MALARIA OUTBREAK AT PULAU TEKONG IN SINGAPORE

By K. L. Chan, P. K. Chew and T. S. Koh

SYNOPSIS

An investigation was made on a suspected malaria outbreak at Pulau Tekong following notification of one local *falciparum* case in January and five others including one *vivax* case in March 1969. Active and passive case detections and other epidemiological surveys revealed further cases and confirmed the outbreak. *Anopheles maculatus* was the vector involved.

A total of 25 cases were detected. The majority (84%) were below the age of 21. A parasite rate of 5.1% occurred in the 2-4 years age group. Distribution of the cases by sex (males: females) was about 2:1, and by ethnic groups was about proportionate to the population distribution.

Transmission was interrupted by residual spraying with 5% DDT. No prophylactic drugs were used. The island was brought under complete oiling control from May 1969. Permanent control measures begun in November 1970 included surface and subsoil drainage. No further cases were reported in 1970.

INTRODUCTION

Between 200 and 400 cases of malaria are notified to the Ministry of Health each year from 1965 to 1969 (Table I). Of these less than 10% are infected locally. The majority of imported cases come from Malaysia and Indonesia (Table I). The majority of local cases had been occurring in the offshore islands, of which Pulau Ubin and Pulau Tekong had the highest number. About 53% of all the local cases in the Republic were found in these two islands (Table II).

Malaria in Singapore since 1945 was most commonly found in P. Tekong. Records from the Quarantine and Epidemiology Branch, Ministry of Health, show 11 cases in 1964, 10 in 1965, 1 in 1966, none in 1967, 6 in 1968 and 25 in 1969. This paper presents the last outbreak of 25 cases in 1969.

DESCRIPTION OF PULAU TEKONG

Pulau Tekong comprises two islands, P. Tekong Besar and P. Tekong Kechil, and is situated to the northeast of the main Singapore island (Fig. 1). The islands are about 1·6 km. (1 mile) from Kota Tinggi in Johore, Malaysia, where malaria is endemic (Huehne *et al*, 1967) and about 4 km. (2·5 miles) from Changi in Singapore. Kota Tinggi in Johore continues to be a frequent source of introduced malaria in Singapore.

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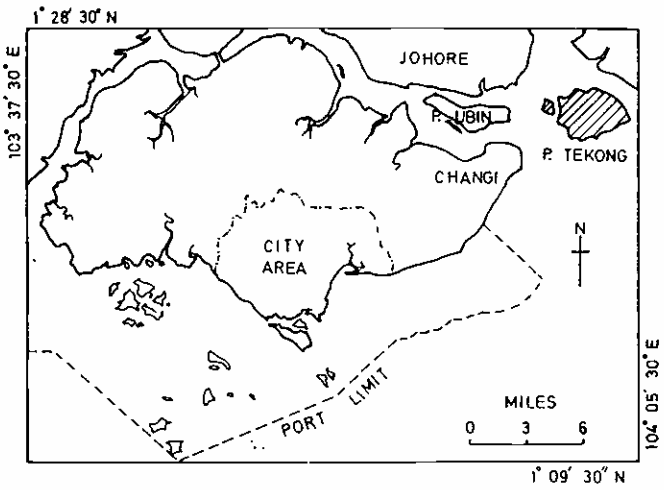

Fig. 1. Map of the Republic of Singapore showing the main Singapore Island and its offshore islands.

P. Tekong Besar is approximately 6·3 km. long and 4·2 km. wide. Its total area is 18·06 sq. km. (6·97 sq. miles). The total population was about 6,000 at the time of survey in 1969 and the total number of houses was 960, thus giving an average population of 6·25 per house.

P. Tekong Kechil is approximately 1·15 km. wide from east to west, and 1·27 km. long from north to south. It has a total area of 1·79 sq. km. (0·69 sq. miles). Its total population was 74 at the time of survey in 1969 and its total number of houses was 14, thus giving an average population of 5·39 per house.

DESCRIPTION OF OUTBREAK

The first case, W.C.K., was notified on 2 January, 1969. He was a 20 year old Chinese rifleman in the Singapore Army. He was training in an uncontrolled area in P. Tekong Besar from December 9 to 24, 1968, and then returned to

Bedok on the main island of Singapore. He had not left Singapore for 15 months previously and gave no history of previous malaria.

On December 30, 1968, W.C.K. felt feverish and reported sick the next day with a temperature of 104°F. He was admitted to Outram Road General Hospital on January 2, 1969, with a temperature of 105°F, and with enlarged spleen and liver. His blood contained *Plasmodium falciparum*. He was treated with chloroquine but developed recurrent parasitaemia—the first case of chloroquine resistant malaria reported in Singapore (Ng *et al*, 1969).

A special malaria survey was carried out in P. Tekong on 24 February, 1969 and 25 February, 1969, covering all areas which the patient had visited, especially the foothills of Kampong Pasir, Kampong Samak, Kampong Ayer Samak Darat and Kampong Sungei Sanyongkong. Eight breeding sites of *Anopheles maculatus* were found. On these days, 170 blood films were collected from houses but none were found positive.

The second case, a 16 year old girl, C.P.C., reported by a general practitioner from the island, was notified on 18 March, 1969. She was residing at Kampong Unum. She gave a history of fever for the past 10 days prior to consulting the general practitioner on 13 March, 1969. At the time of examination, her temperature was about 100°F. She was given some medicine and instructed to return for re-examination. On 17 March, 1969, the patient still complained of fever and her temperature registered 104°F on re-examination. A blood film was taken by the general practitioner and sent to the Vector Control and Research Branch Laboratory for diagnosis. *P. falciparum* was identified. A malaria survey was conducted on 22 March, 1969, following confirmation of the case on 21 March, 1969. The survey covered the surrounding areas within a half mile radius from the patient's home at Kampong Unum. *An. maculatus* was identified from three larval collections.

In a survey of 667 school-children by fourth year medical students of the University of Singapore in early March 1969, four positive blood films, one with *P. vivax* and three with *P. falciparum*, were discovered as reported in Ng *et al* (1969). These four symptomless cases were reported by the University to the Ministry of Health on 8 April, 1969, but this information, however, was not made available to the Vector Control and Research Branch until 14 April, 1969.

On receiving notification of these four new cases in addition to the previous two, we suspected an outbreak on P. Tekong. To ascertain whether indeed an outbreak had occurred, we took five surveyors and carried out an epidemiological survey on the island on the morning of 15 April, 1969. On arriving at the island, and on visiting the island general practitioner's clinic, the general practitioner informed us of two more suspected cases which were subsequently confirmed as positive from slides sent to the Still Road Outpatient Clinic on the main Singapore Island. This now gave a total of 8 confirmed cases.

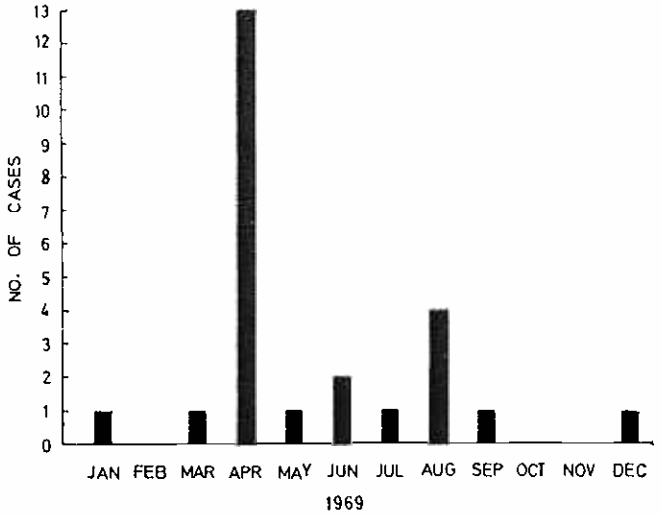

Fig. 2. Monthly incidence of malaria in the 1969 outbreak at P. Tekong.

Active case detection carried out on the morning of 15 April in the home of the two suspected cases (Fig. 3) and another neighbouring house revealed subsequently two more children with fever. From 123 blood films taken on the 15 and 16 of April, three further positive cases were diagnosed on 16 April, 1969. Both thick and thin blood films were taken daily from the various kampongs. On 21 April, three new cases of *P. vivax*, all Malays (a girl of 4 and two boys of 10 and 13) were discovered at Kampong Sanyongkong. With this number of cases confirmed, the suspicion of a malaria outbreak was confirmed. By the end of April, a total of 15 cases were reported. Control measures by residual spraying with DDT, which commenced in the first week of May, brought the outbreak almost to a stop. But in the absence of mass drug administration, transmission was not totally interrupted until the end of the year when it naturally died off (Fig. 2).

ANALYSIS OF CASES

Tables III-VI give an analysis of the 25 malaria cases reported.

1. Distribution by Age

It will be observed from Table III that the majority of cases were in the younger age groups from infancy to 12 years old. Sixteen cases or

TABLE I

SOURCE OF INFECTION BASED ON MALARIA CASES NOTIFIED TO THE QUARANTINE AND EPIDEMIOLOGY BRANCH, MINISTRY OF HEALTH

Year	No. of Local Cases		No. of Imported Cases				No. of Unknown or Doubtful Cases	Total Cases Notified
	Singapore Mainland	Singapore Offshore Islands	Malaysia	Indonesia	Elsewhere	Unspecified		
1965	1	13	146	16	0	25	0	201
1966	1	17	142	21	2	25	7	215
1967	5	13	157	25	8	20	6	234
1968	5	4	281	42	14	41	9	396
1969	23*	41	180	48	8	0	2	302
TOTAL	35	88	906	152	32	111	24	1348
GRAND TOTAL	123		1201				24	1348

*Higher number due to change in criteria of classification.

Local : Imported = 1 : 10·2, i.e. 9·1% of total cases.

TABLE II

NUMBER OF LOCAL MALARIA CASES IN P. TEKONG AND P. UBIN

Year	No. of Cases in Singapore	No. of Total and Local Cases in		Local Cases in P. Tekong and P. Ubin	
	Total (Local)	P. Tekong	P. Ubin	No.	% of Total Local Cases in Singapore
1965	201 (14)	10 (10)	1 (1)	11	78·6
1966	215 (18)	1 (0)	9 (9)	9	50·0
1967	234 (18)	0 (0)	10 (10)	10	55·6
1968	396 (9)	6 (1)	3 (3)	4	44·4
1969	302 (64)	25 (23)*	10 (8)	31	48·4
TOTAL	1,348 (123)	42 (31)	33 (31)	65	52·8†

* Outbreak

† Average

Figures in brackets indicate local cases.

TABLE III

DISTRIBUTION OF MALARIA CASES BY AGE

Age (Years)	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24	53	62	81
No. Cases	0	1	2	0	4	3	6	0	1	1	3	0	1	1	1	1
TOTAL	16							5				4				
GRAND TOTAL	25															

TABLE IV

POPULATION BY AGE GROUPS BASED ON FOCAL BLOOD SURVEYS IN KAMPONGS

Age Group	No. Blood Films Taken in April 1969						
	Male	Female	Total	No. Positive			% Positive (Parasite Rate)
				Male	Female	Total	
0 - 11 months	5	1	6	—	—	—	—
12 - 23 months	5	2	7	—	—	—	—
2 - 4 years	30	29	59	2	1	3	5·08
5 - 9 years	65	73	138	2	—	2	1·45
10 - 14 years	63	68	131	2	—	2	1·53
15+ years	162	218	380	—	1	1	0·26
TOTAL	330	391	721	6	2	8	1·11

Fig. 3. Part of house where 5 malaria cases were detected with rubber plantation in foreground where *Anopheles maculatus* was found breeding.

64% were in these age groups. Twenty-one cases or 84% were below the age of 21. These proportions are in conformity with the general population distribution of Singapore where more than 50% of the people are below the age of 21.

It is significant that 7 cases were in the 2-9 years age group although there were no cases in the infant age group. This strongly suggested local transmission on the island.

Table IV shows a parasite rate of 5·1% in the 2-4 years age group and 1·5% in the 5-9 years age group with a general parasite rate of 2·5% in the 2-9 years age group. The type of endemicity and the state of immunity in the island population was, however, not determined from spleen and parasite rates for all age groups, i.e. infants, young children, older children, adolescents and adults. However, from knowledge based on the past history of malariousness on P. Tekong, malaria was at most only at a hypoendemic level during the outbreak.

2. **Distribution by Sex**

It will be noticed from Table V that there were about twice as many males as females. From active case detections carried out on P. Tekong, in which a total of 721 people had their blood taken in the month of April alone, a male to female ratio of 0·84:1 was obtained. The preponderance of males affected can be explained by the more frequent contact outdoors between the vector *An. maculatus* and men, consistent with their behaviour (Chew, 1968).

TABLE V

DISTRIBUTION OF MALARIA CASES BY SEX

Sex	No. of Cases
Male	16
Female	9
TOTAL	25

3. **Distribution by Ethnic Groups**

Table VI shows that the distribution of cases according to ethnic groups is more or less proportionate to the population distribution of the three major ethnic groups.

TABLE VI

DISTRIBUTION OF MALARIA CASES BY ETHNIC GROUPS

Ethnic Group	No. of Cases			%	P. Tekong Population Based on Active Case Detection (%)
	Male	Female	Total		
Chinese	10	7	17	68·0	71·7
Malays	5	2	7	28·0	27·7
Indians	1	0	1	4·0	0·6
Others	—	—	—	—	—
TOTAL	16	9	25	100·0	100·0

VECTOR SITUATION

In a special vector survey on 24 and 25 February, eight breeding habitats of *An. maculatus* were located as shown in Fig. 4. These are:

1. Earth well —4th instars
2. Earth drain —3rd and 4th instars
3. Earth drain —2nd, 3rd and 4th instars
4. Earth drain —4th instars
5. Seepage drain —4th instars
6. Seepage drain —2nd and 4th instars
7. Seepage drain —4th instars
8. Seepage drain —4th instars

These habitats were located in an uncontrolled area, mostly in rubber estates (Fig. 4) and at short distances along both sides of the main tract around P. Tekong Besar. Fourteen of the 25 cases were located within quarter of a mile from the sources of breeding.

Subsequent surveys revealed further similar types of breeding habitats (usually seepages) at the sources of rivers.

Trapping of mosquitoes with human baits were carried out for four consecutive nights, commencing on 20 April, 1969. Four labourers were used in the human bait traps, two to each trap. The two traps were set up in the vicinity of the home of the second case, where by then five members in the family had malaria (Fig. 3). The traps were set up from 6 p.m. each night to 6 a.m. of the following morning. Respectively 13, 11, 7 and 7 *Anopheles* adult females were caught on the four consecutive nights. On 21 April, 12 of the 13 *Anopheles* caught were *An. maculatus*. Of the 12 females dissected, one harboured gametocytes in its freshly engorged blood in the midgut. This finding strongly indicated that transmission was occurring on the island, albeit at a low level.

Anopheles kochi was the only other *Anopheles* mosquito found breeding on the island, mostly in puddles. *An. sundaicus*, the other vector of malaria in Singapore, was not found breeding nor caught by trapping on the island. It was, therefore concluded that *An. maculatus* alone was responsible for the outbreak on P. Tekong Besar.

MEASURES TAKEN TO INTERRUPT TRANSMISSION

Measures to interrupt transmission was formulated on 24 April by a special Malaria Committee formed for the purpose. The measures formulated followed essentially those outlined by Chew (1968) for the Fuyong outbreak in 1964, i.e. epidemiological (active and passive case detections and focal blood surveys) and remedial (mass drug administration, anti-adult residual spraying and swing fogging and anti-larval oiling).

Meanwhile, susceptibility tests were carried out on 3rd and 4th instar larvae of *An. maculatus* to determine whether resistance had been developed against DDT since this insecticide had been used on the island in 1967. As results of the tests showed no sign of development of resistance, the original arrangement to use 5% DDT as a residual spray on dwellings at an application rate of 200 mg./sq. ft. was carried out.

Preparations were also made to purchase 2,000 Camoprima tablets and 2,000 Camoprima infatabs for weekly administration for 3 weeks, in view of the involvement of both *P. falciparum* and *P. vivax*. This was, however, later found to be unnecessary as the vector control measures alone were adequate to interrupt transmission temporarily.

Residual spraying was commenced on 5 May and was completed on 28 June, with a break in between (5-12 June) as a result of the late arrival of fresh supplies of DDT by the company concerned. Residual spraying was also carried out in a few kampongs in the controlled areas at the border of the uncontrolled areas. Residual spraying in the controlled areas started on 2 July and took a week to complete. A total of 375 dwelling houses and 794 huts were sprayed. These covered a population of about 2,000 and a total of 1,610 lbs. of DDT were used (Table VII).

Resurveys carried out during the period showed no further cases. A total of 2,215 blood slides were taken during the whole outbreak. Of these, 520 were repeat slides taken as a result of resurveys of several kampongs, especially Kg. Unum and Kg. Sanyongkong.

DISCUSSION

Singapore is labelled by the World Health Organization as a country which has eradicated malaria, but no eradication campaign had ever been carried out. Although it is true that the state

TABLE VII

P. TEKONG POPULATION COVERED AND NUMBER OF HABITATIONS SPRAYED WITH 5% DDT AT A RATE OF 200 mg./sq. ft. (i.e. TO POINT JUST SHORT OF RUN-OFF) MAY - JUNE, 1969

Name of Kampong	Date of Spraying	No. of Dwelling Houses	No. of Huts, etc.	Population			DDT Used (lb.)
				M	F	Total	
Kg. Permatang	May 5, 8	9	38	20	34	54	
Kg. Unum	May 5, 6, 7, 19	50	131	88	59	147	
Kg. Sungei Belang	May 7, 19, 20	19	43	63	50	113	
Kg. Semenei	May 8	6	11	16	17	33	
Kg. Sanyongkong	May 9, 10, 12, 13, 14, 16, 17, 21, 26	95	188	241	232	473	1,050 lbs.
Kg. Pangkalan Pakau	May 14, 15, 17, 27	31	47	91	80	171	(15 × 70 lb. drums)
Kg. Ayer Samak	May 17	8	22	36	22	58	
Kg. Pasir Merah	May 5	1	2	5	2	7	
Kg. Batu Koyok	May 22, 23, 26	37	72	121	98	219	
Kg. Pasir	May 28	1	4	5	4	9	
Kg. Pasir Merah	June 4, 13, 14	29	65	68	83	131	
Kg. Permatang	June 14	2	6	4	8	12	
Kg. Pasir	June 17, 18, 19, 20	40	76	100	121	221	
Kg. Pangkalan Pakau	June 19, 24	3	8	11	3	14	560 lbs.
Kg. Ayer Samak	June 20, 21, 24	9	24	19	27	46	(8 × 70 lb. drums)
Kg. Sungei Belang	June 20, 21, 24	20	40	40	39	79	
Kg. Sungei Sanyongkong	June 24	1	—	—	—	—	
Pulau Tekong Kechil	June 27, 28	14	17	42	45	87	
	GRAND TOTAL	375	794	970	924	1,874	1,610 lbs.

of malaria in the main island of Singapore is equivalent to the maintenance-consolidation phase of a Malaria Eradication Programme, this cannot be said of the offshore islands, especially P. Tekong and P. Ubin where, until recently, most of the areas were uncontrolled.

Transmission of malaria was undoubtedly occurring on these islands because of the absence of adequate control measures and their close proximity to Malaysia where malaria is known to be endemic (Huehne *et al*, 1967). Three factors apparently contributed towards local transmission on these islands: (1) a constant influx of parasite carriers from nearby endemic Johore due to the migratory habit of the island population who are mostly farmers and who have relatives across the Causeway; (2) the presence of *Anopheles* vectors, especially *maculatus*, in the large portions of uncontrolled areas where the topography and environmental conditions were ideally suited for the breeding of this vector species, and (3) the possible direct transmission of malaria via infected vectors flying or carried by wind from Malaysia, since both P. Tekong and P. Ubin are within flight range of the vectors, i.e. approximately 2·5 km. (1·5 miles).

In the Fuyong *vivax* outbreak in 1964, one outstanding feature was observed—the outbreak was preceded by the introduction of four imported *vivax* cases (Chew, 1968). In the present P. Tekong outbreak, there was at least one imported *vivax* case in early August 1968. This patient was residing at Kg. Unum and contracted malaria from Johore across the Causeway. In late June and early 1968, there were three other *vivax* cases reported from the island, two coming from the same family in Kg. Salabin. They were labelled as 'doubtful' in origin. Between August and December there were no cases reported from P. Tekong but presumably transmission was going on since it is not infrequent to find asymptomatic malaria by active case detection. In June and July 1970, there was a small outbreak of three *vivax* cases in the Ayer Rajah Road area on the main island. This was again preceded by several imported cases—7 *vivax* cases and one mixed (*vivax* and *falciparum*) case. It is therefore perhaps true to generalize, for Singapore, that outbreaks occur only when the parasite is introduced into areas with *Anopheles* vectors. This indicates that Singapore is by and large a case of "anophelism without malaria" since outbreaks were sparked off by the introduction of parasites. This is logically so since the malaria situation in Singapore now is very different from what it was about 30 years ago. The city area has become so highly urbanized that *Anopheles* vector breeding is virtually impossible. About two-thirds of the Republic are

controlled, i.e. regularly oiled with anti-larval oil. Local transmission of malaria therefore does not normally occur in the city and in the controlled areas. In the remaining third of the Republic where no oiling is done, malaria can occur, especially in the offshore islands like P. Tekong, P. Ubin and the Southern Islands, where vector breeding could be found in most months of the year.

It is also an important observation that, in all three outbreaks, *An. maculatus* was involved. In the Fuyong outbreak in 1964, only *An. maculatus* was found, and again in the present P. Tekong outbreak in 1969, only *An. maculatus* was involved. In the Ayer Rajah outbreak in 1970, both *An. maculatus* and *An. sundaicus* were found but the latter occurred in such low numbers that it could be ruled out to have played any role in the transmission of malaria, since the sporozoite rate in nature of *An. sundaicus* is extremely low (about 1 in 2,000) in contrast to the high natural infection rate of *An. maculatus* (about 1 in 200) (Reid, 1968).

Yet another interesting observation which held true in all three outbreaks is that, within flight range of the breeding grounds of *An. maculatus*, human hosts were found scattered in all directions in proportionately larger numbers than other animal hosts. Vector preference for other animal hosts was thus obviated by their low numbers and this accounted for their deviation to human hosts, thus causing transmission.

The present P. Tekong outbreak, apparently comprised two different episodes since two parasite species, *P. vivax* and *P. falciparum*, were involved, the latter widely distributed over the island but with a distinct focus at Kg. Unum and the former initially confined to Kg. Sanyongkong but later spread to Kg. Ayer Samak Darat. The majority of these cases occurred in April.

P. falciparum in P. Tekong has recently been found to be resistant to chloroquine (Ng *et al*, 1969) which is therefore by itself no more suitable for treatment of this parasite in Singapore. Colbourne *et al* (1970) recommended for its treatment the use of a combination of chloroquine, pyrimethamine and a long acting sulphonamide. Recurrence after such treatment may, however, still occur.

Chew (1968) has reviewed and appraised the anti-malarial control measures adopted in Singapore, and has pointed out the need to provide permanent drainage in areas where this is justified, especially rural areas. Such permanent drainage measures, i.e. the construction of open channel

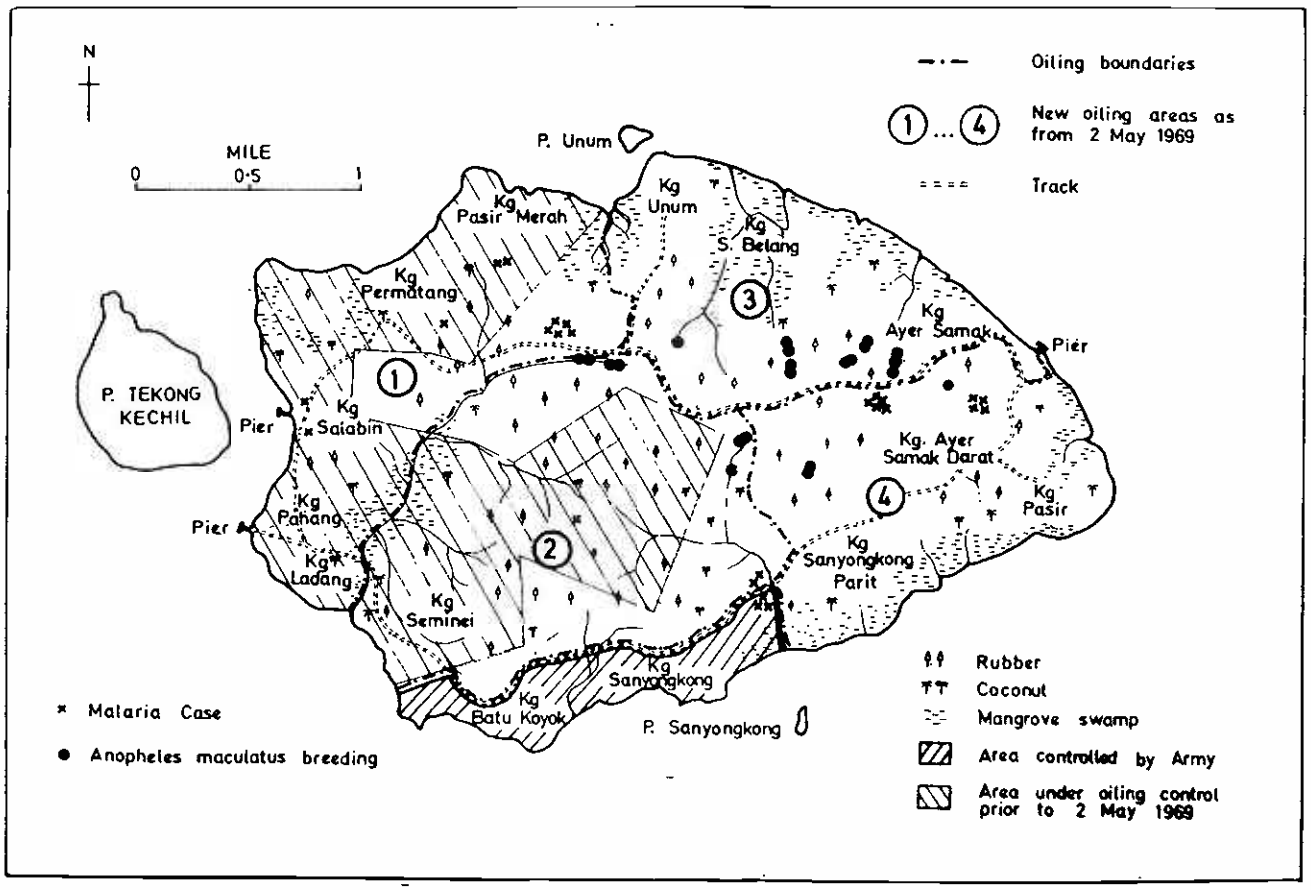

Fig. 4. Map of P. Tekong showing location of malaria cases and *Anopheles maculatus* breeding in the 1969 malaria outbreak, together with old and new oiling areas and other features.

drains and subsoil pipes, have a special place in P. Tekong and P. Ubin. We recommended these permanent measures soon after the outbreak was established, i.e. in May 1969, and since then steps had been taken to bring both P. Tekong and P. Ubin under complete oiling control as well as to install permanent drains.

With effect from May 1969, the whole island of P. Tekong came under oiling control. The island was divided into four oiling areas (Fig. 4). Each oiling area is now oiled on a weekly cycle by a team of one oiling mandore and 8 oilers, supervised by a Public Health Overseer. The remaining two working days in the week are used for maintenance of drains and other oiling areas. With effect from November 1970, the Public Health Engineering Branch began laying of subsoil pipes and outlets for these pipes. Since the placing of the island under complete oiling control and the initiation of permanent drainage measures, there was not even a single malaria case on the island in 1970. The present malaria situation in P. Tekong can be said to be well under control.

ACKNOWLEDGEMENTS

We wish to thank Mr. Tan Teck Khim, Permanent Secretary (Special Duties), Ministry of Health, for permission to publish and to colleagues in the Public Health Division who have helped in the investigations and control of the outbreak.

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