STUDIES ON THE BIOLOGY OF *ANOPHELES LETIFER* SANDOSHAM (DIPTERA, CULICIDAE) AND ITS RESPONSE TO RESIDUAL SPRAYING, CARRIED OUT IN SARAWAK, MALAYSIA.

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INTRODUCTION

ANOPHELES letifer Sandosham 1944, a member of the *Anopheles 'umbrosus'* group was first recognised by Gater (1935) who described it as *A. umbrosus.* Later he re-described it in 1941 giving it the name *A. letifer.* His manuscript apparently was lost in transit during the 1939 - 1945 war, and Sandosham (1944) assuming that publication had taken place described the species ascribing it to Gater. As Sandosham's was the first publication of the name *A. letifer,* he becomes the author of the name.

Reid (1963) described two new species closely resembling *A. letifer* and named them *A. collessi* and *A. whartoni,* forming with *A. letifer* and *A. roperi* the *'A. letifer'* sub-group. *A. whartoni* has been found in Peninsular Malaysia only, while *A. collessi* has been found in Sabah and Brunei and therefore probably occurs in Sarawak also. Up to the time of the present study, all specimens of the sub-group taken in Sarawak, have been identified as *A. letifer* and no *A. collessi* has been found.

The role of *A. letifer* in malaria transmission in Sarawak has been uncertain, although it is a vector of malaria in Peninsular Malaysia. Reid and Hodgkin (1950) found 0.3% and 0.7% sporozoite rates in 8411 and 4964 respectively, wild caught *A. letifer* in Peninsular Malaysia and spleen rates of 48-71% and parasites rates of 22-44% in areas where this species was predominant. In Sarawak, however, it has been suspected as a vector for sometime. Zulueta (1956) found 6 sporozoites in 3195 *A. letifer* dissected from Sarawak but these were later shown to be of non-human origin. From 1963 to 1966, 3725 *A. letifer* had been dissected by the entomology staff of the malaria programme, of which 7 were found with sporozoites, which were also confirmed to be of non-primate origin.

From about 1963, *A. letifer* was found to be the predominant, if not the only anopheline in some areas of proven local transmission, especially in timber camps and road construction sites in the coastal areas of the First and Second divisions of Sarawak. These activities are in the peat swamp areas for which workers come from other parts of the state and live in temporary structures. With the clearing of jungle, there is a high density of *A. letifer* and with an imported parasite carrier, local transmission had been known to occur time and time again, in the absence of the established vectors of Sarawak. Epidemiological evidence, therefore, is overwhelming in favour of considering *A. letifer* a vector of Malaria in Sarawak.

OBJECTIVES

The main objectives of the study were to know more about the biology of *A. letifer* in relation to its biting and resting habits, its seasonal prevalence and its response to residual spraying of houses with DDT.

MATERIALS AND METHODS

3.1 Study area

Although many observations had been made previously in various parts of the State during routine investigations of malaria foci, the main

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part of the present study was conducted at Kampong Bayor (Malaria code no. 144a/101) in the Balai Ringin area of Serian District of the First Division. It is along the main Kuching/Si manggang highway, about 100 km from Kuching and about 15 km from the nearest point on the Indonesian Kalimantan border.

Kpg. Bayor is a typical Iban village with a population of about 130 people living in two longhouses separated from each other by about 60 m. The people are mainly engaged in rubber and pepper cultivation and during the season, plant some wet and dry padi. They had pelamens (semi-permanent huts) in the pepper and rubber gardens which may be from 10 to 30 minutes walk from the main dwelling, where they may spend the working day or sometimes even over-night. During the padi planting season, they may construct sulaps (temporary farm huts) in the planting area in which they may spend varying periods of time depending on its distance from the main dwelling.

From about 1959, the area had been under regular spraying with DDT water dispersible powder at 2 gm/m^2 at six monthly intervals. In spite of this, malaria cases continued to be reported from the area, mostly imported cases from across the border with a few cases of local transmission every year.

The principal vector of Sarawak, *A. leucosphyrus* has never been collected from the area, but *A. letifer* is usually found in high densities with small numbers of *A. donaldi.* Kpg. Bayor was therefore found to be a suitable place for the present study.

3.2 Experimental huts

In order to study *A. letifer* behaviour, four experimental huts were constructed in Kpg. Bayor, each hut being about 60m from each other and from the main dwelling. The huts were built to stimulate the local housing conditions as far as possible, with floor of wooden plank, walls of cadjan (woven palm leaves) and roof of attap (wooven nipah leaves). The huts were 3m long by 3m wide with 1.8m walls and roof 2.4m at the highest point. The floor was raised 0.8m above ground level. Entry louvres 1.8m long and 0.6m high were fixed to the north and south walls. Window traps 0.3m x 0.3m x 0.3m were fixed 1.2m from the floor level, to the east and west walls.

Observations were made in the experimental huts on resting duration, resting position, indoor and outdoor biting, and response to residual spraying. For the observations, one or two collectors were placed either indoor or outdoor and collected mosquitoes biting them. Room kill was also studied by releasing wild caught *A. letifer* into the sprayed huts.

3.3 Duration of the study

The study commenced in early 1967 and after one year's observation one hut was sprayed with DDT and one hut was kept as unsprayed control, and observations continued till the end of 1969.

BIOLOGY OF *A. LETIFER*

4.1 Breeding habitat

In Peninsular Malaysia, Reid and Hodgkin (1950) found *A. letifer* breeding in swampy areas at least with some shade. They also reported a pH of 5.8 for breeding place water. In Sarawak, *A. letifer* is commonly found breeding in the dark brown peaty water as found in the swamps where they could be found large numbers in jungle clearings and at the edge of jungles, but seldom in the jungle itself the sister species *A. umbrosus* predominates. Larvae are usually found under shade but sometimes have been taken in water with no shade at all.

Samples of water from 19 breeding places of *A. letifer* were chemically analysed and found to be slightly acidic with a pH of 4.8 - 5.0. The salinity of the water expressed as ppm chloride was 7.o - 8.2 (for sea water being 30,000 ppm chloride) and the nitrate content, an indication of the organic content, expressed as ppm N was 0.05 - 0.175.

4.2 Seasonal prevalence

High densities of *A. letifer* have been found in almost every month of the year in Sarawak. At Kpg Murut (143b/153) high densities were found in the months of January, April, June and November in 1965. At Junggo Mawang (144a/103) high densities were found during February and March in 1965. In the study area at Kpg. Bayor, observations made for 3 years from 1967 are given in Table I and the rainfall figures for

TABLE I.

Number of *A. letifer* collected per-man-hour, indoor and outdoor, at Kpg.Bayor [144a/101], Serian District, Sarawak, from 1967 to 1969.

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1967	—	161.0 (1127)	11.8 (166)	4.4 (107)	6.3 (75)	4.2 (51)	1.1 (7)	0.8 (10)	0.6 (7)	3.8 (46)	8.5 (611)	34.7 (3313)
1968	53 (1018)	0.6 (15)	30.0 (625)	6.5 (119)	10.0 (63)	25.3 (303)	6.8 (82)	6.8 (82)	0.6 (7)	0.6 (10)	1.4 (17)	0.2 (1)
1969	26.7 (1282)	17.0 (204)	35.5 (1963)	19.3 (932)	16.5 (386)	1.9 (56)	4.3 (104)	2.0 (71)	6.5 (152)	9.6 (348)	12.4 (298)	4.5 (54)

Note: Figures in parenthesis represent the actual number of *A. letifer* collected.

TABLE II.

Monthly rainfall in inches from Balai Ringin, Serian District, Sarawak, about 1 km from the study area of Kpg. Bayor, for the years 1967 to 1969.

MONTH / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1967	13.37	12.67	20.22	13.21	13.47	5.26	2.47	4.42	8.99	9.46	12.50	12.15
1968	14.42	4.71	22.48	8.35	8.39	5.58	6.81	7.30	4.54	10.71	4.54	10.71
1969	8.44	9.26	8.50	2.93	10.44	4.49	5.87	15.60	4.84	12.85	8.97	24.79

the same period from Balai Ringin situated about 1 km from Kpg. Bayor are presented in Table II. Figure 1 shows the seasonal fluctuations with the rainfall and the dates on which the kampong was routinely sprayed. In the study area, high densities were found in December 1967, March and June 1968 and January to May 1969. There appears to be no correlation between the timing of the spraying and the high and low densities. The breeding places of *A. letifer* are perennial, water being generally available in the swamps, and high densities are maintained except during extreme drought when breeding places may tend to dry up. June to August may be considered generally dry months in these areas and *A. letifer* densities are also low during these period.

4.3 Egg laying

To determine the average number of eggs laid by a female, wild caught blood-fed *A. letifer* were kept in the laboratory for egg laying. Twentyfour females laid a total of 3768 eggs giving an average of 157 eggs per female, the range being 24 - 310. The exact time that these females fed was not known but they had all been collected before 10 pm which meant that they would have fed at most three hours before capture. In captivity all laid eggs between 40 and 54 hours after capture which showed that the gonotrophic cycle of this species was two days.

4.4 Resting habits

4.4.1 Resting position

Observations were made in the experimental hut before and after spraying on resting position where the mosquito had a choice of wall or roof to rest. The results are presented in Table III. Before spraying, of the 747 unfed *A. letifer* observed, about 20% rested on the roof and the other 80% on the wall, more or less evenly distributed at different heights. Of the 233 fed mosquitoes observed, about 40% rested on the roof and the rest fairly evenly distributed on the wall. This was somewhat unexpected as fed mosquitoes are usually found at lower heights than unfed ones. One month after spraying with DDT, of 347 unfed observed, 30% were on the roof and the rest on the wall as before. On the 63 fed ones observed, 19% were on the roof and the rest on the wall. Although disturbance by the collectors inside the hut may have been responsible for the mosquito to have moved on to the roof, indoor resting on the roof, especially when the roof is not very high should be of significance to the spraying programme.

4.4.2 Resting duration

Resting duration study was carried out by observing the mosquitoes resting inside the hut at 10 minute intervals. If a mosquito was observed a second time in the same spot, it was noted as resting between 10 and 20 minutes and if observed a third time, then between 20 and 30 minutes, etc. The results of these observations are presented in Table IV. Before spraying, 756 unfed and 362 fed mosquitoes were observed. The average time spent inside the hut by an unfed mosquito before feeding was worked out to be about 16 minutes and for fed mosquitoes, about 24 minutes, although a few fed ones had been observed to stay in for up to three hours. In the sprayed hut, the average time spent by 230 unfed *A letifer* was worked out to be 6 minutes and by 66 fed ones to be about 7 minutes.

Here again there is a definite possibility that a mosquito moved from its original resting place due to he disturbance of the observation. Therefore the average time spent by *A. letifer* inside the house would definitely be more than the total of 40 minutes before and after feeding as calculated from this observation. This time is definitely lower than the figures obtained for *A. campestris* from Peninsular Malaysia in a similar study (Thevasagayam *et al* 1980) where they were found resting for more than 2 hours, and for *A. maculatus* also from Peninsular Malaysia (Afifi 1968) a resting duration of 5 - 9 hours.

The average time after spraying was 13 minutes which may be due to mosquitoes being killed within a short period or due to some irritant effect of DDT which made them move from one spot to another. The studies do show that *A. letifer* spends very little time inside house even during the night.

4.4.3 Daytime resting

In the several daytime indoor searches carried out over the years throughout the State, *A. letifer* has never been caught resting inside houses during the day. They come in to bite and leave the houses before dawn to complete the gonotrophic cycle in outdoor resting sites. In the experimental hut study reported later, all *A.*

TABLE III.

Resting position of *A. letifer* as observed in experimental huts before and after spraying in Kpg. Bayor, Serian District, Sarawak.

Condition of Mosquito	Spray Status	Resting Position — Wall height						Roof	Total No. of Mosquitoes Observed
		0—0.3m	0.3—0.6m	0.6—0.9m	0.9—1.2m	1.2—1.5m	1.5—1.8m		
Unfed	Unspr.	5.2(39)	13.1(98)	17.5(131)	17.8(138)	13.3(99)	12.4(93)	**20.6[154]**	747
	Spr.	4.7(11)	12.4(29)	13.3(31)	8.6(20)	6.4(15)	12.9(30)	**41.6[97]**	233
Fed	Unspr.	4.0(14)	12.7(44)	15.0(52)	15.3(53)	11.5(40)	11.5(40)	**29.7[103]**	347
	Spr.	12.7(8)	14.3(9)	17.5(11)	14.3(9)	6.3(4)	15.9(10)	**19.0[12]**	63

Figures in parenthesis represent the actual number of *Aletifer* observed in each position.

TABLE IV.

Resting duration of *Aletifer* as observed in experimental huts before and after spraying in Kpg. Bayor, Serian District, Sarawak.

Condition of Mosquito	Spray Status	Resting time in minutes						over 60	Total No. of Mosquitoes Observed
		1 — 10	11 — 20	21 — 30	31 — 40	41 — 50	51 — 60		
Unfed	Unspr.	52.2(395)	19.4(147)	10.8(82)	5.6(42)	5.0(38)	3.3(25)	3.6(27)	756
	Spr.	90.4(208)	7.0(16)	1.7(4)	0.4(1)	0.4(1)	0 (0)	0 (0)	230
Fed	Unspr.	30.1(109)	20.7(75)	16.6(60)	10.8(39)	7.2(26)	9.4(34)	5.2(19)	362
	Spr.	89.4(59)	6.1(4)	3.0(2)	0 (0)	0 (0)	1.5(1)	0 (0)	99

Figures in parenthesis represent the actual number of *A. letifer* observed.

letifer that entered the hut normally, left before sunrise, and many of them during the first quarter of the night after feeding.

4.5 Feeding habits

4.5.1 Indoor and outdoor

A. letifer readily enters houses to bite although larger numbers are caught biting outdoors. In observations made in 1964 at Kpg. Junggo Mawang (144a/103) and at Kpg. Murut (143b/153) the ratio of indoor to outdoor biting was about 1:5 in the longhouse where there are many domestic animals. In the farm hut, where there are only a few domestic animals, the ratio was 1:3 in a sprayed hut and 1:2 in an unsprayed hut. In the experimental hut where there was no domestic animal the indoor: outdoor biting ratio was 1:2 (521:1092).

4.5.2 Feeding time

Observations made all over Sarawak show that *A. letifer* feeds mainly during the early hours of the night, about 75% biting between dusk and 10 pm. The results of all-night man-biting collections from the experimental hut are presented in Figure 2. Out of the 521 *A. letifer* caught biting indoor, 72% were caught before 10 pm and of the 1092 caught biting outdoor, 78% were before 10 pm. It was also observed that when numbers are high, *A. letifer* would start biting soon after sunset and well before dark and they will also attack man while he is moving around.

In a 24-hour man-biting study carried out in 1967 during one night at Triso Logging camp (227c/9L), at the edge of the jungle, 253 out of 273 (93%) were caught biting between 5 and 7 pm. It was an overcast night and was almost dark by 5.30 pm and the biting activity had commenced much earlier, at a time when most of the workers in the camp had not gone into their huts for the night. In the same collection, 17 *A. letifer* were caught biting during the day between 7 am and 11 am under heavy shade. This would indicate that loggers would be attacked by this species while at work during the day too.

Zulueta (1956) found 50% of the *A. letifer* between 8 pm and midnight in Sarawak but no data was presented by him on the biting before 8 pm, at which time, subsequent studies have shown that a good proportion of *A. letifer* would bite. This early biting habit of *A. letifer* is of great importance to a malaria control programme where residual spraying of houses is the main control measure. Biting will take place before the people are inside houses, which added to the possibility of day-time biting in jungle areas will render residual spraying of houses ineffective in eliminating malaria transmission.

4.5.3 Host preference

For precipitin analysis of blood meal, it has not been possible to collect blood-fed *A. letifer* from unbiased biotopes like day-time resting places. Therefore analysis was done on blood-fed specimens collected during the first quarter of the night resting around human dwellings wher the mosquitoes had a chance of feeding on humans as well as domestic animals like pigs, chicken, dogs and cats, of which there were plenty. The results of analysis carried out by the courtesy of the WHO and the Lister Institute, London are presented in Table V. Of the total of 180 blood meals analysed, about 50% had human blood. Only three *A. letifer* had been collected from day-time outdoor resting sites and all three had human blood.

Although collecting among bushes surrounding domestic animals might have shown a bias towards animals, the results show a high human blood index not suspected earlier. It is possible that most of these tested might have fed on humans while they were still outdoors in the early hours of the night and some which had fed inside and left the house soon after may have also been included. The data on resting duration after feeding in sprayed houses presented earlier showed that fed *A. letifer* do not stay long inside houses which may also support the fact that at least some of the blood-meals tested were from those that had fed inside and left early.

4.5.4 Time of exit

In order to study the time of exit of *A. letifer* from experimental huts, hourly counts were made from exit window traps with two baits inside the hut. In the unsprayed hut, four nights' observations were made and 207 *A. letifer* were collected from the window traps. Of these 43 were fed, 32.5% of which left during the first quarter of the night and 41.9% left during the last quarter. Of the 164 unfed ones, 65.8% left during the last

quarter of the night, most of them between 6 am and 7 am. This again showed that a good proportion were leaving the unsprayed huts in the early hours of the night.

SUSCEPTIBILITY TO DDT

State wide residual spraying with DDT for malaria control commenced around 1958/59 in Sarawak. A pre-spray L_d100 of 4.0% and L_D50 of 1.2% DDT was reported from Sarawak. In 1963, a series of tests carried out at Sg Klauh (225a/131), 807*A. letifer* tested gave an L_D100 of 4.0% DDT. In 1964, 157*A. letifer* tested from Tapong Lebat (114a/9) and 22 from Pang. Prupok (151a) also gave an L_D100 of 4.0% DDT. In 1967, 205 *A. letifer* tested from Triso Logging Camp (227c/9L) gave an L_D100 of 2.0% DDT. Similar results were also obtained from the study area as well as other areas in Sarawak during 1968 and 1969 where one hour exposure to 4.0% DDT always gave 100% kill. These results show that after nearly ten years of spraying by the malaria programme, the susceptibility of *A. letifer* to DDT remains unchanged. With such large numbers biting outdoors during the early part of the night, the insecticide pressure on this species is not very great and it is not anticipated that it will develop resistance to DDT residual spraying by the malaria programme in Sarawak in the years to come, as spraying becomes more and more localised with less and less malaria in the State.

TABLE V.

Results of precipitin tests of blood meals from *A. letifer* collected from outdoor night-time resting places in Sarawak during 1966 and 1967.

Locality	Year of last Spraying	Resting Place	Date of Collection	No. tested	Positive for				% Positive for man
					man	pig	dog	bird	
135/154 Kg. Putong	DDT 1962	Outd. Night	June '66	47	32	8	1	6	68.1
135/154 Kg. Putong	DDT 1962	Outd. Day	June '66	1	1	0	0	0	
134/168 Kg. Stampin	DDT 1962	Outd. Day	Mar. '66	2	2	0	0	0	
134/176 Meradong Goyam	DDT 1962	Outd. Night	June '66	3	0	1	2	0	
144/101 Kg. Bayor	DDT 1966	Outd. Night	Dec. '66	32	24	7	0	1	75
144/101 Kg. Bayor	DDT 1966	Outd. Night	Jan. '67	77	32	41	0	4	41.6
413/86 Lg. Maligam	DDT 1963 & 1966	Outd. Night	Aug. '66	4	0	4	0	0	
144/111 Kg. Semukoi	DDT 1966	Outd. Night	Nov. '66	9	2	7	0	0	
143/150 Kg. Pan-	DDT 1963	Outd. Night	Jan. '67	6	0	6	0	0	
412/117 Lg. Ikan	DDT 1963	Outd. Night	June '66	4	0	4	0	0	
			Total	185	93	78	3	11	50.3

TABLE VI.

Indoor and outdoor biting *A. letifer* per-man-hour collected from experimental huts at Kpg. Bayor, Serian District, Sarawak.

		Hut No.1 Before & after spraying		Hut No.4 unsprayed control	
		IND.	OUTD.	IND.	OUTD.
1967	FEB	55.0(385)	106.0(742)	—	—
	MAR	6.5(91)	6.8(75)	—	—
	APR	0.3(7)	4.1(100)	—	—
	MAY	0.9(16)	3.2(59)	—	—
	JUN	0.5(6)	3.8(45)	—	—
	JUL	0.3(2)	0.8(5)	—	—
	AUG	0.3(3)	0.6(7)	—	—
	SEP	0 (0)	0.6(7)	—	—
	OCT	0.6(7)	1.0(12)	—	—
	NOV	0.3(4)	2.7(32)	—	—
	DEC	0.2(2)	4.8(58)	7.2(174)	14.0(211)
1968	JAN	(1) 4.1(99)	30.0(721)	10.3(248)	42.7(770)
	FEB	0 (0)	4.2(100)	0.2(5)	0.4(10)
	MAR	1.5(36)	11.4(274)	0.8(20)	25.2(605)
	APR	0.1(2)	7.9(143)	0.3(6)	6.2(113)
	MAY	0 (0)	9.5(114)	0.4(5)	9.6(58)
	JUN	0 (0)	4.2(51)	0.3(3)	25.0(300)
	JUL	(2) 0 (0)	4.1(50)	0.6(7)	6.2(75)
	AUG	0 (0)	0.4(10)	0 (0)	6.8(82)
	SEP	0 (0)	2.3(41)	0 (0)	0.6(7)
	OCT	0 (0)	0.4(5)	0 (0)	0.6(10)
	NOV	0.2(4)	9.9(178)	0.4(5)	1.0(12)
	DEC	0 (0)	0.2(1)	0 (0)	0.2(1)
1969	JAN	1.5(46)	26.7(1282)	—	—
	FEB	6.4(77)	45.6(548)	0.8(9)	16.2(195)
	MAR	2.7(96)	30.8(1663)	5.6(303)	29.9(1663)
	APR	(3) 5.3(252)	17.0(820)	2.3(112)	17.0(820)
	MAY		—	1.9(35)	14.6(351)
	JUN	0.7(8)	1.8(21)	0.2(5)	1.7(51)
	JUL	0.1(1)	3.8(46)	0.1(3)	4.2(101)
	AUG	0 (0)	0 (0)	0.2(7)	1.8(64)
	SEP	0 (0)	5.3(32)	0.6(10)	5.9(142)
	OCT	0 (0)	2.6(31)	1.3(48)	8.3(300)

1, 2 & 3 represent the 1st, 2nd & 3rd spraying of the huts.
Figures in parenthesis represent the actual number of *A. letifer* caught.

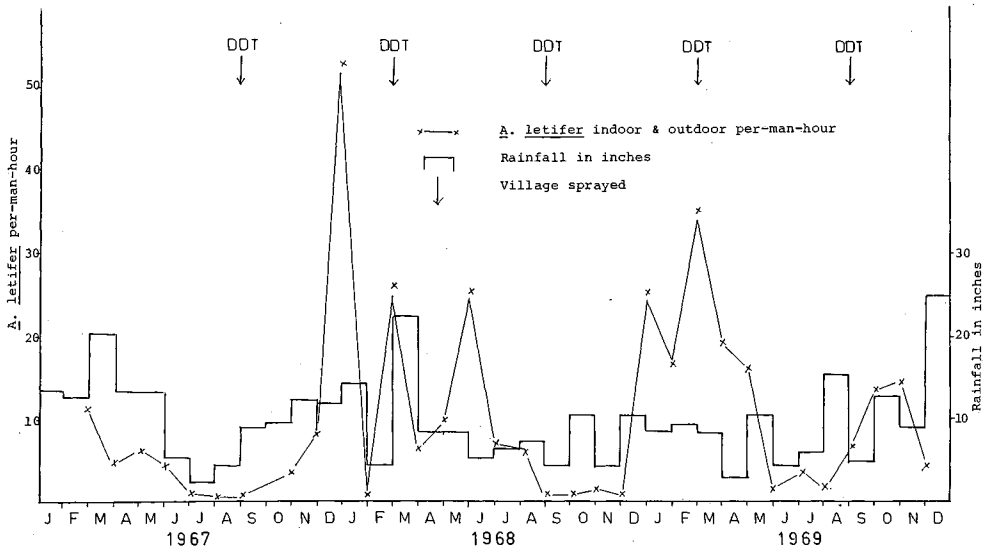

Fig.1 Seasonal prevalence of *A. letifer* as obtained from Kpg. Bayor, and rainfall figures obtained from Balai Ringin, Serian District, Sarawak.

RESPONSE TO RESIDUAL SPRAYING WITH DDT

General experience in the state over the years has been that high densities of *A. letifer* could be found in sprayed areas, even shortly after spraying and density fluctuations could not be attributed to the time of spraying. The experimental hut study was undertaken to see what proportion of *A. letifer* would enter sprayed houses and the fate of those that entered to bite. The results are presented in Table VI.

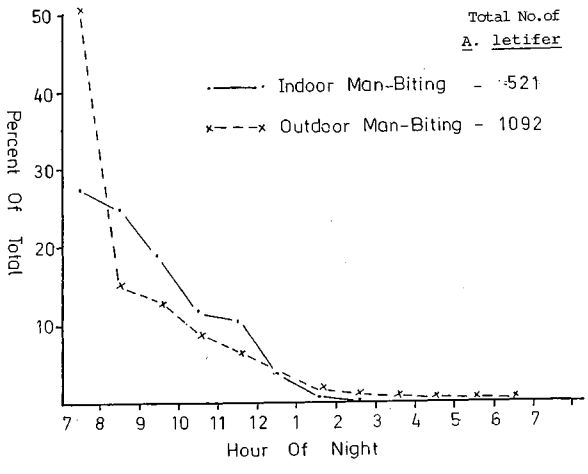

Fig.2 All-night biting activity, indoor and outdoor of *A. letifer* obtained from experimental hut at Kpg. Bayor, Serian District, Sarawak.

In hut No. 1, one year's data was collected before spraying after which the hut was sprayed with DDT water wettable powder at a dose of 2gm/m^2, in January 1968, July 1968 and April 1969. After spraying, indoor biting was greatly reduced except during the months of February and March 1969, 7 and 8 months after the 2nd cycle of spraying. After the 3rd cycle of spraying in April 1969, indoor biting was again greatly reduced, or totally absent. Outdoor biting, however, remained constantly high except during the dry months. In the unsprayed hut, data is available from December 1967 to October 1969 and in this hut too indoor biting was low but still higher than the sprayed hut and outdoor biting also remained high during most of the months. The data for the sprayed hut are also presented in Figure 3. In the data presented in Figure 1, the total indoor and outdoor biting density from Kpg Bayor is shown with the routine DDT sprayings in the Kampong. Here again it could be seen that the density fluctuations are not related to the time of spraying. This would confirm the earlier observations that the biting

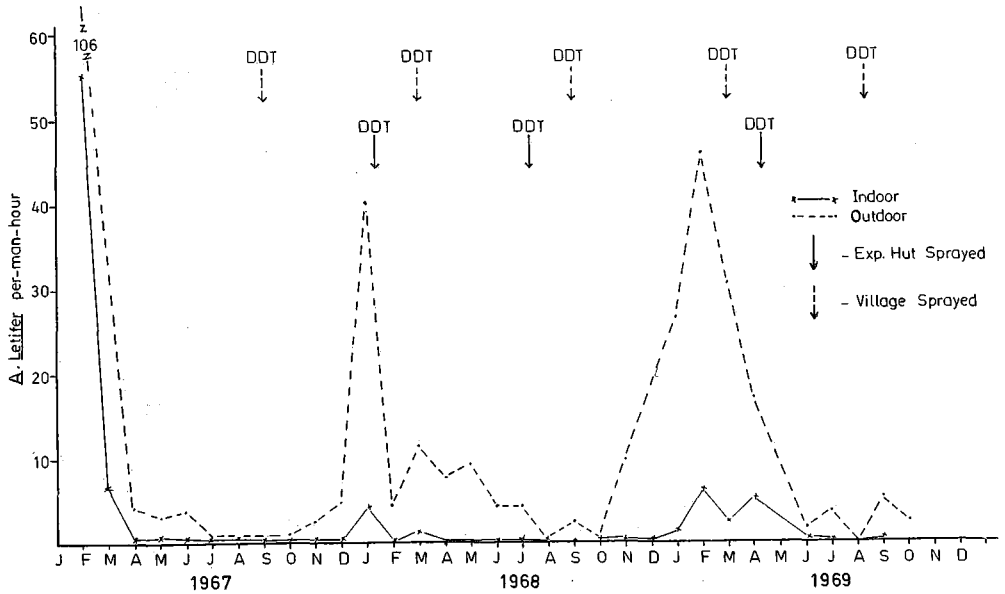

Fig.3 Indoor and outdoor biting of *A. letifer* before and after spraying in experimental hut in Kpg. Bayor, Serian District, Sarawak.

behaviour of *A. letifer* is such that residual spraying would have no real impact on its overall density in the area. After spraying, reduction of indoor man-biting may be due to either the mosquito being killed by its contact with the insecticide before it had a chance to bite or by it being deterred from entering the houses by the presence of DDT. In order to determine this, 207 *A. letifer* were released, into the sprayed hut at 7 pm, 2 weeks after spraying. Of these only 78 (39%) were recovered from the hut of which 32 (16%) were dead on the floor and 46 (23%) were found in the window traps. Of the 78 recovered, 8 (10.2%) survived for 24 hours. Another release of 135 mosquitoes 8 weeks after spraying, with 2 baits inside, 79 (58.5%) were recovered of which 7 (9.3%) survived. The recovery rate in these release studies was only about 50%, the others probably escaping through the louvres and the spaces in the cadjan walls. In another release to determine the escape route, with the louvres closed, the recovery was about 75% showing that the rest escaped through the walls. It is therefore difficult to conclude on the fate of *A. letifer* released into the huts as one is not sure of the 50% that escaped. But the survival rate of about 10%, 2 weeks after spraying suggests that even mosquitoes that were forced into the hut with little alternative but sprayed surfaces to rest, some did in fact escape lethal contact. This may suggest a deterrent effect of DDT at least during the first weeks after spraying which made them escape before picking up a lethal dose. It is also possible that DDT may also deter them from entering sprayed houses.

Although *A. letifer* is still susceptible to DDT, residual spraying has little overall effect on this species, which, added to its early evening outdoor biting enables this species to maintain transmission even at a low level in spite of repeated spraying. Therefore in areas where *A. letifer* is considered important, additional measures to residual spraying are indicated in order to eliminate the transmission of malaria.

SUMMARY

A. letifer has been suspected to be a vector of malaria in Sarawak and although sporozoites found in this species have all been of non-primate origin, epidemiological evidence of proven malaria transmission in areas where this species is the only anopheline present would indicate that *A. letifer* should be considered a vector in Sarawak. It breeds in peat swamps of the coastal plain where transmission occurs among migrant workers to timber extraction and road construction projects.

High densities of *A. letifer* are found in the peat swamp areas in most months of the year except during extreme dry conditions from June to August. The gonotrophic cycle was determined to be two days and the average numbers of eggs laid by a female was about 150.

Studies were conducted in experimental huts to determine feeding and resting habits as well as its response to residual spraying. The main biting activity starts at dusk and more than 75% of the biting is completed by the first quarter of the night. In areas bordering the junge it bites during the daytime under heavy shade and even when people are moving. Outdoor biting is generally more pronounced and is about three times the indoor biting. Precipitin test studies showed that the human blood index is about 0.5. In experimental huts, it rested at all heights of the wall and the roof and spends little time indoors, about 15 minutes before feeding and about 25 minutes after feeding.

A. letifer was still susceptible to DDT after nearly 10 years of residual spraying by the malaria programme. But residual spraying had little effect on the overall density of the vector although indoor biting becomes considerably reduced or even nil after spraying. As the species bites mainly outdoors in the early hours of the night, there is little chance of this biting population coming in contact with indoor residual spraying. Malaria transmission by this species, therefore, could not be eliminated by residual spraying and in areas where *A. letifer* is important, measures to supplement residual spraying are indicated.

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