THE CONDITIONS OF MALARIA TRANSMISSION IN KUALA PENYU DISTRICT, SABAH AND THE RESIDUAL EFFECTS OF SUMITHION, DDT AND MALATHION

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During 1976 – 1977, the Sabah Malaria Control Programme carried out an extended field trial comparing the residual effects of Summithion[a], DDT and Malathion[b] against the primary vector of Sabah, **An. balabacensis balabacensis** *Baisas in Kuala Penyu district. In the courseof this work and continuiting into 1978, a study was made of the conditions of increased malaria transmission in 3 areas four month after residual applications of Sumithion, DDT and Malathion. Since the findings relate to the south-western part of Sabah which suffers annual anticipated seasonal outbreaks of malaria they are of particular epidemiological interest*

A detailed description of the area in which the insecticide trial was carried out is given in the earlier paper (Farid and Hii, in press) and is therefore not repeated here. The plan of the trial area is shown in figure 1. Table 1 shows the arrangement of the sprayed areas in terms of population distribution, the number of *kampungs* (villages) and sprayable structures (houses and sulaps[c]), entomological indicator stations and district dispensaries.

The experimental area was divided into three parts: a Sumithion test area (Area I), a DDT test area (Area II) and a Malathion test area (Area III) where Sumithion 50%, DDT 25% and Malathion 84% emulsifiable concentrates were all used at a target dose of 2 g/m^2 of the technical grade. The insecticides were all applied using 3 US gallons Hudson X–pert sprayers fitted with 8002 HSS nozzle tips. By using the three insecticides in the from of emulsion (5%) it was hoped to obtain a better response from the inhabitants and achieve a good coverage. No insecticide was applied after the second cycle in Area I and II (after July, 1977) and after the third cycle in Area III (after September, 1977) due to an unseasonably dry weather which makes resumption of spraying impossible until May, 1978.

Data on the incidence and prevalence of malaria was obtained from a longitudinal study of persons of all age groups from 1976 through 1978. A general reduction in the number of *P. falciparum* cases by quarterly periods was seen in all areas. In area II the drop in *falciparum* incidence was more pronounced and steady, a result that was not noticed in the other two areas. The decrease was noticeable in the third and fourth quarters of 1977 when transmission was expected to be higher. In the fourth quarter of 1977, *P. falciparum* cases reappeared in this area while the other two areas showed some improvement. By the end of 1977, the total *falciparum* incidence in areas I, II and III were 32.6%,

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a. 0,0-dimethyl 0-4 Nitro-meta-tolyl, phosphothioate (or fenitrothion)
b 0,0-dimethyl phosphorodithioate
c temporary farm huts which are built before harvesting or planting of hill rice and are usually made of local nipah attap roof and partially walled with sago/kajang branches; they are usually situated on hill slopes and are close to the fringe of the jungle forest or plantations of rubber.

Figure 1 Map of Kuala Penyu showing the insecticide trial area. (Areas 1,2 and 3 are sprayed with sumithion, DDT and malathion respectively)

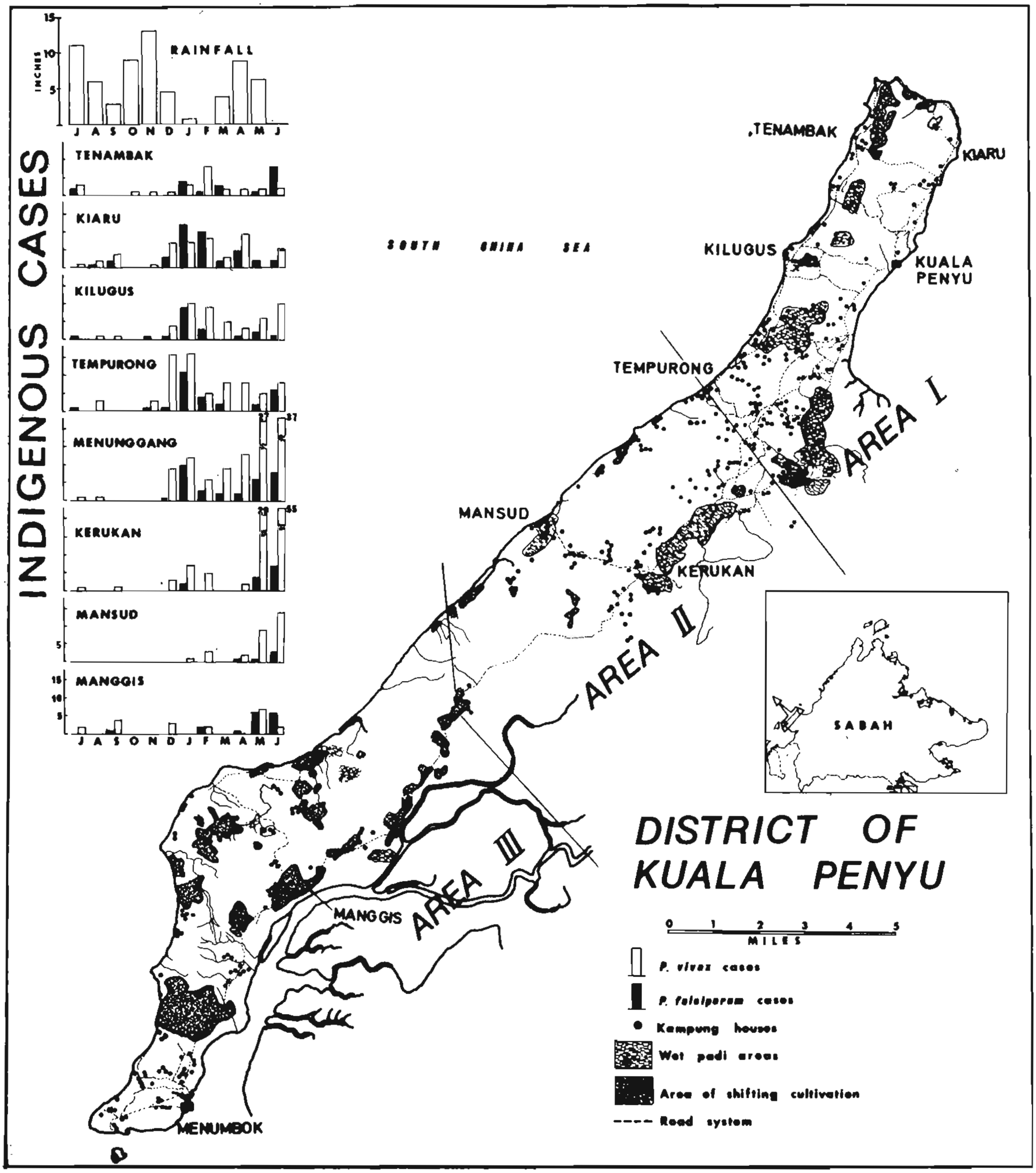


Table 1 General reconnaissance data, population and house and sulap census for each spray area in Kuala Penyu district, December 1976

Area	Population	Kampongs	No. of Structures		Insecticide Used	Entomology Station	Dispensary
			Houses	Sulaps			
I	5524	10	1080	25	Sumithion	Kiaru	Kuala Penyu
II	3637	7	671	62	D.D.T.	Menunggang	–
III	3273	17	626	75	Malathion	Menumbok Darat	Menumbok

13.5% and 53.9% respectively. Area II showed a dramatic drop change in the parasite formula for *P. alciparum* (63.1% drop) followed by area I (44.8% drop) one year after the trial. Area III did not show much change. No infants were found infected in Area II, whereas two and three were found in area I and III respectively. Mixed infections were more common in area III than areas I and II.

EPIDEMIOLOGICAL INVESTIGATIONS AND RESULTS

Surveillance and case detection

Surveillance include both ACD and PCD. ACD was assigned to and carried out by four junior canvassers and they visited each house within their assigned area on a monthly schedule. When they found anyone with fever, chills or other symptoms suggestive of malaria, they took a blood smear and administered presumptive treatment. Each canvasser covered each of the operational areas while the fourth canvasser rotated from one area to another accelerating ACD in an area reporting a high number of malaria cases. They also carried out follow ups of confirmed malaria cases monthly and to collect as many slides as possible from fever cases. PCD was based on malaria microscopy and treatment centres in Kuala Penyu and Nenumbok dispensaries figure 1.

Case investigations were done by malaria technicians and their reports were revised and analyzed by the authors at Headquarters and district office and during monthly visits. Contact surveys were also carried out at the time of case investigations. All persons with malaria were given radical treatment in accordance with age. Most of the cases were treated in the two dispensaries as inpatients, however some *P. vivax* and a very small number of *P. falciparum* cases continued their treatment at home.

Although it was considered that the transmission is all year round but at higher levels from August to December 1977 it was detected, further transmission mainly in area I from January to March 1978 when the rainfall was very low (total for 3 months = 4.88 in), figure 1. During this dry season five positive slides were found in the examination of 70 newhorn infants in area I table 2. No infants were found infected in areas II and III. The results are shown in table 3. Investigations of these infants with positive blood slides showed that one *(vicax* infection) was infected in mid January, one in early Februaru (mixed *falciparum* and *vivax* infection) and two *(vivax* and *falciparum)* in early March respectively. The other infant *(falciparum)* was an imported case found on 7 January, 1978. The mothers of four of these infants were asked whether they had ever taken them away from the home kampung only one admitted having done

Table 2 Result of malaria case detection activities showing P. falciparum ratio, indigenous cases and number of heavy infections and affected age groups from July 1977 to June 1978, Kuala Penyu.

Spraying status	Rainfall and quarter of year	Test area	No. of P. falciparum cases	P. falciparum ration (%) (no. slides examined)	Indigenous cases (no.falciparum cases)	Heavy infections of P. falciparum & P. vivax (total infected	Mixed infections	Age groups 0-11 mths	1-9 yrs	10 yrs
Onset of second cycle in areas I and II	19.8" (inter-monsoon) July-September	I	23	57.5 (989)	23 (10)	4 (40)	0	0	12	28
		II	0	0 (769)	10 (0)	2 (14)	0	0	8	6
		III	36	51.4 (983)	49 (24)	8 (70)	2	1	34	35
Onset of second cycle in area III	26.9" (northeast monsson rains)	I	23	31.5 (829)	60 (19)	25 (73)	0	0	31	42
		II	5	29.4 (551)	12 (1)	2 (17)	0	0	5	10
	October-December 1977	III	20	50.0 (651)	30 (40)	11 (40)	0	0	11	29
Post spray	4.88" (dry season) January-March 1978	I	95	44.8 (1840)	169 (73)	60 (212)	3	5	87	120
		II	19	26.0 (792)	64 (19)	15 (73)	0	0	33	40
		III	23	60.5 (492)	33 (16)	7 (38)	0	0	14	24
Onset of third cycle in areas I and II; fourth cycle in area III	25.5" (southwest mon soon rains)	I	69	41.6 (1341)	118 (44)	29 (166)	2	3	53	110
		II	37	15.3 (1571)	219 (33)	52 (242)	0	11	84	147
	April-June 1978	III	26	35.6 (514)	64 (25)	9 (73)	0	1	35	37

Table 3 Results of ovarian dissections parous rate[1] probability of daily survival[2] and estimated life expectancy of An balabacensis balabacensis[3] from July 1977 to June 1978

Month	Sumithion (I)			DDT II)			Malathion (III)		
	% parous		P^3	% parous		P^3	% parous		P^3
July 1977	49.6	(470)[3]	0.791	72.8	(125)	0.899	63.1	(217)	0.858
August	56.1	(355)	0.825	61.7	(60)	0.851	68.1	(163)	0.880
September	76.4	(314)	0.914	25/30		–	70.2	(131)	0.888
October	63.7	(267)	0.860	11/38		–	70.4	(115)	0.889
November	52.3	(595)	0.805	61.4	(83)	0.850	46.5	(204)	0.775
December	62.8	(1070)	0.856	54.9	(111)	0.819	65.0	(40)	0.866
January 1978	87.6	(137)	0.957	8/9		–		20/20	–
February	82.3	(124)	0.937	6/7		–		10/10	–
March	2/2		–	2/3		–		–	–
April	15/17		–	–		–		–	–
May	63.9	(119)	0.861	17/27		–	50.0	(56)	0.794
June	67.7	(220)	0.878	92.5	(40)	0.974	55.9	(281)	0.824

Life expectancy (in days)

Month	Area I	Area II	Area III
July-September 1977	5.68	8.81	7.36
October-December	5.81	24.24	5.23
January-March 1978	18.69	–	–
April-June 1978	7.62	13.91	5.00

[1] Monthly samples with less than 40 mosquitoes are not included;

[2] P^3 = probability of daily survival with the power of 3; and gonotrophic cycle of balabacensis is 3 days; probabilities were derived from HGarrett-Jones (1964).

[3] ( ) Figures in parenthesis indicate total number of *balabacensis* dissected.

so and she had visited another village in the DDT treated area (Area II). All the five positive cases were evenly situated in five seriously affected foci in area I. The possibility of congenital malaria was considered but no infant under the age of 1 month was found to have a positive blood slide.

Continuing transmission occured in all three test areas after the rains in April and May 1978, the highest rate occurring in area II followed by area I and area III. During the second quarter of 1978, April to June, nine infants (one *falciparum* and eight *v9vax* infections) were found to have contracted indigenous malaria in three serious foci (Kerukan, Menunggang and Mansud). One *vivax* case was a relapse. The indigenous cases were infected from as early as late April to mid June. An additional three infants were also found infected in area I (one mixed *falci-*

parum and *vivax* indigenous, one *vivax* relapse and one *falciparum* relapse). In area III, one *vivax* infant case was found only.

The average age at which an infant living in area I first gave a positive blood slide during January to March 1978 was determined as 22 weeks; for the DDT test area II, the comparable figure was 33.6 weeks. Thus infants in the test area II were on average 11.6 weeks older than those in area I when the first positive blood slides were obtained. This would appear to indicate that sumithion and DDT, by reducing the mosquito population, reduced the inoculation rate and thereby affected the age at which infants were first infected. It may therefore be possible to use the age at which infants first give positive slides as an indication of the efficacy of an insecticide. This point would open the scope of carrying out longitudinal infant studies on an area basis during minor and major transmission periods.

Entomological investigations.

The densities of *An. balabacensis balabacensis* were determined in sprayed experimental huts and outdoors by human bait catches from 2100 to 2400 hours and 1800 to 2400 hours respectively. The huts were particularly suitable for the use of this method of sampling as they were of the louvre-type and had two window traps attached to opposite sides of the walls. Indoor man-biting catches were made two to five times a month while outdoor catches were made two to nine times a month The collected anophelines were identified as to species and classified according to the stage of ovarian development by ovary dissections for parity. Exit window-trap collections were also made each morning after indoor collections. Dissections fro physiological age were confined to *balabacensis* only with the ovarian development of Christopher's Stage III.

Figure 2 shows the period of abundance, indoor hut and outdoor man-biting densities of *balacacensis*. No such data is available for *An. sundaicus* at the respective entomological stations, due to the location of the sampling huts. However, previous data before the trial revealed that both species prevail during different parts of the year, *An. sundaicus* being the predominant coastal species from February to June and *An. balabacensis balabacensis* from April to December. It will be seen that rainfall has more influence on the *balabacensis* population during different parts of the year and this seasonal pattern probably depends on the presence of suitable habitats for breeding. It is known that *balabacensis* breeds in shaded pools, ground seepages, wells, hoof prints; during the dry weather these pools usually disappear and from April to Juni suitable conditions usually occur for breeding. Heavy rains commenced in the third week of April (the first heavy rain in 1978 was on 17 April); by the end of May all the wells and water pools were filled up and production of *balabacensis* increased.

Throughout 1877 to 1978, the fall in temperatures and humidities was not significant enough to allow for the densities of *balabacensis* to drop, as these climatological variables did not fluctuate greatly month by month. Both *sundaicus* and *balabacensis* transmit malaria in this area and it will be seen that either one or both of them occur throughout the year.

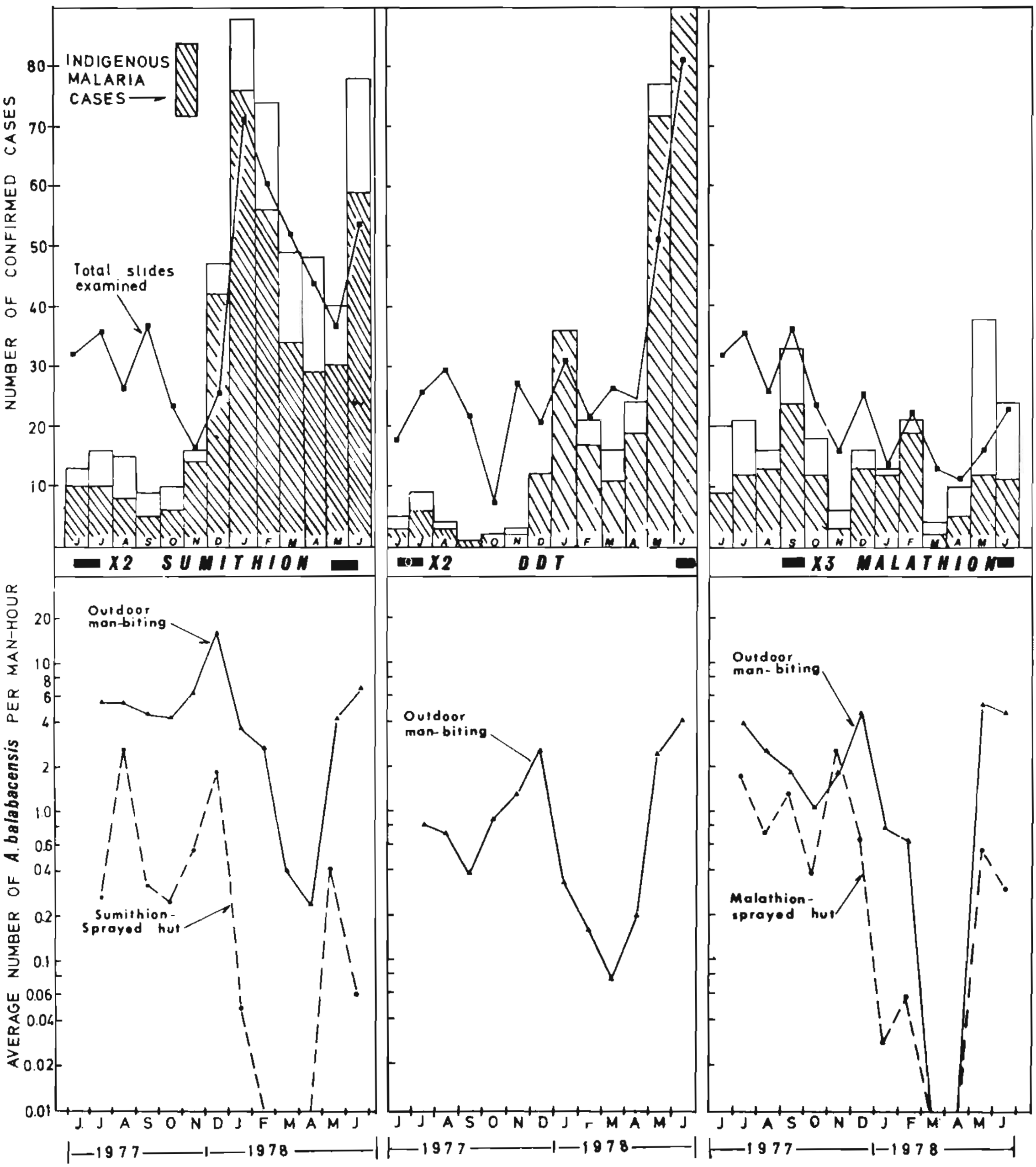
Longevity and survival rate of *An. bal. balabacensis.*

Simple- age-grading using the Deteniova technique of examining ovarian tracheation was used on samples of *balabacensis* population monthly throughout the year in all three test areas, table 3 summarises the results obtained.

During the period April to Juni 1978 when transmission was taking place at a high rate by *An. balabacensis balabacensis* the proportion of parous mosquitoes in the samples dissected was 0.67, 0.80 and 0.55 in areas I, II, and III respectively. On the assumption that *balabacensis* have a gonotrophic cycle of three days during this period, the probability of survival through one day *(p)* is given by the formula :

$$p = \sqrt[3]{\text{proportion parous}}$$

Figure 2. Graph showing epidemiological, entomological and spraying data in Area I, (Sumithion), II (DDT) and III (Malathion) in Kuala Penyu district, Sabah.



Thus, from the present results, p for *balabacensis* were 0.877, 0.931, and 0.819 respectively for areas I, II and III, i.e., the survival rates per day were 87.7%, 93.1% and 81.9% respectively.

Behaviour patterns after residual spraying

An. sundaicus is an early biter (1800-2000 hours) but *An. balabacensis balabacensis* is a late biter (2100-0200 hours). Spraying has little effect in reducing outdoor densities. Both species were found to be biting outdoors when baits were present outdoors. However, as there were very few people sleeping outdoors at any time of the year, outdoor transmission by both vectors may not be significant.

After spraying a considerable drop in the lethal effect of sumithion and malathion was observed for as long as four and three months respectively (Hii and Chin, in press). As *balabacensis* rarely remained in huts long after feeding, it might be thought that residual insecticides would have little effect on it, but in was found that for at least two months, a high proportion (80%) that left the sumithion-sprayed hut soon died. This phenomenon in conjunction with a reduction in the biting rate, resulting in an increased number of unfeds leaving the huts showed that presumably short contacts with the insecticide are sufficient for effective control of *balabacensis.* The reduction in feeding, due to the irritability of DDT and the airborne effects of sumithion and malathion might, in themselves, contribute to a decline in malaria transmission from January to December 1977. The repellent action of DDT was demonstrated by the smaller numbers of adults obtained from indoor sprayed huts than from control huts (Hii and Chin, in press).

Classification of the abdominal stages of *An. balabacensis balabacensis* collected in the window exit traps during the morning catch showed that, during the dry months of 1977 to 1978, the ratio of fed to unfed mosquitoes was about 50 : 50 (65 *balabacensis* examined), whereas during the rainy months, it was near 35 : 65 (309 *balabacensis* examined). This shows that, during the rainy months, less mosquitoes leave the huts than would be normal solely for the accomplishment of the gonotrophic cycle These mosquitoes usually leave early for outdoor vegetation where humidity is high and temperature is low and optimal.

Transmission during the dry season January to March 1978

At the end of the year 1977 it was postulated that transmission in the trial area would be seasonal i.e. during and after the rains, and that during the dry season transmission would occur only in very few localities with permanent water wells, brackish streams or seepage streams so that the vector mosquitoes would survive the dry spell. This view was based on the belief that the extreme dryness of the weather, especially in January to February 1978 which seriously affected the water-table and ground wells, would provide an atmosphere whose humidity was too low for mosquitoes to survive long enough to play their part in the transmission cycle. However this was not the case.

Assuming that the rainfall in Kuala Penyu was representative for all three test areas it was noted that transmission reaches a peak in January 1978 in areas I and II and then decreases steadily after as the rainfall increases; secondly, transmission appears to be concentrated within area I in the dry season and area II during the wet season. The last DDT and sumithon spraying was in June to July 1977. The investigations during the trial led to conclusion that these insecticides could have exerted little influence on the mosquito population after the end of December 1977. On epidemiological grounds sumithion can exert good control of malaria for as long as four months, DDT for five months and malathion three months under the prevailing conditions of the trial area.

The majority of cases during January to March 1978 originated from certain sections of the western coastal areas where possible breeding sites of *An. sundaicus* were found. In Tenambak which lies north-west from

Kuala Penyu town, a village of some 650 people, 207 blood slides from all age groups were examined at the Kuala Penyu dispensary during this period; 21 indigenous cases were found but from April to June, 15 such cases out of 214 slides were positive for malaria. Indoor and outdoor biting catches in kampung houses were made in February and the man-biting density was 0.37 *sundaicus* per man-hour indoors and 1.15 per man-hour outdoors. No *balabacensis* were caught. One infant *(falciparum)* was discovered in early March and the number of heavy infections during and after the dry season were about equal.

In Kiaru, population 480, which lies midway between Kuala Penyu town and Tenambak one positive infant-blood slide *falciparum)* was obtained among 40 indigenous cases during the dry season, Nine of these cases had heavy infections including the infant. After the dry season 23 indigenous cases and 4 heavy infections were found, a drop of 42.5% and 55.6% respectively. Monthly indoor hut catches were carried out in an entomological station (experimental hut was sprayed on 23 June 1977) at regular intervals and between January and March 1978 only one *balabacensis* was found in 6 night hut cathes giving a man-biting density of 0.02 per man hour. Three night indoor catches in kampung houses revealed no biting mosquitoes. By the end of January 1978, airborne bioassays of sumithion hut gave 0% 12-hour knockdown rate and 0% mortality after 24 hours. Window trap mortality on 23 January 1978 in this hut also gave 0% mortality after 24 hours. The last contact biossay on 9 December 1977 gave 42% mortality. Thus it was concluded that there was hardly any residual insecticidal potency of sumithion after January 1978.

In Kilugus, population 943, 34 indigenous cases (including one mixed-infection infant) were found during the dry season in 361 blood films collected; 9 heavy infection of brackish pools at the mouths of four small streams revealed heavy breeding of *An. sundaicus* close to the seashore. Previous man-biting density was 0.2 *sundaicus* per man-hour outdoors in this area. In Tempurong, population 208, which is 3.5 miles south of Kilugus figure 1, 45 indigenous cases were found in the dry season including one *vivax*-infected infant in early March; heavy infections accounted for 19 cases but this dropped down to 6 after the dry season. No mosquito catches were done but heavy *An. sundaicus* breeding was found in brackishwater streams and rivers in the latter part of the dry period.

In Menunggang, population 1480, transmission started in early January in two wet sago areas where *An. balabacensis balabacensis* was still found breeding during the dry period. Vector density collected outdoor ranged from 0.07 to 0.35 per man-hour; no vectors were caught in indoor experimental huts. During the dry period there were 42 indigenous cases from 427 blood slides including 10 heavy infections.

In area III, malaria transmission was maintained at a low level during the dry season (33 indigenous cases from January to March 1978) and no infected infants were found. Slide collection was relatively low compared to that in areas I and II.

Transmission during the wet season April to June 1978

After the dry season, several residual parasite pools were concentrated along the coastal to inland areas (Tempurong – Mansud) and in the central wet sago areas of Menunggang figure 2. However, when the south west mansoon rains began in April, a buildup of *balabacensis* population occured. Coinciding with this increase of vector density, a large scale transmission of *vivax* malaria occured in previously non-malarious areas which were kept under good control during the spraying phase in 1976–1977. By the end of June 1978 spraying operations were almost completed, but this not significantly affect the epidemiological picture during the wet period. Out of 612 slides collected in Menunggang during this period there were 93 indigenous cases amongst which four infants (3 *vivax* and 1 *falciparum)* were found infected. There were also 24 heavy infections. Vector density increased rapidly after the rains. In another focus, Kerukan, 97 indigenous cases (in 592 blood slides) were found including five infants (4 *vivax* 1 *falciparum*); in Mansud (pupulation: 500) there were 30 indigenous cases (in 275 blood slides) including one-*vivax*-infected infant. In areas I and III resumption of malaria transmission was seen but at a less intense magnitude compared to that in area II.

CONCLUSIONS

Conclusions based on the results obtained from this study are:

(a) The residual effectiveness of sumithion was estimated to be four months after the second spraying round based on epidemiological and entomological observations; whereas that of DDT was four to five months and malathion three months under the prevailing local conditions;

(b) monthly ACD and PCD surveillance definitely show the persistence of malaria transmission;

(c) during the dry period, secondary transmission appeared to be caused by *An. sundaicus* in four discrete coastal areas when indoor *An. balabacensis balabacensis* populations were as low as 0.04 per man-hour and outdoor man-biting density were 0.1 (DDT station), 0.4 (sumithion station) and 0.8 (malathion station) per man-hour. These densities of the primary vector during the dry period did not contribute to a high transmission in the badly affected localities in area I (sumithion) but high densities were mainly responsible for persistent transmission at the onset of monsoon rains;

(d) recovery of vector populations after the monsoon rains following delay of spraying operations was dramatic and reached a peak of 6 *balabacensis* per man-hour;

(e) for good control of malaria caused by *balabacensis*, it is advisable to spray residual insecticided regularly, viz. every four months for sumithion and DDT and every three months for malathion.

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