12.5	11.4
Annual	28.1		808	525	54			10.5	

Kurmuk

Month	Mean Temperature	Rainfall in mm	Relative Humidity 8 AM	2 PM	Evaporation
Jan	29.9	-	29	22	13:5
Feb	29:9	-	26	18	13.5
Mar	32:9	-	25	15	14:9
Apr	30:9	99	53	31	8.2
May	27.6	157	70	46	4:9
Jun	25:7	100	81	62	2:6
Jul	24:9	194	82	61	2.1
Aug	24:3	198	85	64	2:1
Sep	25:3	145	84	66	2:5
Oct	26:1	117	73	45	3:7
Nov	27:5	33	48	30	7:2
Dec.	28.4	-	47	27	10.3

Table 2

Population

Province		Population
Bahr el Ghazal	219,751	991,022
Blue Nile	142,138	2,069,614
Darfur	495,269	1,328,559
Equatoria	198,121	903,718
Kassala	340,665	941,379
Khartoum	20,971	505,157
Kordofan	380,546	1,762,760
Northern	477,074	870,765
Upper Nile	236,180	889,700
- Total -	2,505,805	10,262,674

Table 3

Seasonal prevalence of Anopheles gambiae adults

Month	Anopheles gambiae collected per structure					
	Average All shelters (tube)	Day-time Village (flit)	Night Vill. 9 Pm & 4 Am	Day-time Village	by tube Nomads	Cotton Pickers
Jan	0.4	-	-	0.03	2.2	-
Feb	0.9	0.0	-	0.0	1.1	4.7
Mar	0.8	0.0	-	0.0	0.5	3.2
Apr	0.2	0.06	-	0.0	0.5	2.0
May	0.04	0.0	0.0	0.0	0.3	0.0
Jun	0.005	0.1	0.5	0.0	0.04	0.0
Jul	0.05	0.9	1.8	0.0	0.7	-
Aug	2.3	6.0	2.5	1.2	4.3	-
Sep	3.2	5.0	-	1.0	4.9	-
Oct	1.3	2.3	2.5	0.02	2.2	-
Nov	1.4	0.9	1.3	0.0	-	-
Dec	0.4	1.0	0.7	0.1	0.7	0.5

Table 4

Seasonal prevalence of Anopheles gambiae larvae.

Month	Number of searches	Number of Larvae	Number per 100 dips
January	103	175	18
February	104	93	9
March	122	14	1
April	95	11	1
May	112	16	1
June	96	6	1
July	56	24	4
August	45	103	20
September	40	115	30
October	37	101	30
November	41	8	2
December	57	5	1

Table 5

Months of Mean Temperature over 30°C

Place	Months			
Sennar		April	May	June
Roseires		April	May	
Kurmuk	March	April		

Table 6

Anopheles gambiae prevalence during the coldest period.

Place	Months	Anopheles gambiae per shelter		
		Villages	Nomads	Cotton pickers
Sennar	April	0.0	0.5	2.0
	May	0.0	0.3	0.0
	June	0.04	0.04	0.0
Kurmuk	March	0.0		
	April	0.0		

Table 7

Stomach and Ovarian examination of A. gambiae dissected

Month	**Stomach				Ovar (Chri stophers)					Total
	I	II	III	IV	I	II	III	IV	V	
March	72	76	26	19	9	47	104	26	7	193
April	21	25	-	-	6	20	15	5	-	46
May	8	15	-		4	5	9	3	2	23
June	8	10	-	-	3	3	4	5	3	18

** I Fresh blood III Ovary well developed
II Partially digested IV No blood and no ovarian development

Table 8

Sex Proportion of A. gambiae

Month	Number captured	
	Male	Female
March	14	66
April	2	22
May	3	8

Table 9

Gold dusting experiments

Anopheles gambiae

Date 1959	Released	Number recovered			
		Dead	Alive	Total	% Recovery
4th March	80	4 (5PM) 4 (8AM)	2 3	13	16
17th March	57	1 (5PM)	1 5	7	14

PART II

FURTHER ENTOMOLOGICAL DATA ON A. GAMBIAE

CONTENTS

ANOPHELINE LARVAL VECTORS IN THE MALARIA PROJECT AREA OF THE
BLUE NILE PROVINCE - SUDAN

I. INTRODUCTION

1.1 The general distribution and taxonomy of anophelines in Sudan has been dealt with in the accounts on mosquitoes of the Ethiopian region by Evans (1938), Hopkins (1941), and Edwards (1941). Some twenty-six anopheline species were recorded from the country (Lewis-1945).

Within the Sudan-6 Malaria Eradication Pilot Project Area, extending to cover the Blue Nile Province, nine species were recorded so far. These are:

A. gambiae Giles, A. funestus Giles, A. pharoensis Theobald, A. nili Th. and A. coustani Laveran, A. squamosis Th., A. maculipalpis Giles, A. pretoriensis Th. and A. rufipes Edwards. Of these nine species A. gambiae and A. funestus are supposed to be the primary malaria vectors in the area. No other species could be incriminated in malaria transmission in the area as yet. However, A. pharoensis is suspected as a secondary vector in view of what is reported from neighbouring regions.

II. SEASONAL DENSITIES

The favourable breeding period for anophelines common in the project area [illegible] somewhere in August following the rainy season, with the peaks of populations variable according to species concerned.

Information on the seasonal abundance of A. gambiae, indicate that this species is present throughout the year in Homra camps, but in seasonal occurrence in villages and cotton under canal during August through April. There are two peaks for the population of this species, (a) a general peak all over the area occurring somewhere during the period August through October, and (b) a second more localised peak occurring during the months of November through February or March. The former peak is dependent on rains which are general during that period, the latter is dependent on local conditions particularly in relation with cotton irrigation.

Larval surveys revealed the higher breeding index during the period from August through October.

Various species differ in their seasonal abundance as figured out from the following data (Table I).

TABLE I

SEASONAL DENSITY OF SOME ANOPHELINE DURING 1957 IN CHECK AREA

SPECIES	Adult-Density Index of Rate Per Man/Hour From Dwellings		
	August	September	October
A. gambiae	0.4	2.3	2.8
A. pharoensis	0.3	0.4	0.3
A. squamosus	0.1	0.1	0.0
A. coustani	0.3	0.0	0.0

From Table I, it is clear that while A. gambiae shows a rise in population during September, A. pharoensis maintains more or less the same level throughout the season.

II. REDUCTION IN ANOPHELINE DENSITY IN RESPONSE TO SPRAYING

The extensive post operational Anopheline surveys indicate very clearly that Anopheline densities for both adults and larvae drop considerably as a result of insecticide application. Although Anopheline eradication is by no means the target of the project, yet such drop in population density is necessary as an essential element in antimalaria work. ((Macdonald 1957). The reduction in Anopheline density indicates simultaneously the effectiveness of spraying and the success of the campaign in general.

IV. RESTING HABITS

A. gambiae was found to prefer human dwellings than cattlesheds for resting. They rest on the walls and roofs of such huts as well as inside, behind or underneath household articles of various nature. An analysis of the catch of this mosquito from the check area from different resting sites within the conical type of huts (No this) is given below (Table II).

TABLE II

A. RESTING CATCHES FROM DIFFERENT PARTS OF HUTS AND THEIR RATIO OF THE TOTAL CATCH

SITUATION	PERCENTAGE OF CATCH
Roof	6.0
Walls	25.4
Junction between roof and wall	62.0
Other situations	6.6

These figures indicate that A. gambiae has a definite preference for the sides of the junction between roofs and walls of huts as their resting places.

V. BITING HABIT AND HOST PREFERENCE

A. gambiae is an endophagic mosquito; however, exophagy is also encountered. Although this species rests indoors (i.e. endophilic) yet it could be collected elsewhere from outdoors particularly from artificially constructed outdoor resting places (e.g. pits dug nearby breeding places).

The biting activity, although a variable element subject to both environmental factors as well as to the physiological rhythm of the mosquito, yet is of utmost interest in antimalaria work. Comparison of the biting habit of the mosquito in the sprayed and check areas might lead to spotting of any behaviouristic avoidance upon emergence. The biting rate also helps to figure out the rates of inoculation and reproduction of the malaria in activity among a certain community (Macdonald 1957). At present a comparative study of the indoor and outdoor biting rates of A. gambiae in the sprayed and check areas is being carried out. Rates available at present are those obtained in September from one station of the pilot study zone (i.e. Sanyo), and for Gevel Moya one of sprayed stations of the project area outside the pilot study zone, are given in the following table (Table III).

TABLE III

THE BITING RATE FOR A. GAMBIAE IN THE PILOT STUDY ZONE CENTER (P.Z.)

AND SPRAYED PROJECT AREA (S.A.)

DURING DECEMBER 1959

PERIOD OF NIGHT	Biting Rate Indicated by No./Man			
	OUTDOORS		INDOORS	
	P.Z.	S.A.	P.Z.	S.A.
8th. Hour (from 8-9 pm)	0.0	1.5	-	3.6
9th.	0.0	1.0	0.7	3.5
10th.	0.0	1.0	1.0	3.5
11th.	0.0	0.8	1.7	1.8
12th. (12 midnight to 1 a.m.)	0.3	1.8	1.0	2.8
1st. Hour (1 - 2 am)	0.3	2.3	0.7	2.3
2nd.	0.3	3.0	0.3	1.8
3rd.	1.0	2.5	-	2.8
4th. (4 - 5 am)	2.3	3.3	0.7	3.6

From the foregoing table it is noticed that A. gambiae practises both exophagy as well as endophagy, it enters to feed even within sprayed structures. Result also indicate that the biting rate of A. gambiae (and hence its density) in the sprayed project area outside the pilot study zone, is much higher than within the latter. Study is in progress to analyse the biting activity of this vector as well as its various other activities.

A. gambiae proved to be anthropophilic; 84 per cent of the blood smears collected from this species in the project area and tested by the Lister Institute, turned out to be of human source.

VI. BREEDING HABITS

Larvae of A. gambiae were collected from various types of breeding places at different times of the year. It was collected from river pools and streams during April through June, and from rain pools during October through November. Also it was found to breed in the foot and hoof prints of animals around different water holes (e.g. hafirs and the like) where such animals drink. Larvae have also been collected from drains leading to such hafirs following rains directly.

As far as rain pool breeding is concerned, it was noticed that an initial rain of about 150 mms. is essential for the formation of the suitable breeding places in the clay soil of the project area. Further continuance of such breeding places is dependent on the succession of rains. Casual breeding places together with the more stable ones, which usually beside nearby waters, help this species to overcome the season of adverse conditions (i.e. cross over the dry season).

VII. RESIDUAL EFFECT OF INSECTICIDES:

Under conditions prevailing in the project area dieldrin at the rate and spacing chosen proved to stay effective against anopheles throughout the suspected transmission season (July through October). Information about the residual effect of insecticides is sought through both survival rate studies as well as bioassaying techniques. Results of the survival rate tests for A. gambiae captured from sprayed huts appear in the following table (Table IV).

TABLE IV

SURVIVAL RATES OF A. GAMBIAE RECOVERED FROM DID SPRAYED HUTS

PERIOD	TIME ELAPSED SINCE SPRAYING	NUMBER A.GAMBIAE TESTED	SURVIVAL RATES 24 HOURS
1958			
August	2 months	80	0.0
September	3 months	103	0.0
October	4 months	9	11.1
1959			
August	1 month	177	0.0

Study along the same line is in progress at present. Bioassay tests under field conditions with this species (A. gambiae) will be carried out in the check area in experimental huts. Such study will cover a comparison between the residual effects of DDT, DID and BHC Similar studies are planned for Sennar under laboratory conditions pending the success in raising an A. gambiae colony in the insectarium, now under construction.

VIII. TRANSMISSION SEASON

The main malaria transmission season in the area of the project is limited to and extends little beyond the rainy season. It is directly correlated with both the amount of rains on one hand and the density as well as the biotic potential of the concerned vector on the other. Infected A. gambiae were only encountered during September through November. None of the other anopheline species common in the area were found infected so far. In the following table results of dissections carried out in the check area for 1957 are included. (Table V).

TABLE V

INFECTIVITY OF SOME COMMON MOSQUITOES DURING 1957 IN THE CHECK AREA

Species	Dissected and Positive (between brackets) during					
	June	July	August	September	October	November
A. gambiae	10(0)	5(0)	31(0)	94(7)	153(2)	110(1)
A. pharoensis	-	-	39(0)	68(0)	8(0)	1(0)
A. rufipes	21(0)	-	-	10(0)	20(0)	1(0)

Epidemiological commentary on the infectivity rates*

Assessments carried out in the check area revealed the existence of a long dry period, free of malaria transmission, causing the reservoir to drop to its annual minimum level (June through August). The noticed increase of sporozoite rate (0.043) during September is attributable, therefore, to the prolongation of the life span of the vector as a result of favourable environmental conditions that prevail during such period. In spite of the decrease in longevity and density of the vector during October, a high sporozoite rate is again recognized in November. This is because by then most of the earlier September infections had passed the incubation interval (prevalence of falciparum) and thus became already infective for vectors towards end of October. Shortening of life span and decrease in density of A. gambiae in November are partially compensated by the enlarged and more suitable reservoir.

IX. PLAN FOR THE FUTURE

Studies planned for the future and recommended by WHO (1959) for the present attack phase of our programme, will cover the assessment of:

(a) The response of vectors to insecticides.
(b) The persistence of residual deposits, in the area under spraying.

It is hoped that a surveillance system will be expanded to cover the whole pilot project area before discontinuation of spraying. The Government has also agreed in principle to carry out a pre-eradication survey study by mid 1960 to develop a comprehensive plan of operation for the implementation of a future malaria eradication programme including the whole country.

X. CONCLUSIONS

A review of the data presented in this report indicate that:

1. No physiological resistance has emerged so far in the number one vector namely A. gambiae within the project area. This mosquito is still very susceptible to both DDT and DLD. In 1958 the LC_{50} were found to be 0.06 for DLD and 0.27 for DDT.

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* Epidemiological comment initialed by Dr. W. Wernsdorfer, team leader.

2. The residual effect of DLD under prevailing conditions extends for enough time to cover the anticipated main transmission season (July thru.Nov.) in the area.

3 A. gambiae has developed no behaviourisms to avoid success against DLD in the sprayed-project-area so far.

4. The density of A. gambiae has dropped considerably as a result of spraying. This achievement, together with the drop in average longevity of adult females, resulted in significant reduction in transmission of malaria in the area.

5. A. gambiae practises both exophagy and endophagy. The biting rate (and hence its density) within the pilot study zone is much less than in the outer project sprayed area.

XI. LITERATURE CITED

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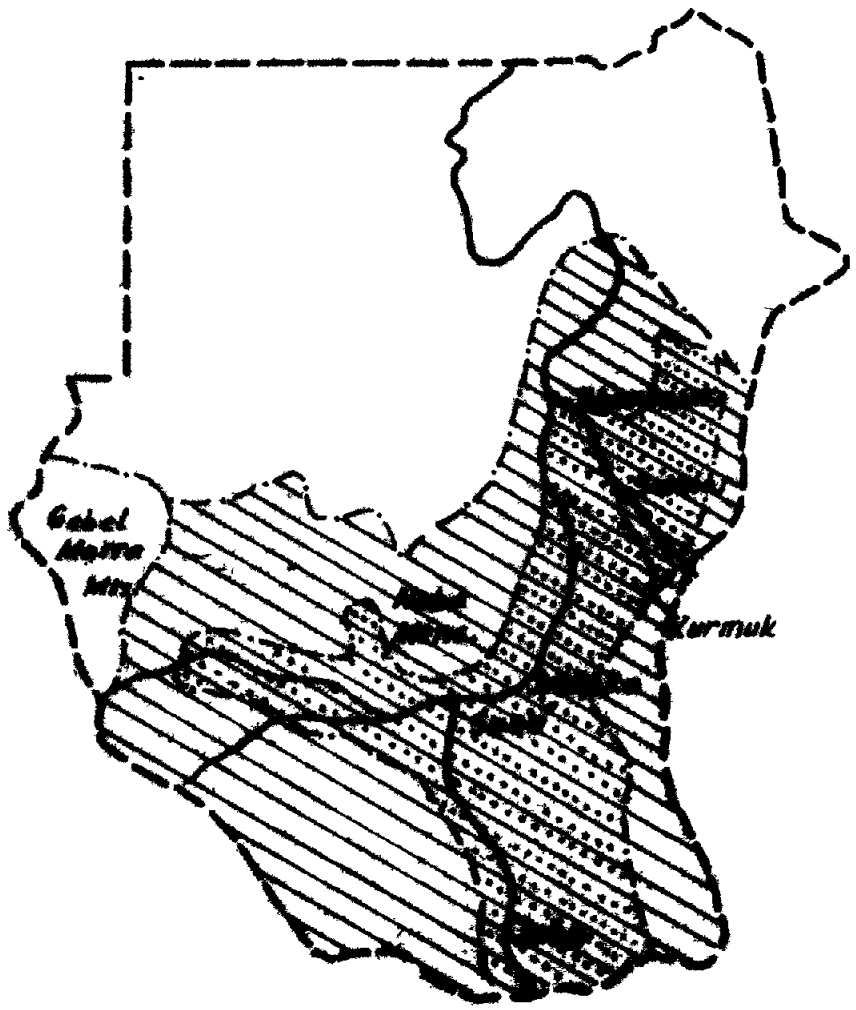
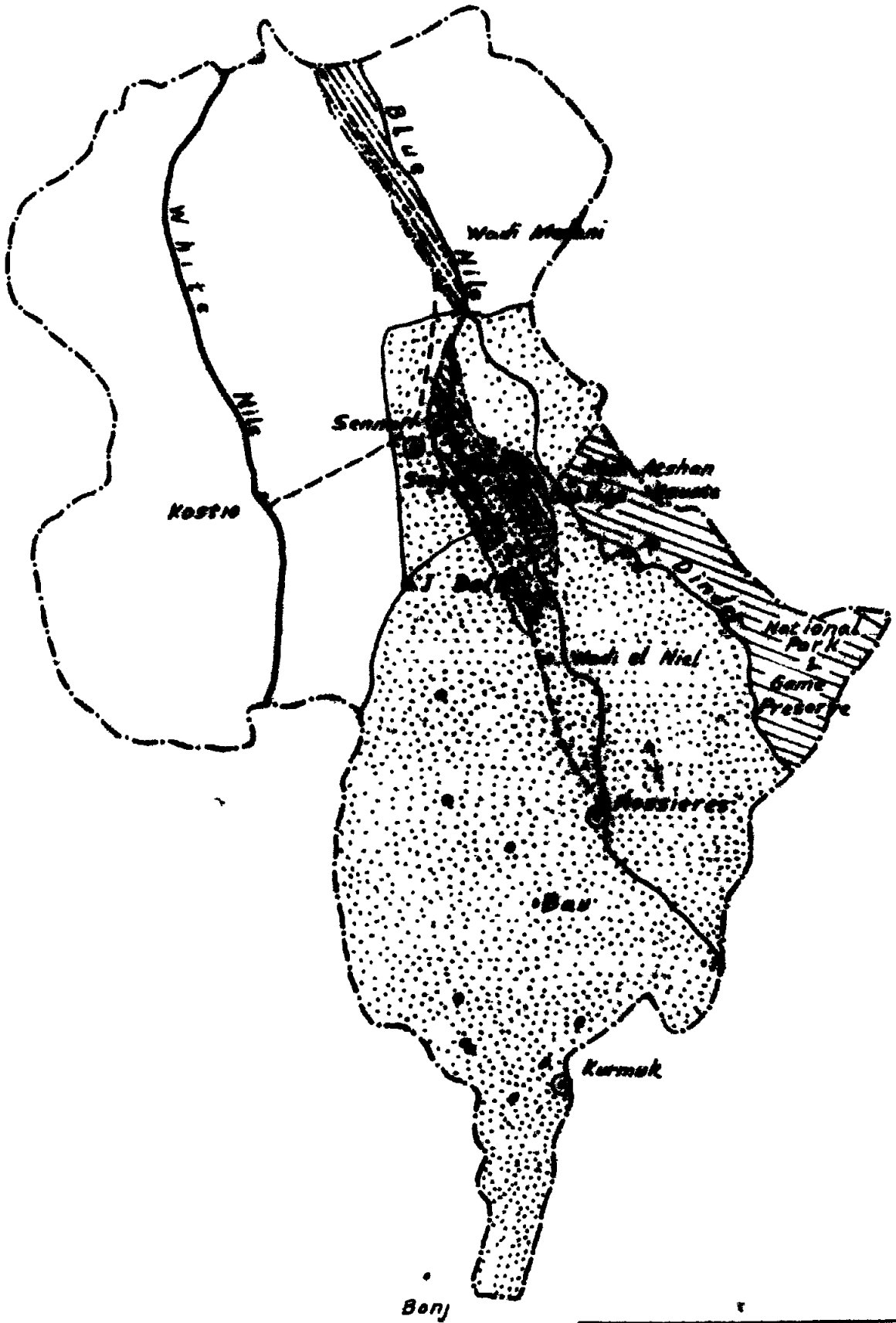
MAP OF SUDAN



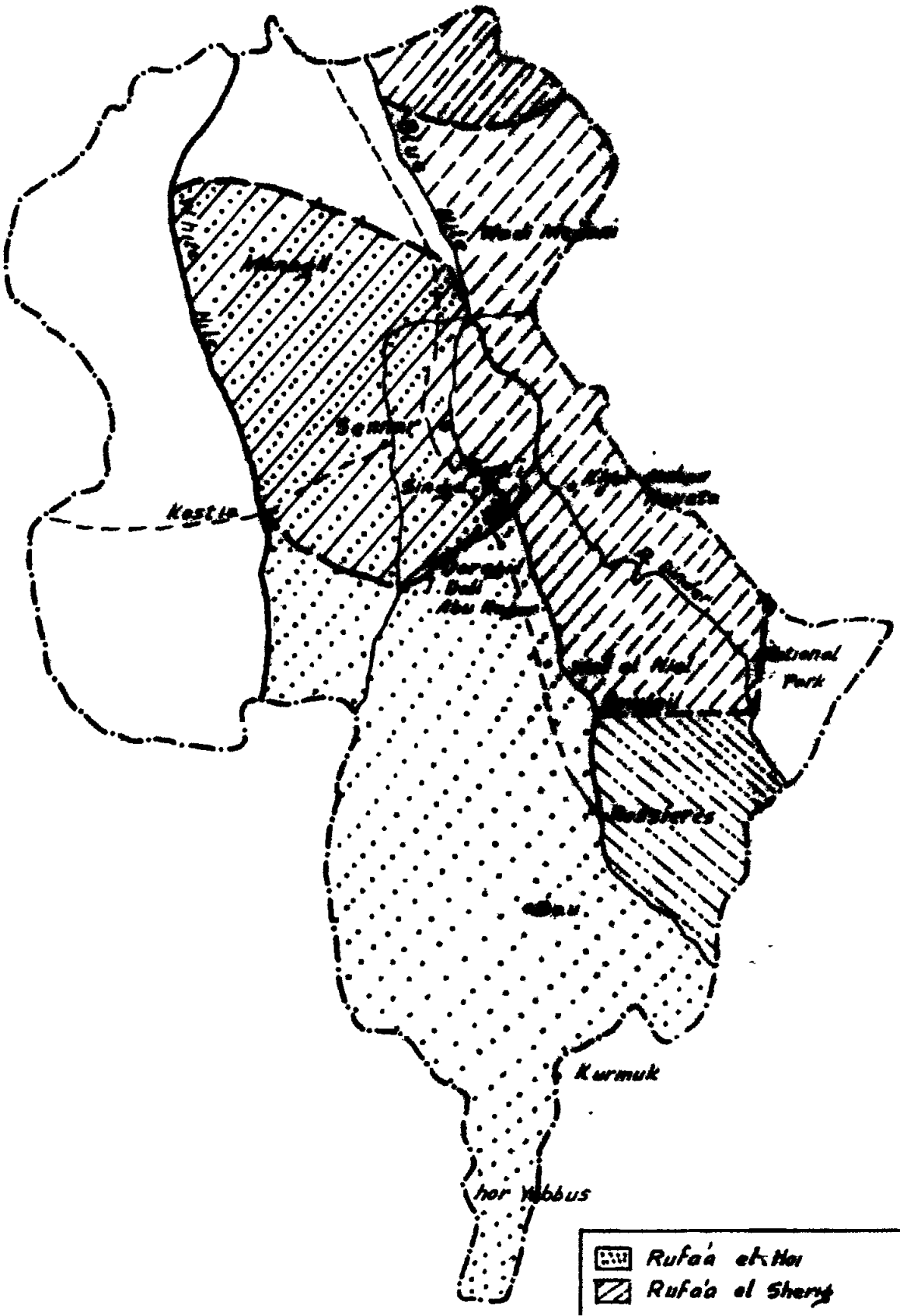
Clayey area

Water - shed

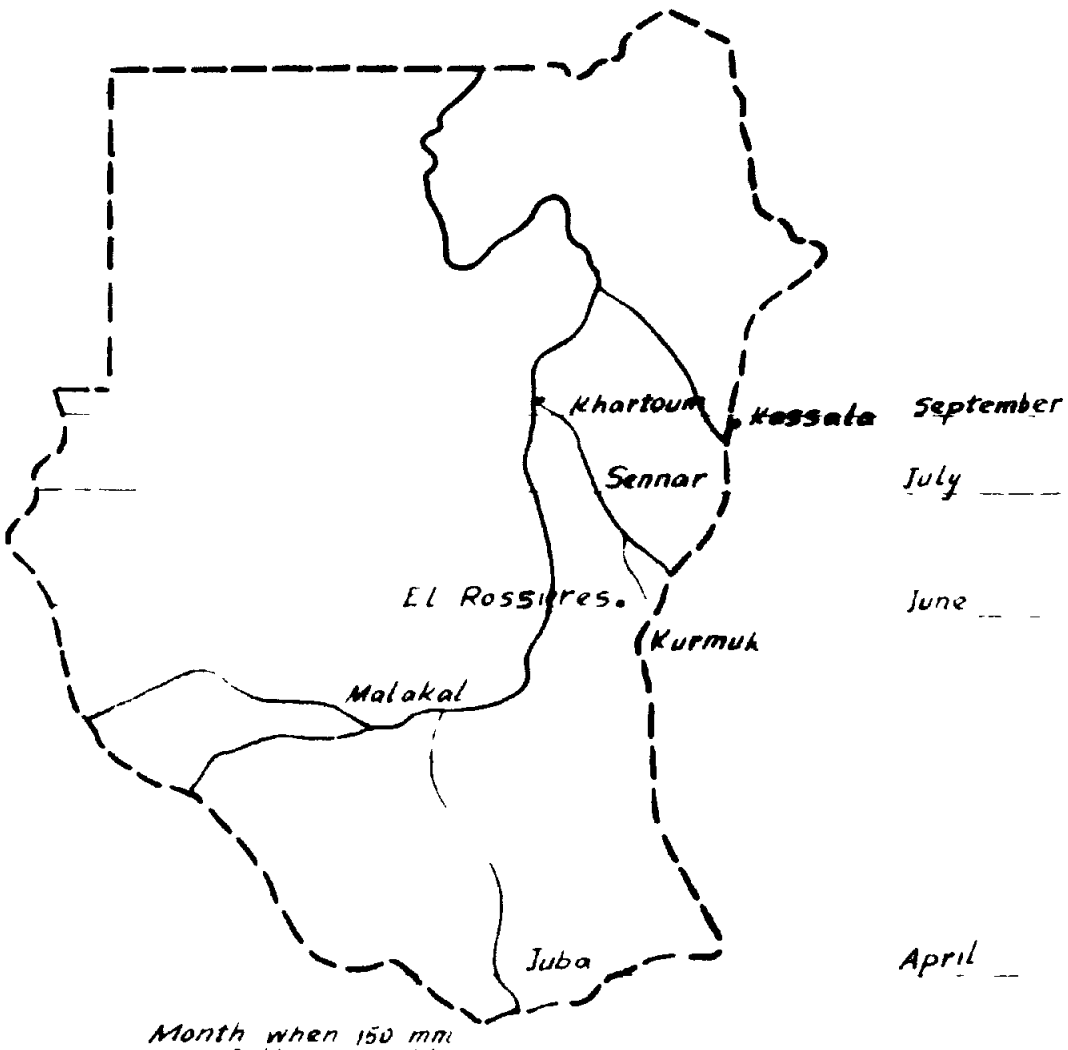
WHO MALARIA CONTROL PROJECT AREA

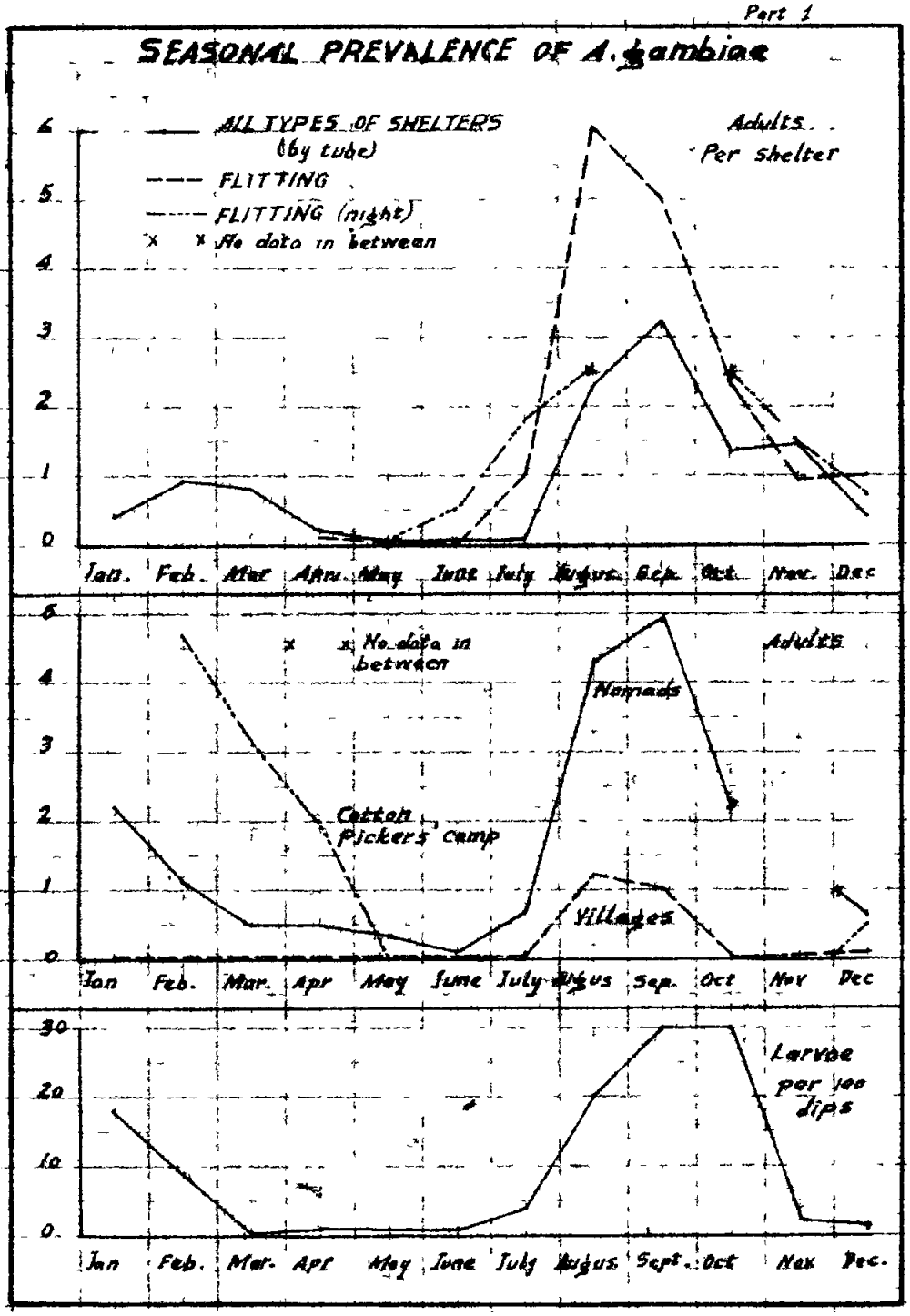


MAP OF BLUE NILE PROVINCE
SHOWING
THE WHO MALARIA CONTROL PROJECT AREA



MAP OF SUDAN

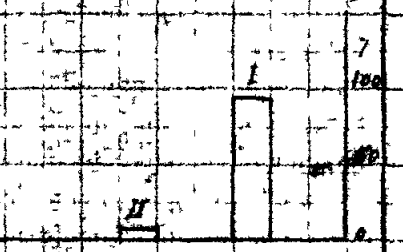

Khartoum
Kassala
September
Sennar
July
El Rossieres.
June
Kurmuk
Malakal
Juba
April
Month when 150 mm Rainfall threshold reached


SEASONAL PREVALENCE OF A. gambiae
ALL TYPES OF SHELTERS (by tube)
FLITTING
FLITTING (night)
x x No data in between
Adults Per shelter
Jan. Feb. Mar Apr. May June July August Sep. Oct. Nov. Dec
x x No data in between
Adults
Nomads
Cotton pickers camp
Villages
Jan Feb. Mar. Apr May June July August Sep. Oct Nov Dec
Larvae per 100 dips
Jan Feb. Mar. Apr May June July August Sept. Oct Nov Dec.

Graph II

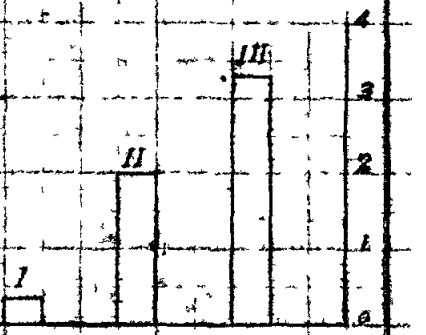
Part 1

TYPES OF SHELTER



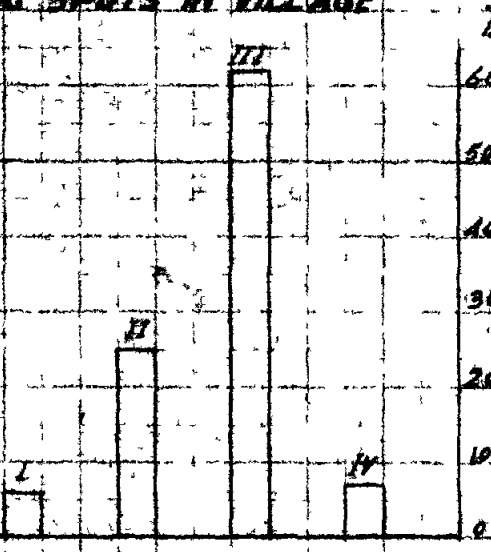
I Round dwelling
II Cattleshed
V. capture

TYPES OF DWELLING



I Village
II Nomads
III Cottonpickers' camp
No. per dwelling

RESTING SPOTS IN VILLAGE



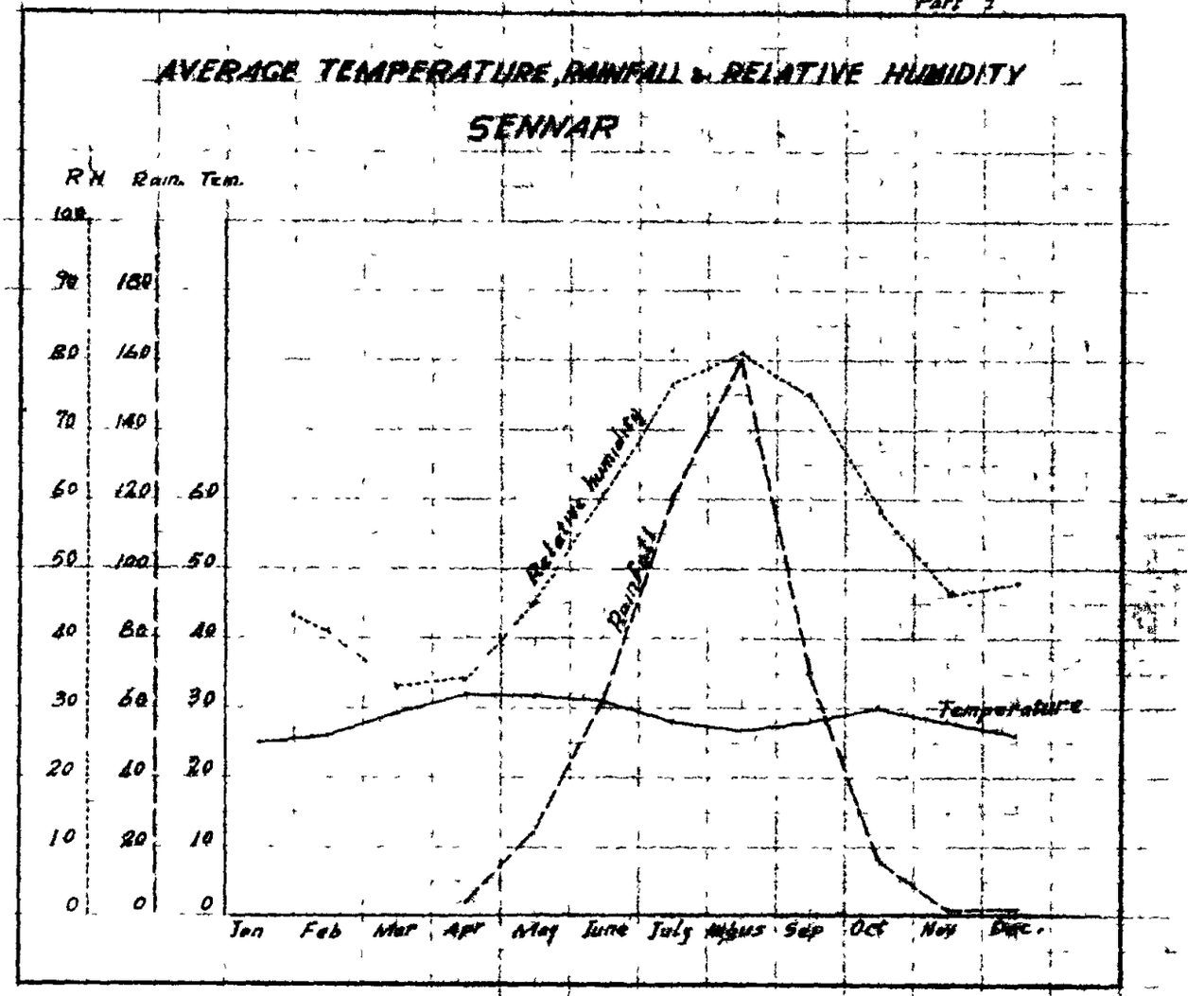
I Roof
II Well
V. capture
III Eaves
IV Others

RESTING HABITS OF ANOPHELES GAMBIAE

E N.

Chart I

EM/ME Tech 2/21
Part 1



Graph I