ERADICATION OF MALARIA FROM SINGAPORE

K T Goh

SYNOPSIS

The comprehensive system of antimalaria drainage and oiling programme developed since 1911 has been very successful in the control of malaria in Singapore. In the 1970's, there was a resurgence of local malaria, as massive land development created environmental conditions favourable for the breeding of *Anopheles* vectors while the need to import labourers from malarious countries further increased the risk of transmission. A new control strategy with emphasis placed on epidemiological and vector surveillance was implemented in 1975. This has been shown to be efficient in recognising the primary focus of transmission at an early stage for epidemic control measures to be taken to prevent secondary transmission of infection. Singapore was certified by the WHO on 22 Nov 82 as having achieved the status of malaria eradication. However, vigilance must be maintained indefinitely as the country remains both receptive and vulnerable to the reintroduction of malaria.

INTRODUCTION

On 23 May 1980, Singapore applied to the World Health Organisation (WHO) for the certification of malaria eradication from the country. This was followed by the visit of a senior WHO malariologist from 25 August to 6 September 1980. The objectives of the visit were to undertake a preliminary review of the relevant documentation substantiating achievement of malaria eradication, and to look into the effectiveness of malaria surveillance operations, with particular reference to:

(a) comprehensiveness and efficacy of the case detection mechanism;
(b) reliability of the microscopic diagnosis of blood smears;
(c) thoroughness of epidemiological investigations and satisfactoriness of the epidemiological situation;
(d) adequacy of preventive and remedial action taken on discovery of cases; and
(e) adequacy of the general health services and of the system of notification and epidemiological follow-up for the prevention of the re-establishment of malaria.

**Quarantine and Epidemiology Department
Ministry of the Environment
Princess House
Alexandra Road
Singapore 0315**

K T Goh, MBBS, M Sc
Head

The report of the visit was carefully examined by the WHO Regional Office in Manila and then submitted to the WHO Headquarters in Geneva. In view of the favourable findings, a three-member WHO Malaria Evaluation Team comprising a malariologist, a public health administrator and an entomologist visited Singapore from 7 April to 4 May 1981. A comprehensive programme was drawn up for the team members to discuss with senior officials of both the Ministry of Health and Ministry of the Environment and relevant data and reports made freely accessible to them. Arrangements were also made for them to visit the malaria receptive areas in particular, those areas where cases have been experienced more recently. They were briefed on the epidemiological and vector control activities in operation in Singapore, the hospital and primary health care services, public health laboratory services, military health services and the system of collection and analysis of health statistics. The areas visited included Sentosa, Pulau Tekong, Changi, Bedok, Bukit Timah quarry (Rifle Range), Western Catchment area, Tampines and Pasir Ris reclaimed land, Jalan Tiga Ratus, Whampoa/Kallang area, Kampong Java Road Store (where vector control equipments and materials are kept) and the Barter Trade Centre. They also examined school children in some of the areas visited.

A comprehensive report of the team's findings was submitted through the WHO Regional Office in Manila for scrutiny by the WHO Expert Committee on Malaria. At the recommendation of the Director of the Regional Office for the Western Pacific and endorsed by the Expert Committee on Malaria, the name of Singapore was entered on 22 November 1982 in the Official Register of areas where malaria has been eradicated. The other countries in the register are the United States of America, Puerto Rico, Virgin Islands (USA), Dominica, Venezuela, Grenada and Carriacou, Jamaica, Saint Lucia, Trinidad and Tobago, Cuba, Hungary, Spain, Bulgaria, Poland, Romania, Italy, Netherlands, Portugal, Yugoslavia, Cyprus, Taiwan, Mauritius, La Reunion and Australia.

The confirmation of malaria eradication refers not only to the situation at a given point of time, but more importantly it concerns with the probability that the malaria free status ca be maintained in the infinite future. The WHO is confident that Singapore, with its comprehensive health service networks in the urban setting and with its effective malaria vigilance mechanism that has proved adequate in preventing the reintroduction of local malaria transmission in the past six years, is confident that this state can be maintained.

This paper gives a review of the evolution of the various phases of malaria control activities which ultimately led to the eradication of the disease from the country. The epidemiological situation during the period 1970 — 1982 and the measures taken to prevent the reintroduction of malaria into Singapore are also described.

Evolution of the antimalaria programme

Malaria was rampant in early Singapore (1). During the period 1907 — 1910, about 2,000 deaths were reported annually. The disease was the second leading cause of death (after tuberculosis) in 1908. In 1911, a large epidemic claimed 2,930 lives and at its peak, about 20 deaths a day were reported (2).

Malaria control activities in Singapore began in 1911 when the eminent malariologist, Sir Malcolm Watson, introduced the antimalaria drainage system in a highly receptive area in Telok Blangah (3 — 4). Following its dramatic success in the control of malaria in that area, the drainage system was immediately extended to other receptive areas within the Municipality by Hunter and to the rural areas by Scharff in 1921 (5). With the cutting down of forests for cultivation and the opening of quaries, malaria epidemics continued to occur. An Anti-mosquito Ordinance was passed in 1921 and quinine tablets were made available to the population at risk. However, it was the comprehensive network of antimalaria drains and the oiling programme that effectively brought the malaria epidemics under control. Malaria mortality rate and spleen rate were markedly reduced (6 — 11).

During the Second World War, complete disruption of antimalaria control activities again gave rise to widespread epidemics, and 2771 deaths were reported in 1945 alone (12). The malaria situation was quickly brought under control during the postwar period and there were practically no deaths from malaria. In the mid 1950s, indigenous malaria was believed to have been eradicated in the main island of Singapore (13).

A localised outbreak of 29 cases in 1964 in an *Anopheles maculatus*-receptive area at Fuyong Estate led to a review of the national malaria control activities (14). It was realised that the general health services should also participate in the control programme by eliminating the parasite reservoir through both active and passive case detection. Malaria became a notifiable disease in February 1966, and a malaria registry was maintained. All notified cases were investigated. Based on the epidemiological and entomological information collected, the cases were classified according to the origin of infection, and appropriate actions taken. Legislation to control the breeding of *Anopheles* vectors was tightened under the Destruction of Disease Bearing Insect Act, 1968. Contractors of major development projects could be prosecuted for failure to take adequate steps to eliminate all vector breeding habitats.

A comprehensive review of the malaria and mosquito control activities was undertaken by Professor M J Colbourne in 1965. In his opinion, malaria control in Singapore had been exceptionally successful (15). The malaria situation then was believed to be equivalent to that of the late consolidation phase of a classical malaria eradication programme.

Malaria transmission continued to occur in the offshore islands (16). An outbreak of 25 cases was reported in another *Anopheles maculatus* — receptive area in Pulau Tekong in 1969 (17). In the same year, the first chloroquine-resistant falciparum malaria in Singapore was detected in the island (18-20). Permanent antimalaria drainage system was extended to Pulau Tekong in 1970 and subsequently to Pulau Ubin in 1973. This has successfully terminated malaria transmission in these islands.

As the result of rapid urbanisation and industralisation, transmission of indigenous malaria recurred in the main island of Singapore. Massive land development created environmental conditions favourable for the breeding of vectors, while the need to import labourers from malarious countries further increased the risk of malaria

transmission. Precautionary measures against the breeding of vectors were undertaken right from the planning stage of major development projects; eg. Kranji reservoir project, and foreign labourers repeatedly screened for malaria parasites (21). In spite of these actions, a large localised outbreak of 55 cases occurred in Telok Blangah/Pasir Panjang and the offshore islands of Sentosa and Pulau Brani from May to November 1974 (22), followed by an even larger localised outbreak of 82 cases in a densely populated urban area at Whampoa/Kallang from December 1974 to March 1975 (23).

Epidemiological situation during the period 1970 — 1975 (24 — 28)

A total of 2,339 cases were notified during the period 1970-1975. Of these, 69% to 86% were imported. There were 18 cases of induced malaria. The mortality from malaria was low, with two to three deaths reported per year. The case fatality rate varied from 0.24% to 0.86%. All deaths were due to *P. falciparum* infection. The two predominant parasite species were *P. vivax* (62.7%) and *P. falciparum* (33.0%). Infections with *P. malariae* were uncommon (0.6%), while mixed infections accounted for the remaining proportion of the cases.

The majority of the infections contracted locally involved males in the 15 — 34 year age group. Transmission occurred throughout the year. In the Southern Islands, the peak period of transmission was in August. This was attributed to the increased population movement between these offshore islands and the malarious areas of the Rhio Archipelagoes in association with the annual festive occasions during this period. In fact, malaria contracted in the Southern Islands accounted for 20.8% of the local cases as these offshore islanders were related socio-economically with those of the neighbouring endemic islands. In the main island, the cases were distributed along the east and west coastal regions. Localised outbreaks occurred in the receptive areas in Siglap, Pasir Panjang, Telok Blangah and the offshore islands of Pulau Ubin, Pulau Tekong, Sentosa, Pulau Brani and Pulau Semakau. Of great concern were the outbreaks in several urbanised areas; viz Whampoa/Kallang, Macpherson and Jalan Kukok/Outram estates in 1975. The epidemiological features of these localised outbreaks are shown in Table 1.

In 1974, of 128 cases followed up at one month after discharge from hospitals, 2.6% were still positive for malaria parasites. Three chloroquine-resistant falciparum malaria were also detected; two from a family at Pulau Tekong, and one from Sentosa.

The new control strategy

The large outbreak of urban malaria at Whampoa/Kallang in 1974/75 together with the report of chloroquine-resistant falciparum malaria in the offshore islands led to another comprehensive review of the malaria control activities in Singapore. In several localised outbreaks, control measures implemented were too slow to prevent secondary cases from arising.

It was decided that more aggressive steps should be taken to prevent local malaria transmission and a new control strategy was evolved. The existing system of vector surveillance and control was further strengthened and stepped up. Maps of malaria receptive areas are updated six-monthly. As more than 93% of the existing antimalaria drainage system have become obsolete with the rapid pace of national development, the oiling programme was extended to other uncontrolled areas where vectors have been consistently detected. More than two-thirds of the country are covered by the weekly oiling cycle, while the highly receptive and vulnerable areas are oiled more frequently to eradicate all sources of vector breeding. Temporary shelters housing foreign contract workers are also routinely residual-sprayed with insecticide. About $2.25 million are spent annually for this elaborate vector surveillance and control programme (29). Consequently, the vector population has virtually been eradicated. At present, only about 13% of the 616 sq km of the country can support the breeding of three local vectors; viz. *Anopheles maculatus, Anopheles sundaicus and Anopheles letifer* (30).

Epidemiological surveillance has also been stepped up. The WHO's criteria for the classification of malaria was adopted (31). As soon as transmission is suspected, epidemic control measures are immediately implemented to eliminate the focus of infection. These include active and passive case detection and mass blood surveys which continue until the reservoir of infection has been detected and transmission has ceased; intensified larvicidal measures; and aerial and residual spraying with insecticides. Special attention is also given to imported cases in receptive areas.

Epidemiological situation during the period 1976 — 1982 (32-35)

The number of local malaria cases continued to decline (Fig. 1) Between 86.9% and 97.9% of the reported cases were imported (Table 2). *P. vivax* remained the predominant parasite species (Table 3). All the ten malaria deaths reported during this period were from *P. falciparum* infections. Eight of them were imported infections, while the other two were contracted in the offshore islands (one from Pulau Sebarok in 1976, and the other from Sentosa in 1977). High morbidity rates were noted in the 25 — 44 year age group (Table 4), with the male to female ratio of 4.9:1. The ethnic-specific morbidity rate for Indians was 8.4 times higher than that of Chinese and 4.7 times that of Malays (Table 5), because of the increasing number of imported cases from the Indian subcontinent (from 36 cases in 1976 to 151 cases in 1982) (Table 6). On the other hand, the number of imported cases from Malaysia had decreased markedly following the successful implementation of the malaria eradication programme in the State of Johore.

From an analysis of the imported cases, it was found that between 27% and 62% of the cases were local residents who contracted the disease in malaria endemic countries without adequate chemoprophylaxis (Tables 7 & 8); eg. in 1978, nine of 38 holiday makers contracted malaria after visiting a malarious holiday resort. The number of imported cases amongst foreign contract workers rose more than twenty times from five in 1976 to 114 in 1982 following increased recruitment of labourers from the Indian subcontinent. This category of foreigners is of special epidemiological importance because they had been responsible for both sporadic transmission and localised outbreaks in malaria receptive areas.

Table 1

Main epidemiological features of localised malaria outbreaks in Singapore, 1970 — 1982

Period	Locality	No. of Cases (Deaths)	Sex Ratio M : F	% of Cases above 15 years	Vectors found	Parasite species	Remarks
22 Feb 71 to 18 Mar 71	Pasir Panjang	7	2 5 : 1	57 1%	*Anopheles sundaicus* (adults) *Anopheles maculatus* (larvae)	*P. vivax*	Adult vectors not infected
22 Jul 71 to 25 Aug 71	Pasir Panjang	841)	All males	75%	–	*P falciparum*	Associated with Southern Islands outbreaks
23 Jun 71 to 31 Aug 71	Southern Islands (P Semakau Sentosa P Brani	12	5 : 1	46 7%	–	*P. vivax* *P falciparum*	Two cases were national servicemen attached to Sentosa
16 May 71 to 5 Aug 71	Pulau Ubin	5	All males	20%	*Anopheles sundaicus* (larvae) *Anopheles maculatus* (larvae)	*P vivax* *P falciparum*	One case from P Tekong working in a quarry at P Ubin
4 Dec 72 to 13 Jan 73	Pulau Ubin	19	2 8 : 1	89 5%	*Anopheles maculatus* (larvae & adults)	*P vivax* *P. falciparum* *P malariae*	Six cases attached to Outward Bound School nine campers and one visitor Residual spraying carried out Permanent anti-malarial drains laid in November 1973
26 Sep 73 to 26 Feb 74	Upper East Coast	7	1 3 : 1	85 7%	*Anopheles sundaicus* (larvae)	*P. vivax* *P. falciparum*	Extensive land reclamation projects in progress
May to November 1974	Telok Blangah Pasir Panjang Sentosa P Brani	55	2 9 : 1	74 5%	*Anopheles sundaicus* (larvae & adults)	*P vivax* *P falciparum* Mixed infection	Land reclamation in P Brani 29 cases in Sentosa 11 in P Brani 15 in Telok Blangah Pasir Panjang
13 Dec 74 to 21 Mar 75	Whampoa Kallang	82	1 2 : 1	75 6%	*Anopheles letifer* (adults) *Anopheles sundaicus* (larvae & adults)	*P vivax* *P falciparum* Mixed infection	The outbreak was traced to an imported case of vivax malaria involving a foreign worker living in the area
22 Apr 75 to 13 May 75	Ayer Rajah	4	3 : 1	75%	–	*P. vivax* *P falciparum*	Two foreign contract workers found to be parasite carriers
15 Jun 75 to 16 Jul 75	Pulau Brani	4	All males	75%	–	*P vivax*	Land reclamation in progress. Source of infection probably Vietnam refugees stationed at St John's Island
4 Jul 75 to 6 Jul 75	Pipit Road/ Lorong Kenah	5	1 5 : 1	80%	–	*P falciparum*	No parasite carrier detected during mass blood surveys
19 Aug 75 to 20 Aug 75	Jalan Kukoh/ Outram Park	5	1 : 1 5	40%	–	*P vivax* *P falciparum*	No parasite carrier detected during mass blood surveys
21 Aug 75 to 4 Sep 75	Sentosa	6	All males	33 3%	–	*P vivax* *P falciparum*	Construction of a salt lake in progress
25 Oct 75 to 30 Nov 75	Pulau Semakau	6	1 : 1	83 3%	*Anopheles sundaicus* (larvae)	*P vivax* *P. falciparum*	No secondary case occurred following implementation of epidemic vector control measures
8 Jun 76 to 16 Jun 76	Pulau Semakau	5	4 : 1	40%	*Anopheles sundaicus* (larvae)	*P vivax*	One gametocyte carrier detected at P Sebarok
2 Aug 76 to 6 Sep 76	East Coast/ Chai Chee	8	7 : 1	100%	*Anopheles sundaicus* (larvae)	*P vivax*	Reservoir of infection traced to four imported cases in the area
8 Aug 76 to 28 Aug 76	Changi Village	7	All males	100%	*Anopheles sundaicus* (larvae)	*P. vivax* *P. falciparum* Mixed infection	Two foreign contract workers (one gametocyte carrier) found to be the reservoir of infection
1 Aug 77 to 14 Aug 77	Pulau Tekong	3	2 : 1	33 3%	*Anopheles letifer* (larvae)	*P vivax*	Construction of reservoir Two imported falciparum malaria cases detected
18 Aug 77 to 22 Aug 77	Sentosa	4	All males	100%	–	*P. vivax* *P. falciparum*	No parasite carrier detected
18 Aug 79 to 1 Sep 79	Sentosa	3	2 : 1	100%	–	*P. falciparum*	No parasite carrier detected
5 Oct 80 to 18 Oct 80	Siak Kuan Road	5	4 : 1	80%	*Anopheles sundaicus* (larvae & adults)	*P vivax*	Reservoir of infection traced to an imported case (a foreigner)
14 Jan 81 to 15 Jan 81 and 22 Apr 81 to 8 May 81	Sentosa	6 * –	2 : 1	100%	*Anopheles sundaicus* (larvae & adults)	*P vivax*	No parasite carrier detected
17 Apr 81 to 22 Apr 81	Pasir Panjang Power Station Quarters	5	1 5 : 1	80%	*Anopheles sundaicus* (larvae)	*P falciparum*	Two of the cases picked up during active case detection No parasite carrier detected

Fig. 1 Reported malaria cases in Singapore, 1963 — 1982

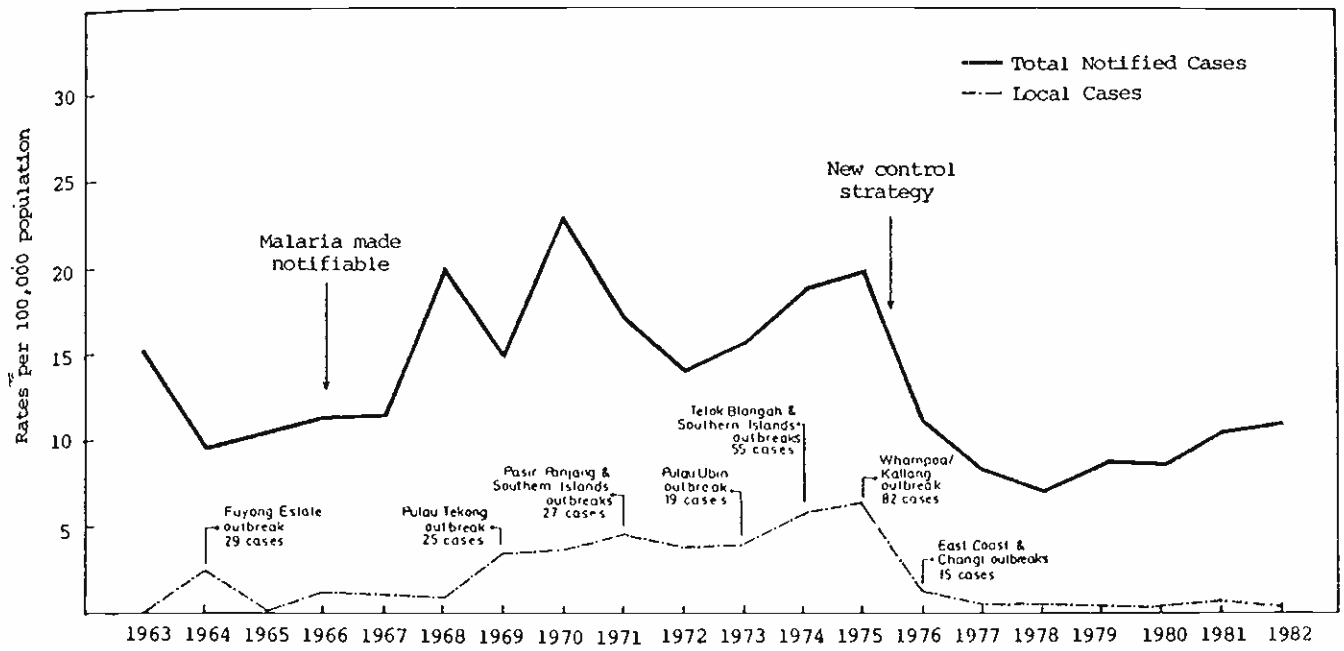


Table 2

Classification of reported malaria cases in Singapore, 1976 — 1982

Classification	1976 (%)	1977 (%)	1978 (%)	1979 (%)	1980 (%)	1981 (%)	1982 (%)
Imported	218 (86.9)	174 (94.6)	159 (95.8)	202 (97.1)	195 (97.5)	244 (93.5)	276 (97.9)
Introduced	30 (12.0)	9 (4.9)	7 (4.2)	5 (2.4)	5 (2.5)	17 (6.5)	4 (1.4)
Induced	1 (0.4)	0 (0)	0 (0)	1 (0.5)	0 (0)	0 (0)	2 (0.7)
Relapsing *	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cryptic	2 (0.8)	1 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Indigenous	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	**251 (100)**	**184 (100)**	**166 (100)**	**208 (100)**	**200 (100)**	**261 (100)**	**282 (100)**

N.B.

"Imported" : as shown by tracing the case to its origin : in a malarious area outside Singapore.

"Induced" : as shown by its relation to a blood transfusion with an appropriate interval, or to another form of parenteral inoculation to which infection could be properly attributed.

"Relapsing" : a relapse of a pre-existing infection as shown by the history of the case and the absence of any associated cases in the neighbourhood of its origin.

"Introduced" : directly secondary to a known imported case.

"Cryptic" : isolated and not associated with secondary cases, as determined through appropriate epidemiological investigation, including a mass blood survey after the expiry of the incubation interval.

"Indigenous" : a malaria infection which has been proved or cannot be disproved to be due to recent local transmission.

*An imported relapsing case is classified as an imported case:-
1976 — data not available
1977 — 44 cases
1978 — 37 cases
1979 — 80 cases
1980 — 45 cases
1981 — 48 cases
1982 — 127 cases

(Source: Black RH:Manual of epidemiology & epidemiological services in malaria programmes WHO, Geneva, 1968 : 120)

Table 3

Distribution of malaria parasites species in Singapore, 1976 — 1982

Parasite species	1976 (%)	1977 (%)	1978 (%)	1979 (%)	1980 (%)	1981 (%)	1982 (%)
P. vivax (P.v.)	167 (66.5)	138 (75.0)	113 (68.7)	156 (75.0)	157 (78.5)	179 (68.5)	225 (79.8)
P. falciparum (P.f.)	76 (30.3)	42 (22.8)	47 (28.3)	47 (22.6)	41 (20.5)	73 (28.0)	51 (18.1)
P. malariae (P.m.)	3 (1.2)	1 (0.5)	1 (0.6)	3 (1.4)	0 (0)	7 (2.7)	0 (0)
Mixed (P.v. + P.f.)	5 (2.0)	3 (1.6)	5 (3.0)	2 (1.0)	2 (1.0)	2 (0.8)	6 (2.1)
Unknown	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	**251 (100)**	**184 (100)**	**166 (100)**	**208 (100)**	**200 (100)**	**261 (100)**	**282 (100)**

Table 4

Age-sex distribution and age-specific morbidity rate of malaria cases in Singapore, 1976 — 1982

Age Group \ Sex	Male	Female	Both Sexes (%)	1980 Census* population	Morbidity Rate per 100,000
0 — 4	9	9	18 (1.2)	193,684	9.4
5 — 14	41	22	63 (4.1)	459,439	13.7
15 — 24	377	80	457 (29.4)	583,612	78.3
25 — 34	432	71	503 (32.4)	464.571	108.3
35 — 44	221	24	245 (15.8)	267,242	91.7
45 — 54	123	37	160 (10.3)	200,381	79.8
55 — 64	64	12	76 (4.9)	131,092	58.0
65+	22	8	30 (1.9)	113,924	26.3
TOTAL	**1289**	**263**	**1552 (100)**	**2,413,945**	**64.3**

*Source: Dept of Statistics, Singapore

Table 5

Ethnic distribution and ethnic-specific morbidity rate of reported malaria cases in Singapore, 1976 — 1982

Ethnic group	Male	Female	Both Sexes (%)	1980 Census* population	Morbidity Rate per 100,000
Chinese	357	74	431 (27.8)	1,856,237	23.2
Malays	107	39	146 (9.4)	351,508	41.5
Indians	219	81	300 (19.3)	154,632	194.0
Others	606	69	675 (43.5)	51,568	1308.9
TOTAL	**1289**	**263**	**1552 (100)**	**2,413,945**	**64.3**

*Source: Dept of Statistics, Singapore

Table 6

Imported malaria cases in Singapore by geographical area of origin, 1976 — 1982

Geographical area	1976 (%)	1977 (%)	1978 (%)	1979 (%)	1980 (%)	1981 (%)	1982 (%)
Southeast Asia	182 (83.5)	110 (63.2)	103 (64.8)	97 (48.0)	91 (46.7)	141 (57.8)	121 (43.8)
Indian Sub-continent	36 (16.5)	60 (34.5)	47 (29.6)	92 (45.5)	81 (41.5)	92 (37.7)	151 (54.7)
Pacific region	0 (0)	1 (0.6)	5 (3.1)	3 (1.5)	20 (10.3)	6 (2.5)	4 (1.4)
Africa	0 (0)	3 (1.7)	3 (1.9)	7 (3.5)	2 (1.0)	5 (2.0)	0 (0)
Middle East	0 (0)	0 (0)	1 (0.6)	3 (1.5)	1 (0.5)	0 (0)	0 (0)
TOTAL	**218 (100)**	**174 (100)**	**159 (100)**	**202 (100)**	**195 (100)**	**244 (100)**	**276 (100)**

Table 7

Classification of imported malaria cases in Singapore, 1976 — 1982

Classification	1976 (%)	1977 (%)	1978 (%)	1979 (%)	1980 (%)	1981 (%)	1982 (%)
Local residents who contracted malaria overseas	104 (47.7)	108 (62.1)	82 (51.6)	87 (43.1)	81 (41.5)	79 (32.4)	74 (26.8)
Tourists from other countries	42 (19.3)	20 (11.5)	19 (12.0)	12 (5.9)	25 (12.8)	38 (15.6)	21 (7.6)
Foreigners seeking medical treatment in Singapore	21 (9.6)	17 (9.8)	18 (11.3)	21 (10.4)	20 (10.3)	39 (15.9)	32 (11.6)
Work Permit/ Employment Pass Holders	5 (2.3)	5 (2.8)	10 (6.3)	42 (20.8)	29 (14.9)	51 (20.9)	114 (41.3)
Other categories of foreigners	46 (21.1)	24 (13.8)	30 (18.9)	40 (19.8)	40 (20.5)	37 (15.2)	35 (12.7)
TOTAL	**218 (100)**	**174 (100)**	**159 (100)**	**202 (100)**	**195 (100)**	**244 (100)**	**276 (100)**

Table 8

Epidemiological characteristics of local residents who contracted malaria overseas, 1977-1982

	1977	1978	1979	1980	1981	1982
Purpose of travel						
Social visits	75	48	59	54	39	55
Business travel/Employment	24	19	21	21	16	15
Servicemen	0	0	0	4	7	2
Tourists	9	15	7	2	17	2
Chemoprophylaxis						
Took complete course of chemoprophylaxis	3	0	0	3	6	9
No chemoprophylaxis	94	74	77	72	69	68
Irregular/incomplete chemoprophylaxis	11	8	10	6	4	6
Ethnic group						
Chinese	43	45	34	36	44	33
Malays	12	8	13	5	6	8
Indians	52	29	39	40	29	33
Others	1	0	1	0	0	0
TOTAL CASES	**108**	**82**	**87**	**81**	**79**	**74**

About two-thirds of the imported cases developed fever within six weeks after entry into Singapore. Unlike primary imported *P. vivax* infections, relapsing vivax malaria could be expected up to 30 weeks after leaving malaria endemic areas (Table 9).

Most of the local transmission occurred in the east coastal region and the offshore islands (Fig. 2), especially between the months of May and November (Fig. 3). The rapid development of the Southern Islands into industrial and recreational complexes and resettlement of the population in the main island have helped to eliminate both potential vector breeding habitats and the risk of malaria transmission (Fig. 4).

International cooperation such as the annual Malaysia-Singapore Border Health Conference and the WHO-sponsored bi-annual Indonesia-Malaysia-Singapore Malaria (Border) Meeting also contributed to the reduction in the incidence of malaria in Singapore during this period.

Table 9

Imported malaria cases by interval between period of entry and onset of illness and by parasites species, 1982

Interval in weeks \ Parasite species	P.v.		P.f.	P.v. + P.f.	TOTAL	%
	Imported	Imported relapsing				
<1	46	4	23	2	75	27.2
1 — 2	33	12	19	0	64	23.2
3 — 4	15	8	5	2	30	10.9
5 — 6	2	10	2	1	15	5.4
7 — 10	0	15	0	0	15	5.4
11 — 14	0	12	0	0	12	4.4
15 — 18	0	5	0	0	5	1.8
19 — 22	0	15	0	1	16	5.8
23 — 26	0	20	0	0	20	7.2
27 — 30	0	24	0	0	24	8.7
TOTAL	**96**	**125**	**49**	**6**	**276**	**100.0**

P.v. = *Plasmodium vivax*

P.f. = *Plasmodium falciparum*

Fig. 2 Geographical distribution of introduced malaria cases in Singapore, 1976 — 1982

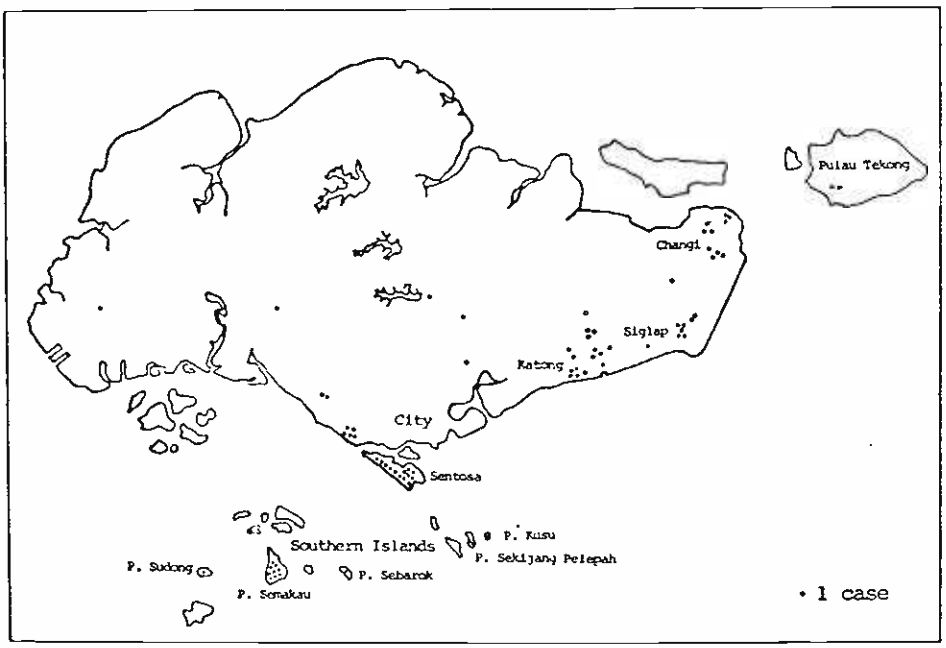


Fig. 3 Monthly distribution of malaria cases in Singapore, 1976 — 1982

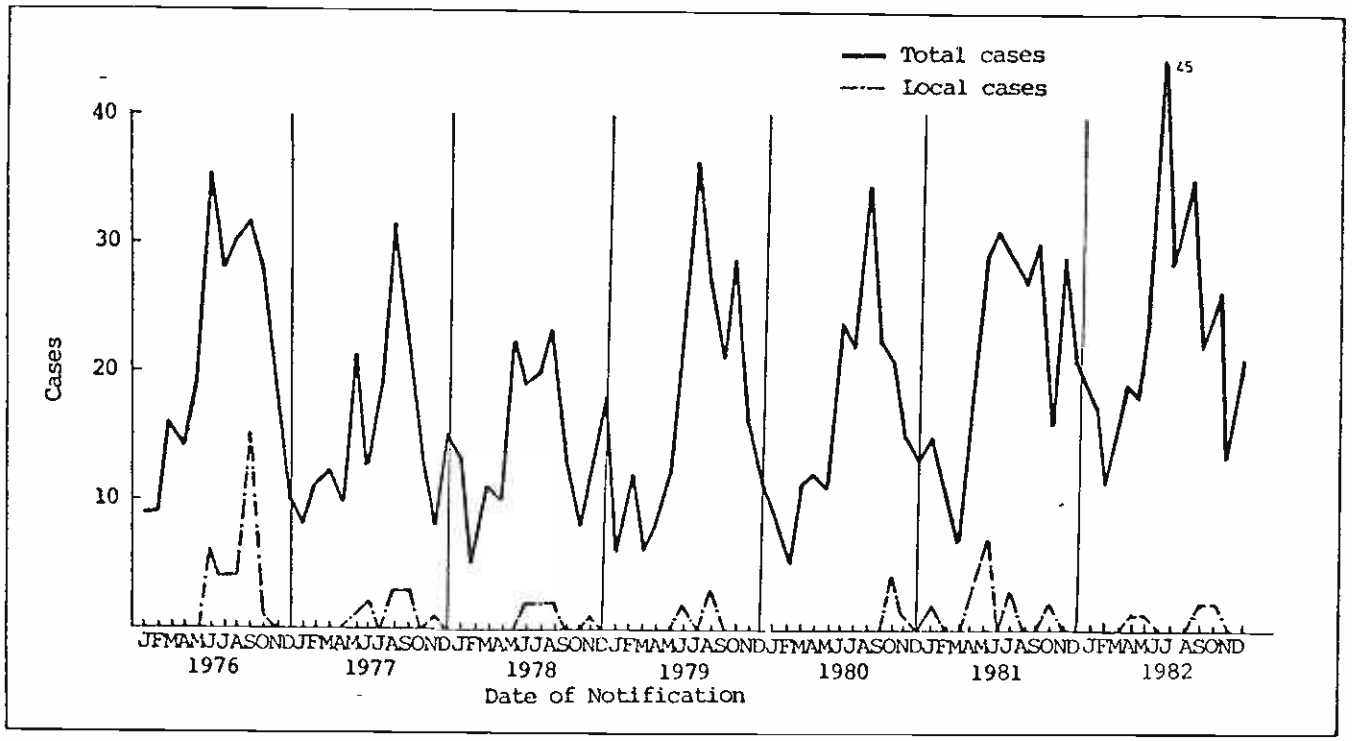
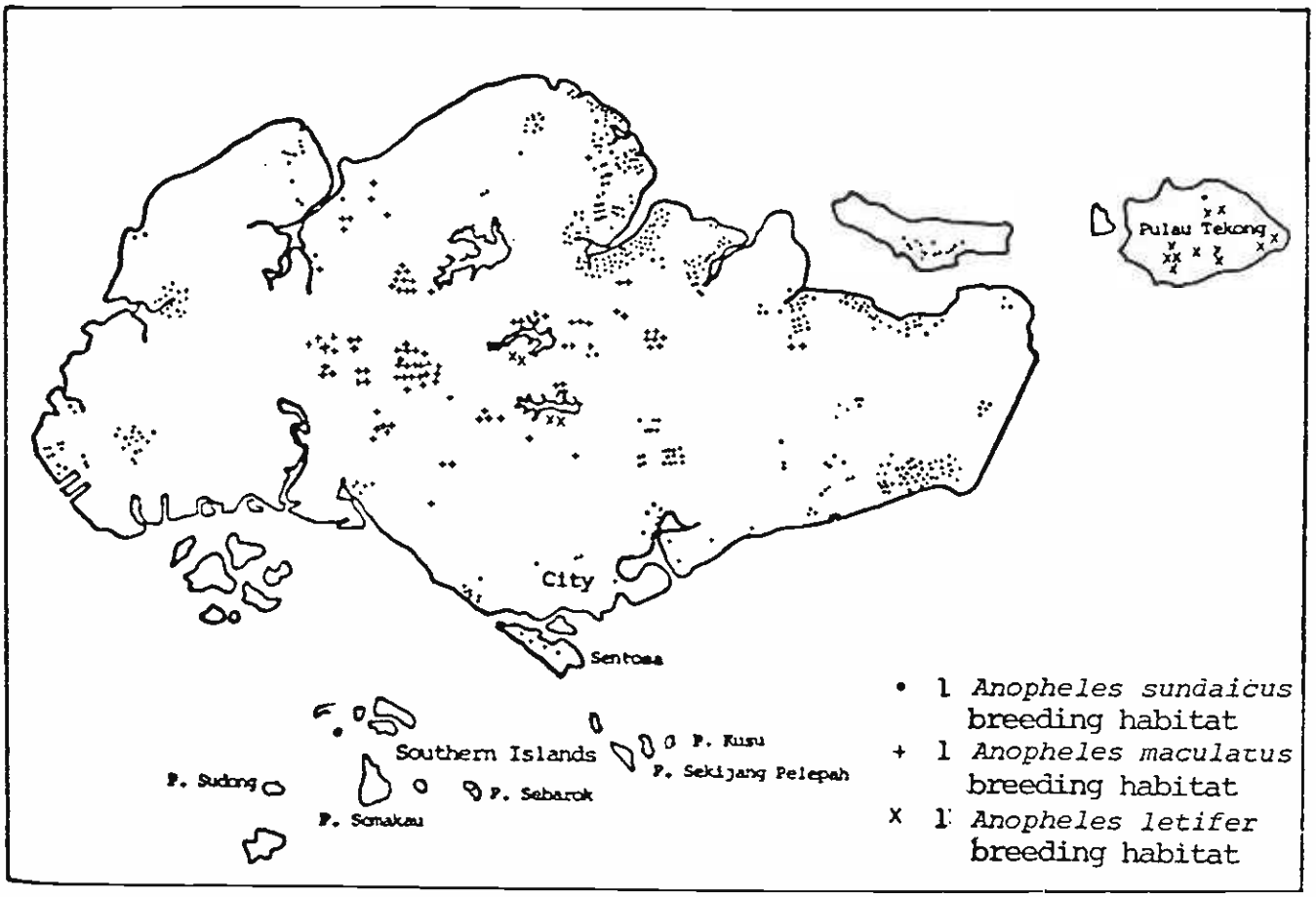


Fig. 4 Geographical distribution of malaria vectors in Singapore, 1976 — 1982



Localised malaria outbreaks 1976-1981 (36)

In most foci of transmission, *Anopheles sundaicus* were either not found or were present in low numbers. Although this *Anopheles* species is known to be a less efficient vector than *Anopheles maculatus* (37), it was the only vector detected in outbreak areas in recent years.

The localised outbreaks described below illustrates the vulnerability of Singapore to the reintroduction of malaria from importation of cases and influx of asymptomatic parasite carriers. The outbreak areas were receptive because land development provided suitable conditions for the propagation of *Anopheles sundaicus*. Prompt notification of malaria cases by medical practitioners (by telephone as soon as diagnosis was confirmed, followed by written notification) enabled the outbreak to be identified at an early stage so that immediate epidemic vector control measures could be planned and implemented. The outbreaks were quickly contained and no secondary cases occurred.

Changi outbreak

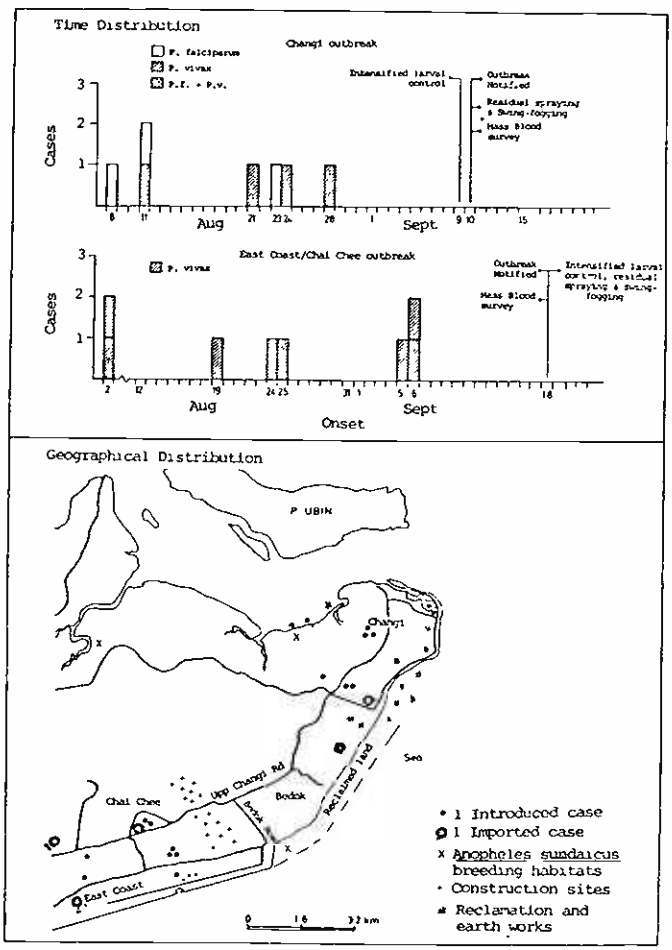
On 6 September 1976, a 19-year national serviceman from Changi Air Base was found to have malaria with onset of symptoms on 24 August 1976. Three days later, another six malaria cases from Changi were notified with onsets between 8 and 28 August 1976. Epidemiological investigations showed that all these cases were infected at various localities in Changi. Three were national servicemen from Changi Air Base, one was an army officer from Selarang Barracks, two were engineers involved in Changi airport project (and staying at Wyton Road) and one was an inmate of Telok Paku Drug Rehabilitation Centre.

An outbreak was recognised on 10 September 1976. Adulticidal vector control measures were immediately organised and implemented between 10 and 18 September 1976 at three focal points where these cases occurred. More than 1,200 premises were swing-fogged with 0.2% bioresmethrin from 'Reslin 10/10' and 1,400 premises were residual-sprayed with 5% DDT emulsion. These were carried out by the Vector Control and Research Department and Katong District of the Environment Ministry, assisted by the Hygiene and Malaria Unit, MINDEF.

An sundaicus was detected in a fish pond at Kampong Loyang on 6 August 1976, approximately 2.4 km from the first case at Wyton Road. No adult vectors were trapped. All contract workers at Changi were screened by the Epidemiology Unit. Of the 569 blood films taken, one from a 24-year old asymptomatic foreign contract worker was positive for *P. falciparum*.

The different malaria parasites species detected *(P. vivax* and *P. falciparum)* suggest more than one index case for this outbreak. The index case for the three *P. falciparum* cases could have been the asymptomatic carrier. For vivax cases, another foreign contract worker (an imported case) at Wing Loong Road, with onset on 4 August 1976 and isolated on 7 August 1976, could have been the origin of infection (Fig. 5).

Fig. 5 Malaria outbreaks at Changi and East Coast/Chai Chee, 1976



East Coast/Chai Chee outbreak

Locally contracted malaria cases at Chai Chee (two cases in one family) and Kee Sun Road (one case) were reported in August with onset of fever between 19 and 25 August 1976. On 16 September, another three cases (two in one family at Woo Mun Chew Road and one at Telok Kurau) with onsets on 5 September, 6 September and 1 August 1976 respectively, were notified. On 17 September 1976, a blood film taken from an asymptomatic home contact at Woo Mun Chew Road was positive for *P. vivax*. Epidemiological investigations showed that all the vivax cases were infected at these localities situated not more than 2.4 km from each other. In view of this, another case at Still Road with onset on 2 August 1976 and previously thought to be infected at Nanyang University campus, was reclassified as also being infected in the area.

An outbreak was notified on 18 September 1976. Intensified vector control measures were organised and immediately implemented between 18 and 23 September 1976. More than 4,600 premises were simultaneously swing-fogged and residual-sprayed.

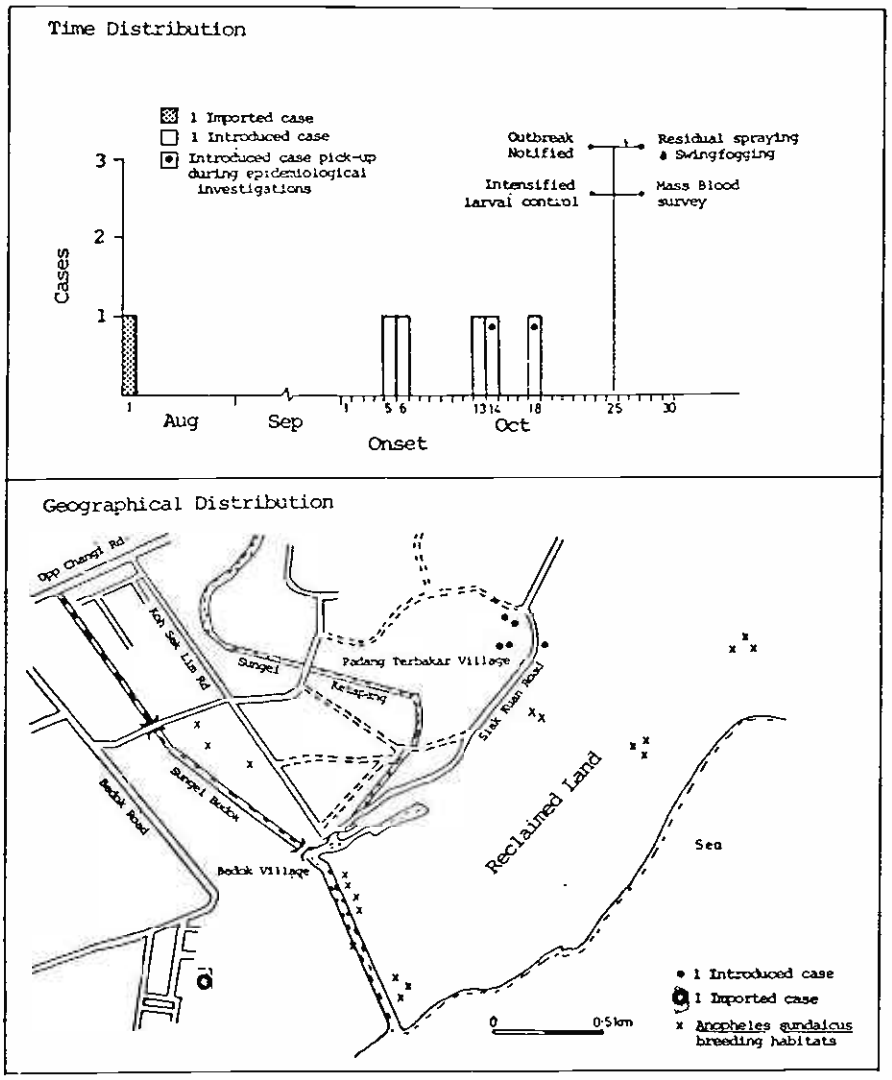
An sundaicus breeding was detected at Bedok reclaimed land (April and September 1976) and along Sungei Bedok (May and June 1976). No adult vectors were trapped. Blood films taken from 196 contract workers at Bedok New Town were negative for malaria parasites.

There were four imported cases in this area and these could have been the reservoir of infection. They were from Jalan Eunos (onset 1 July 1976, isolated on 7 July 1976), Marine Drive (onset 20 July, isolated on 27 July 1976), Geylang Serai (onset 10 August, isolated on 13 August 1976) and Chai Chee Estate (onset 16 August, isolated on 30 August 1976).

Siak Kuan Road

Five vivax malaria cases were reported in the Siak Kuan Road area in October 1980. They were a 26-year-old female factory worker, a 14-year-old female student, a 28-year-old shop assistant, a 30-year-old housewife and another housewife, 43 years of age. Their onset of symptoms was between 5 October and 18 October 1980. The last two cases were picked up during mass blood surveys in which a total of 1,036 blood films were taken. The reservoir of infection was probably an imported vivax case who developed fever on 1 August 1980 and staying in the vicinity. *Anopheles sundaicus* breedings were detected. Adult vectors were trapped but when dissected were found to be negative for sporozoites. Epidemic control measures implemented successfully eradicated the focus of transmission (Fig. 6).

Fig. 6 Malaria outbreak at Siak Kuan Road, Oct 1980



Measures taken to prevent the reintroduction of malaria

As Singapore is situated in a malaria endemic region, it is both vulnerable and receptive to the re-introduction of malaria (38). Based on the findings of relevant epidemiological data collected, the following steps were implemented to prevent the re-introduction of malaria into Singapore.

(a) **Health Education**

This is by far the most important preventive measure, as a large number of local residents continues to come down with malaria when visiting malaria endemic countries. Health education is directed at the need for chemoprophylaxis.

A national health campaign on the theme "Combat infectious diseases" was held in September 1976 and malaria was one of the diseases highlighted (39). Health education is also routinely given on a personal basis during epidemiological investigations of reported malaria cases. Pamphlets on malaria prevention are distributed to all travellers to malarious areas at Government Vaccination Centres. Organisers of group tours are periodically advised on the need for chemoprophylaxis. It is also compulsory for national servicemen to be on adequate chemoprophylaxis when training in malarious areas. Medical practitioners are informed of the latest malaria situation through the weekly "Bulletin of Infectious Diseases" and the monthly "Epidemiological News Bulletin". They were reminded on the radical treatment schedule for vivax malaria, and to put all local residents engaged in development projects in malarious countries on adequate chemoprophylaxis.

(b) **Screening of parasite carriers**

Because of the potential risk posed by the influx of foreign workers involved in various land developments, a project to screen all Work Permit applicants was initiated in 1976. However, no parasite carriers were detected from mass screening of a total of 3,840 of these workers. The screening programme was subsequently restricted to those working in receptive areas where malaria cases have been reported, and intensified during period of malaria transmission. Blood films are only taken from Work Permit applicants during pre-employment examination if direct enquires suggest the possibility of malaria.

Special groups of foreigners such as Vietnamese refugees are also routinely screened when they land in Singapore (Table 10).

(c) **Follow-up of past cases**

Blood films for malaria parasites are routinely taken from febrile patients at Government hospitals and clinics (Table 11) while all confirmed malaria cases discharged from hospitals are followed up to monitor drug resistance and to detect early relapses. In 1977, two cases of falciparum malaria contracted in an offshore island were probably resistant to chloroquine; both subsequently cleared up with quinine and sulfadoxine-pyrimethamine. Seven imported cases followed up during the period 1978-1980 were also resistant to chloroquine.

(d) **Special preventive measures**

In some major development projects; eg. the construction of dams across tidal rivers at Western Catchment, Kranji, Pulau Tekong and Sentosa, special steps are taken to prevent breeding of *Anopheles sundaicus* in brackish water. The risk of transmission in such area is high as foreign contract workers are employed. Water from the impounded area is periodically sampled for salinity analysis. Whenever *Culex sitiens* (which breed in almost similar conditions as *Anopheles sundaicus*) are detected, or when salinity tests show conditions faovurable for the breeding of vectors, extra precautionary measures are taken. Vector surveillance and larvicidal measures are intensified and foreign workers repeatedly screened for malaria parasites. Epidemiological surveillance activities are also carried out to detect any fever cases amongst them. If necessary, mass drug prophylaxis is administered to these workers. National servicemen on training in these areas are also put on chemoprophylaxis. Because of the rigid measures implemented, malaria outbreaks have been averted in these areas.

CONCLUSION

Although Singapore did not embark on an official malaria eradication programme, the WHO has certified the country as having achieved the status of malaria eradication. The malaria control activities which brought about this state may be classified as follows (40):-

Before 1910 — period of uncontrolled malaria
1911 — 1965 — preparatory and attack phases
1966 to 1974 — consolidation phase
1975 onwards — maintenance phase

It was the revised control strategies implemented after 1975 that have led to the eradication of indigenous malaria from Singapore. This eradication did not involve countrywide insecticide spraying or mass drug administration to the population. Thus, no insecticide resistance has been encountered (41 — 43), while the problem of drug resistance is mainly confined to imported falciparum malaria infections. The primary method has been environmental control aimed at source reduction. This is backed by a well-established general health service and an epidemiological surveillance system which is capable of detecting and eliminating the focus of transmission and thereby prevent the re-establishment of endemicity (44). Insecticides are reserved for use in epidemic situations only. In fact, DDT, BHC and dieldrin have been banned from general use since October 1973.

The battle against malaria must go on unabated until the whole country is fully developed and thus no longer receptive to malaria. In the meantime, Singapore remains both vulnerable and receptive to the re-introduction of the disease; vulnerable because of the constant influx of parasite carriers from malarious countries; receptive because of the presence of vectors. The risk of malaria outbreaks in the non-immune population remains. There is no practical way to prevent the importation of malaria brought in by the influx of tourists and other foreigners. There is also the risk of introduction of insecticide-resistant vectors and drug-resistant parasites into the country (45 — 46). Therefore, vigilance has to be maintained. Efforts will continue to be directed at health education of both medical practitioners and

Table 10

Malaria surveillance in Singapore, 1976-1982*

Type of surveillance	No. screened							No. positive for malaria parasites						
	1976	1977	1978	1979	1980	1981	1982	1976	1977	1978	1979	1980	1981	1982
Work Permit Holders and other foreign contract workers	4980	1415	510	887	1215	1288	3276	2	0	0	6	0	1	1
Follow-up of past cases	116	122	109	143	240	145	387	4	2	0	0	0	0	0
Epidemiological investigation of reported cases	984	319	1027	568	1084	1806	1661	14	0	3	3	3	2	0
Vietnamese refugees and other foreigners	0	94	1905	3488	4729	7300	4812	0	0	11	10	9	13	9
TOTAL	**6080**	**1950**	**3551**	**5086**	**7268**	**10539**	**10,136**	**20**	**2**	**14**	**19**	**12**	**16**	**10**

*Excluding blood films routinely taken from fever cases in hospitals and clinics.

Table 11

Examination of blood films at Government hospitals and outpatient clinics for malaria parasites, 1976-1982

Laboratories in	Number of Blood Films Examined						
	1976	1977	1978	1979	1980	1981	1982
Singapore General Hospital	7270	4776	7847	9489	11,559	14,641	13,476
Tan Tock Seng Hospital	1592	1384	1593	2503	2802	2394	2,085
Toa Payoh Hospital	1897	1860	2440	1555	3200	3408	4,139
Alexandra Hospital	818	1241	1011	1166	1377	1885	2,144
Changi Hospital	109	239	263	183	131	527	321
Middleton Hospital*	—	1088	884	680	666	820	558
Outpatient Dispensaries	—	—	—	396	133	55**	218
Total	**11,686**	**10,588**	**14,038**	**15,972**	**19,868**	**23,730**	**22,941**

*Laboratory services functioned as from 1977.

**Data available only from Maxwell Road Outpatient Clinic

members of the public concerning the constant threat of malaria.

ACKNOWLEDGEMENTS

Eradication of malaria in Singapore has been achieved through the work of the Joint Coordinating Committee on Epidemic Diseases. The cooperation given by medical practitioners who continue to notify all malaria cases promptly is greatly appreciated. I would also like to take this opportunity to thank my colleagues in the Ministry of the Environment and Ministry of Health for their assistance in the preparation of this paper; especially PHI Lim Ah Hock, PHI Mohd Kassim, Mr Tan Im Siew and Mrs Indumathy K of the Quarantine & Epidemiology Department.

REFERENCES

1. Brooke G E, Mackepeace W D, Braddel R J: One hundred years of Singapore. London, John Murray, Albemarle 1921: 1: 515.
2. Nah W T, Chew P K: A historical review of environmental health work in Singapore. Sing Pub Hlth Bull 1972; 10: 30-4.
3. Watson M: Notes on malaria conditions in Telok Blangah District. Singapore Government Publication, 1911.
4. Teo B T, Miles C, Alias O: A review of anti-malarial drainage in Singapore city since 1911. Sing Pub Hlth Bull 1972; 9: 33-9.
5. Sandosham A A: Malariology with special reference to Malaya. University of Malaya Press, 1965: 22.
6. Scharff J W: Notes on practical measures of malaria prevention from the point of view of mosquito control. Malayan Med J 1927; 2: 49-56.

7. Watson M: Twenty-five years of malaria control. Malayan Med J 1928; 3: 7-10.
8. Gross R D: Effectiveness of antimalaria measures in rural Singapore. Malayan Med J 1929; 4: 91-2.
9. Scharff J W: The Singapore cold storage dairy farm in its relation to antimalaria control measures. Malayan Med J 1931; 6: 82-8.
10. Watson M: Some pages from the history of the prevention of malaria. Glasgow, Alex MacDougall 1935: 19.
11. Scharff J W, Faris D W G, Nicholas W A: Malaria-mosquito control in Singapore. Singapore Government Publication, 1937.
12. Vickers W J: Annual report of Medical Department, Colony of Singapore, 1946: 14.
13. Singapore Government Health Department, Annual Report, 1956: 49.
14. Chew P K: The outbreak of malaria at Fuyong Estate in Singapore. Sing Med J 1968; 9: 111-26.
15. Colbourne M J: Malaria and mosquito control in Singapore. Sing Pub Hlth Bull 1967; 2: 12-20.
16. Paul F M, Kleevens J W L: Transfusion malaria in an infant in Singapore. J Sing Paed Soc 1969; 11: 62-6.
17. Chan K L, Chew P K, Koh T S: Malaria outbreak at Pulau Tekong in Singapore. Sing Med J 1971; 12: 276-83.
18. Ng W C, Fung W P, Colburne M J, Gilles H M: Chloroquine resistant malaria in Singapore. Ann Trop Med Parasit 1969; 63: 313-6.
19. Colbourne M J, Fung W P, Paul F M: The importance of chloroquine resistant malaria in Singapore in 1969. Sing Med J 1970; 11: 71-4.
20. Paul F M, Colbourne M J: Chloroquine resistant malaria in children from a Chinese albino family in Pulau Tekong. Sing Med J 1971; 12: 147-53.
21. Teo B T, Ng S K: Malaria control in the Kranji Reservoir. Sing Pub Hlth Bull 1979; 20: 44-9.
22. Goh K T: Malaria in the Southern Islands of Singapore. Sing Pub Hlth Bull 1977; 18: 37-43.
23. Chan K L, Goh K T, Koh T S: The Whampoa-Kallang malaria outbreak, 1974-1975. Sing Med J 1976; 17: 124-32.
24. Toh K K, Yeo K L: Present trend of malaria infection in Singapore. Sing Med J 1971; 12: 2-7.
25. Chan K L, Teo B T: Malaria control in Singapore. In: Chan Y C, Chan K L, Ho B C eds. Vector control in Southeast Asia, Proc 1st SEAMEO-TROPMED Workshop, Singapore 1972: 11-4.
26. Leong H K: Malaria in Singapore: a review. In: Harinasuta C, Reynolds D C eds. Proc 13th SEAMEO-TROPMED Seminar: Current problems of infectious diseases of public health importance in Southeast Asia, Saigon, 1974: 53-61.
27. Koh T S, Goh K T: The malaria situation in Singapore 1970-1974. Sing Pub Hlth Bull 1976; 17: 29-39.
28. Chan K L: Control of vectors towards a better Singapore. In: Tan I K ed Towards a better Singapore. Proc 1st Singapore Professional Centre convention, 1975: 107-17.
29. Chan K L: The antimalaria programme in Singapore, with special reference to the period 1974-1978. Asian J Infect Dis 1979; 3: 1-18.
30. Chan K L: A study on *Anopheles maculatus* and *Anopheles sundaicus* in Singapore. Sing Med J 1969; 10: 57-63.
31. Black R H: Manual of epidemiology and epidemiological services in malaria programmes. WHO, Geneva, 1968: 120.
32. WHO. Malaria surveillance, Singapore. Wkly Epidem Rec 1978; 53: 215-6.
33. WHO. Malaria surveillance, Singapore. Wkly Epidem Rec 1979; 54: 229-30.
34. WHO. Malaria surveillance, Singapore. Wkly Epidem Rec 1980; 55: 337-9.
35. WHO. Surveillance of vector-borne diseases, Singapore. Wkly Epidem Rec 1981; 56: 345-6.
36. WHO. Malaria surveillance, Singapore. Wkly Epidem Rec 1976; 51: 393-4.
37. Reid J A: Studies from the Institute for Medical Research, No. 31. *Anopheles* mosquitoes of Malaya and Borneo. Government of Malaysia, Kuala Lumpur, 1968.
38. Goh K T: Prevention of re-introduction of malaria into Singapore. Ann Aca Med Singapore 1979; 8: 40-6.
39. Ministry of Health and Ministry of the Environment. Sing Pub Hlth Bull 1977; 18: 1-36.
40. Goh K T: Malaria in Southeast Asia: Is the end in sight? Viewpoint from Singapore. Medical Progress 1982; 9: 13-4.
41. Ong K H, Chew L M, Tan K K, Phua S G, Chan K L: The susceptibility status of some common Singapore vectors to some common insecticides. Proceedings of the 3nd symposium on our Environment: Institute of Natural Science, College of Graduate studies, Nanyang Univ. 1979: 81-9.
42. Ong K H, Chew L M, Chan K L: Current insecticide susceptibility status of mosquitoes in Singapore. South-east Asian J Trop Med Pub Hlth 1981; 12: 222-7.
43. WHO. Resistance of vectors and reservoirs of diseases to pesticides. WHO Expert Committee on Insecticides. WHO Techn Rep Ser 1976; No. 585.
44. Farid M A: Singapore: the impressions of a malariologist. World Health Forum 1981; 1: 578-80.
45. Harinasuta T, Gilles H M, Sandosham A A: Malaria in Southeast Asia. Southeast Asian J Trop Med Pub Hlth 1976: 645-78.
46. Wernsdorfer W H, Kouznetsov: Drug-resistant malaria-occurrence, control and surveillance. Bull Wld Hlth Org 1980; 58: 341-352.