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Aedes aegypti (L.) and *Aedes albopictus* (Skuse) in Singapore City

1. Distribution and Density *

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The distribution and density of Ae. aegypti *and* Ae. albopictus *in Singapore were assessed from extensive larval surveys carried out from 1966 to 1968 to evaluate their respective roles in the epidemiology of dengue haemorrhagic fever and to study their ecology in the urban areas. Ten urban areas where the majority of dengue haemorrhagic fever cases occurred were surveyed.*

The results showed that both species were common in the city, with Ae. aegypti *being the dominant species. The distribution of* Ae. aegypti *was more uniform and related to the prevailing housing types and conditions. Its premise index was highest in slum houses, intermediate in shop houses, and lowest in multistorey flats.* Ae. albopictus, *on the other hand, did not seem to be related to the prevailing housing type in its distribution but tended to be more widespread in areas with open spaces.*

The larval density index (the average number of larvae per housing unit) was higher for Ae. aegypti *than for* Ae. albopictus, *in agreement with the relative densities shown by their premise indices. The larval density index correlated well with the premise index and correlated best with the infested-receptacle index. For practical purposes, the most suitable, convenient, and reliable measure of density of* Ae. aegypti *population seems to be the infested-receptacle index.*

An attempt was made to estimate the rate of dispersal of Ae. aegypti *from a stable population to an adjacent area of multistorey flats. The rate of dispersal, estimated from the premise index and the larval density index, was approximately 2% per year of the " donor " population.*

Outbreaks of dengue haemorrhagic fever have been occurring annually in Singapore since the disease was first recognized in 1960 (Chan, Lim & Ho, 1967). Limited epidemiological observations during the 1960 outbreak incriminated *Aedes aegypti* as the primary vector of the disease. Adult mosquitos of this species were found in more than 50% of the houses in the urban areas and their distribution was consistent with that of the cases of dengue haemorrhagic fever (Lim, Rudnick & Chan, 1961). Five strains of dengue type 2 virus were also isolated from *Ae. aegypti* and one strain of dengue type 2 virus from *Aedes albopictus*, collected during the outbreak (Rudnick & Chan, 1965). Although dengue virus was isolated from *Ae. albopictus* and the species was also common in the urban areas, it was not incriminated as a vector of dengue haemorrhagic fever because its distribution was not consistent with that of the disease, which was almost entirely urban (Lim, Rudnick & Chan, 1961; Rudnick, 1966).

Apart from the limited observations in 1960, only two other studies on *Ae. aegypti* and *Ae. albopictus* in the urban areas of Singapore have been reported.

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Macdonald (1956), in a survey of *Ae. aegypti* in Singapore City, found that the premise index ranged from 9% to 37%, depending upon the type of house surveyed. Yin-Coggrave & Pong (1964) reported an abundance of both *Ae. aegypti* and *Ae. albopictus* adults in their house collections in the urban areas.

In view of the isolation of dengue virus from *Ae. albopictus* and the common presence of this species in the urban areas, further investigations of this species and of *Ae. aegypti* were carried out between 1966 and 1969. The objectives of the investigations were to study the ecology of the two mosquitos in the urban areas and to evaluate their respective roles in the epidemiology of dengue haemorrhagic fever. The results of the study are reported in this and the following papers of the series. This paper describes the distribution and density of the two species.

GENERAL DESCRIPTIONS OF SINGAPORE AND STUDY AREAS

The Republic of Singapore is situated 137 km (85 miles) north of the equator, at latitude 1°15′ N and longitude 104° E, and lies at the extreme tip of the Malay Peninsula. The main island measures about 42 km (26 miles) from east to west and 22.5 km (14 miles) from north to south. There are a few small islands scattered around the north-eastern and southern shores of the main island and together they comprise the land area of Singapore, which is approximately 581.5 km² (224.5 mi²). Singapore City is the only city and it is situated at the southern tip of the main island and has an area of 96 km² (37.2 mi²).

The resident population in 1968 was estimated as 2 003 800, of which about 60% lived in the city. The densest population (about 34 250 persons per km², or 89 000 per mi² is found in the 9 km² (3.5 mi²) of the inner city on either side of the Singapore River. Half of the population live in degenerated slums in the central area, in attap houses[1] in the rural area, or in squatter settlements on the urban fringe. A third of the population live in low-cost multistorey flats in housing estates, and the remaining population live mainly in shop houses. About 90% of the multistorey flats are 10–16 storeys high, and each block of flats is built on the basis of about 50 families or 250 persons to an acre of land (125 families or 620 persons per ha).

Houses in the urban areas are supplied with piped water. The water is distributed from 5 service reservoirs situated on the island.

The climate of Singapore is characterized by uniform temperature, high humidity, and abundant rainfall. The average daily maximum temperatures for the three years 1966, 1967, and 1968 were 31.0°C, 30.5°C, and 32.1°C, respectively, while the average daily minimum temperatures were 23.7°C, 23.4°C, and 22.9°C, respectively. The average humidity is around 70%. The island generally has rainfall throughout the year, with the drier months averaging 16.5–17.8 cm (6.5–7.0 in) per month and the wetter months occurring during the monsoon season from November to January. The average monthly rainfall for the year is about 24.1 cm (9.5 in).

Study areas

Ten areas in the city were surveyed between September 1966 and May 1968 (Fig. 1). These areas included some of the most densely populated parts of the city, and represented the areas where the majority of dengue haemorrhagic fever cases have been reported since 1960.

The 10 areas are classified according to the most prevalent type of housing in the area as slum house, shop house, or flat areas. Slum houses and shop houses are very similar to those described by Macdonald (1956). Slum houses were generally constructed for temporary occupation but many of them have been occupied for more than 10 years. They usually have a galvanized iron or attap roof,[1] wooden walls, and a cement floor. They do not have individual piped water supplies but share a communal standpipe, and containers for water storage are generally plentiful, both inside and outside the houses. Slum-house areas are generally overcrowded, insanitary, and littered with discarded small containers, such as tin cans and bottles. Many families in these areas also rear pigs and chickens. Shop houses usually have two or three storeys and adjoin one another. They are built of brick or cement and have tiled roofs. The entire shop house, or a portion of it, may be used for business or residence and each house is usually occupied by more than one family. Many shop houses have what is known as an " air well ", a section of the house not covered by a roof. A piped water supply is available in each house and also on each floor. The sanitary condition of shop houses varies with area.

Blocks of flats may have two or more storeys, and they are generally clean. They are used mainly

[1] Houses with thatched roofs often made with palm leaves.

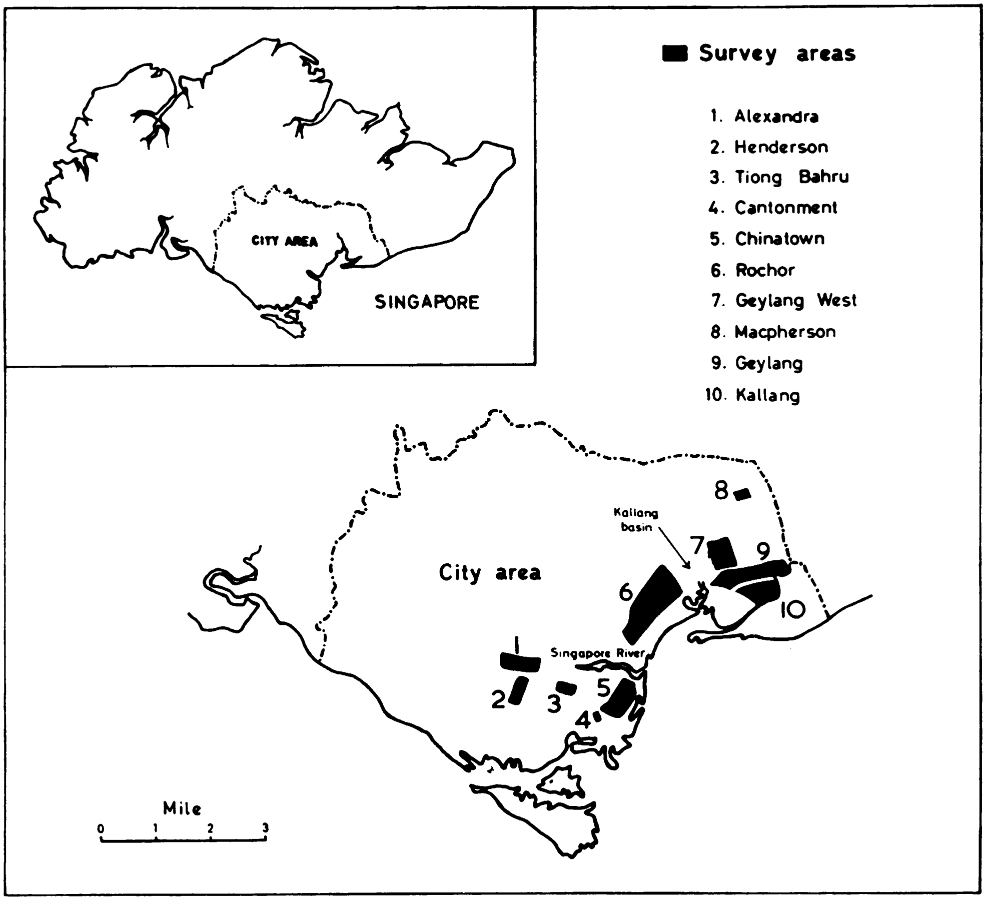

Fig. 1. Singapore city with the ten larval survey areas of *Ae. aegypti* and *Ae. albopictus*

for residence but in some areas the ground floors are occupied by shops. Blocks of flats are usually separated from each other by an open grass field, which is planted with shrubs and shade trees.

METHODS

Definitions

For the purposes of this study, the following terms are used as defined:

Housing unit. The entire area of a house that bears one house number. A block of flats thus has as many housing units as there are house numbers.

Indoor. Any part of a house that is under a roof. " Air wells ", although within a house, are not covered by a roof and are thus not considered as indoor.

Outdoor. That part of a house that is not under a roof but is within the confines of a housing unit, e.g., an " air well ", a garden, or a compound outside a house.

Open space. Any piece of land that is not part of a housing unit, such as vacant land between two housing units or between two blocks of flats or a public park.

Collection of larvae and pupae

Both larvae and pupae were collected in this study but, for simplicity, they are collectively referred to as larvae. Trained surveyors were used to search for larval breeding places in all the accessible houses and open spaces in an area. All the larvae from

Table 1. Distribution of *Ae. aegypti* and *Ae. albopictus* in Singapore city

Area	Date surveyed	Housing type	No. of housing units surveyed	*Ae. aegypti*		*Ae. albopictus*	
				No. of housing units positive for larvae	Premise index (%)	No. of housing units positive for larvae	Premise index (%)
Henderson	Sep.–Nov. 1967	Slum house	460	136	29.6	73	15.9
Geylang West	June 1967	Slum house	917	228	24.9	35	3.8
Geylang	Sep.–Oct. 1966	Shop house	3 032	563	18.6	205	6.8
Chinatown	Apr.–Dec. 1967	Shop house	8 422	1 343	15.9	68	0.8
Rochor	Feb.–Mar. 1967	Shop house	6 026	894	14.8	173	2.9
Alexandra	Aug.–Oct. 1967	Flat	2 120	201	9.5	62	2.9
Cantonment	Jul.–Aug. 1967	Flat	1 326	90	6.8	4	0.3
Macpherson	May 1968	Flat	363	23	6.3	47	12.9
Tiong Bahru	Jun.–Aug. 1967	Flat	3 093	164	5.3	53	1.7
Kallang	Sep.–Oct. 1966	Flat	4 828	109	2.3	50	1.0
Total			30 587	3 751		770	
Mean					12.3		2.5

each breeding habitat, except those from large ones such as jars, drums, and rubber tires, were collected into bottles with the aid of pipettes and ladles. In the case of large containers as many larvae as possible were collected in one or more samples of water. Each bottle was labelled with the area of collection and the type and location of the habitat. Potential breeding habitats—that is, habitats with water but no larvae—were also recorded. Information was also obtained on the type of housing, the number of occupants in each housing unit, and other relevant factors. The larvae were taken to the laboratory for identification and counting. A detailed description of the method of identification of larvae and pupae of *Ae. aegypti* and *Ae. albopictus* will be published elsewhere.

RESULTS

Distribution of Ae. aegypti *and* Ae. albopictus

A total of 30 587 housing units in 10 areas in the city centre and surrounding areas was surveyed for breeding of *Ae. aegypti* and *Ae. albopictus.* Table 1 shows the premise indices of the two species. The premise index of *Ae. aegypti* ranged from 2.3% to 29.6%, with a mean index of 12.3% for the 10 areas. The distribution of this species appears to be related to the type of housing in the area, with the highest premise index in slum houses, an intermediate index in shop houses, and the lowest index in flats. The mean premise indices for slum houses, shop houses, and flats were 27.2%, 16.4%, and 5.0%, respectively (Table 2).

Table 2. Distribution and density of *Ae. aegypti* in three types of housing

Housing type	No. of housing units surveyed	Premise index (%)		Larval density index [a]	
		Range	Mean	Range	Mean
Slum house	1 377	24.9–29.6	27.2	2.93–8.11	5.52
Shop house	17 480	14.8–18.6	16.4	1.90–2.59	2.31
Flat	11 730	2.3– 9.5	5.0	0.20–1.86	0.81

[a] Average number of larvae per housing unit.

Table 3. Distribution of *Ae. aegypti* and *Ae. albopictus* in Chinatown

Section	Date surveyed	No. of housing units surveyed	*Ae. aegypti*		*Ae. albopictus*	
			No. of housing units positive for larvae	Premise index (%)	No. of housing units positive for larvae	Premise index (%)
Tanjong Pagar	Jul.–Aug. 1967	1 273	318	25.0	18	1.4
Havelock	Apr.–May 1967	897	163	18.2	6	0.7
Anson	Jun.–Jul. 1967	1 211	200	16.5	11	0.9
Hong Lim I	Apr.–May 1967	1 594	243	15.2	6	0.4
Telok Ayer	Sep.–Oct. 1967	1 496	220	14.7	26	1.7
Hong Lim II	Sep.–Dec. 1967	1 951	199	10.2	1	0.05

Ae. albopictus, in general, was less widely distributed than *Ae. aegypti*, except in the Macpherson area where the premise index of *Ae. albopictus* was higher than that of *Ae. aegypti*. The premise index of *Ae. albopictus* ranged from 0.3% to 15.9%, with a mean index of 2.5% (Table 1). In contrast to *Ae. aegypti*, the premise index of *Ae. albopictus* does not seem to bear any relationship to the prevalent type of housing in the area. The Henderson (slum house) and Macpherson (flat) areas had the highest premise indices of 15.9% and 12.9%, respectively, while the Chinatown (shop house) and Cantonment (flat) areas had the lowest indices of 0.8% and 0.3%, respectively.

In any one area with a single type of housing, wide variations in the premise indices of *Ae. aegypti* and *Ae. albopictus* were also found. In the shop house area of Chinatown, for instance, the premise indices in the different sections varied from 10.2% to 25.0% for *Ae. aegypti* and 0.05% to 1.7% for *Ae. albopictus* (Table 3).

The distribution of the two *Aedes* species in Geylang and Kallang is shown in Fig. 2, in which the location of each breeding habitat is indicated. Both species occurred widely in the two areas but a particularly high concentration of *Ae. albopictus* was found in the part of Geylang adjacent to Kallang Basin. Kallang Basin was originally a tidal swamp, and it became a large breeding ground of this species as a result of the dumping of refuse including containers.

Density of Ae. aegypti *and* Ae. albopictus

In this study, the population density of each species in an area is expressed as the average number of larvae per housing unit, which, for simplicity, is referred to as the larval density index. Table 4 shows the larval density indices of the two species.

Ae. aegypti had a higher density (mean larval density index of 1.87) than *Ae. albopictus* (mean larval density index of 0.26) in the surveyed areas, except in the Macpherson area where the density of *Ae. albopictus* was about 3 times that of *Ae. aegypti*. Like the premise index, the larval density index of *Ae. aegypti* shows an apparent relationship with the type of housing prevalent in the area, but no such relationship is seen with the larval density index of *Ae. albopictus*. The larval density index of *Ae. aegypti* was highest in slum houses, intermediate in shop houses, and lowest in flats (Table 2).

Ae. aegypti had a higher density indoors than outdoors, as shown by a higher larval density index of the indoor population in 7 of 8 areas investigated (Table 5). In 4 of these areas, however, more than 20% of the population was found outdoors. The larval density index of *Ae. albopictus*, on the other hand, was higher outdoors than indoors in 4 of 8 areas surveyed (Table 5). The indoor population of this species was high in all areas, varying from 24% to 100%.

Table 6 compares the number of larvae of the two *Aedes* species collected in and around houses and in open spaces, in three of the areas surveyed. A very small population, not exceeding 7% of the total population in the area, of *Ae. aegypti* was found in open spaces far removed from the immediate vicinity of houses. The open-space population

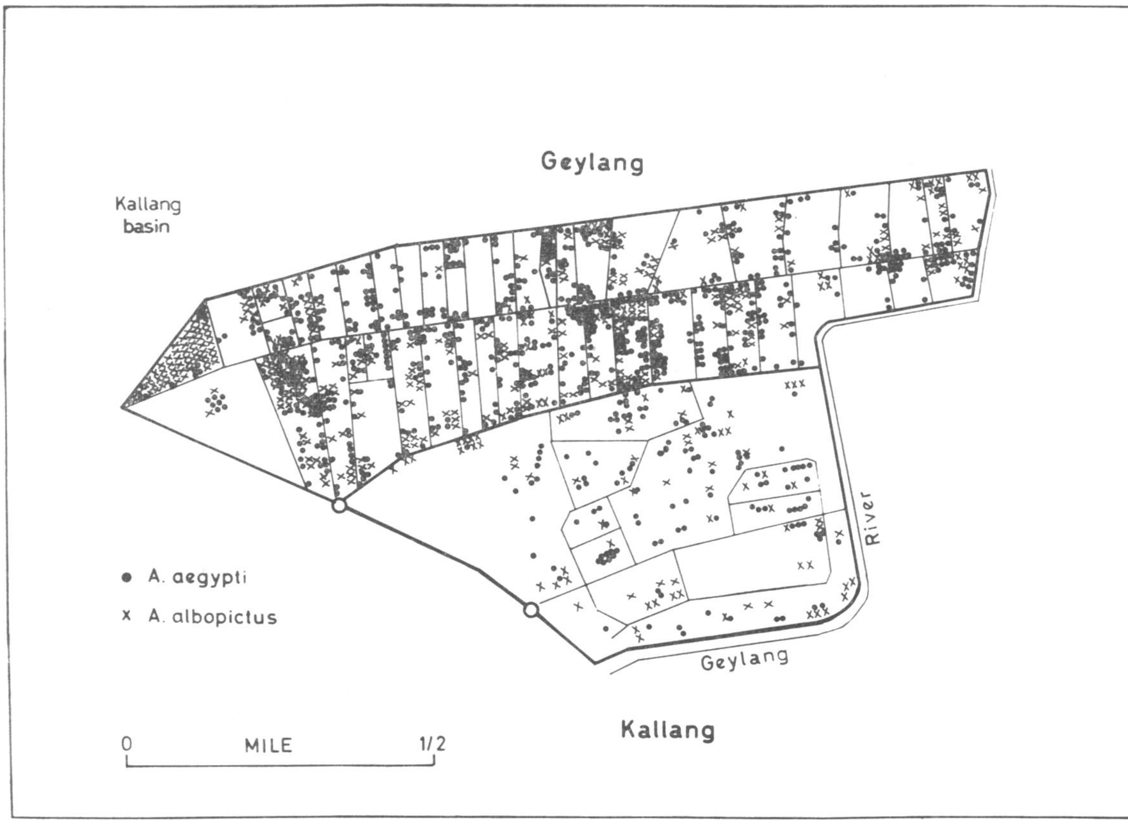

Fig. 2. Distribution of *Ae. aegypti* and *Ae. albopictus* in Geylang and Kallang. Each dot or cross represents one larval breeding habitat.

Table 4. Density of *Ae. aegypti* and *Ae. albopictus* in houses in Singapore city

Area	Housing type	No. of housing units surveyed	*Ae. aegypti*		*Ae. albopictus*	
			Larval count	Larval density index [a]	Larval count	Larval density index [a]
Henderson	Slum house	460	3 729	8.11	1 819	3.95
Geylang West	Slum house	917	2 683	2.93	296	0.32
Geylang	Shop house	3 032	5 756	1.90	1 487	0.49
Chinatown	Shop house	8 422	20 503	2.43	625	0.07
Rochor	Shop house	6 026	15 617	2.59	1 339	0.22
Alexandra	Flat	2 120	3 951	1.86	853	0.40
Cantonment	Flat	1 326	815	0.61	12	0.01
Macpherson	Flat	363	157	0.43	446	1.23
Tiong Bahru	Flat	3 093	2 914	0.94	655	0.21
Kallang	Flat	4 828	973	0.20	566	0.12

[a] Average number of larvae per housing unit.

Table 5. Density of indoor and outdoor *Ae. aegypti* and *Ae. albopictus*

Area	*Ae. aegypti*				*Ae. albopictus*			
	Larval count		Larval density index [a]		Larval count		Larval density index [a]	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
			(%)	(%)			(%)	(%)
Henderson	2 264	1 465	4.92 (60.7)	3.19 (39.3)	433	1 386	0.94 (23.8)	3.01 (76.2)
Geylang West	2 100	583	2.29 (78.2)	0.64 (21.8)	171	125	0.19 (59.4)	0.13 (40.6)
Chinatown	15 191	5 312	1.80 (74.1)	0.63 (25.9)	272	353	0.03 (42.9)	0.04 (57.1)
Rochor	13 310	2 307	2.21 (85.3)	0.38 (14.7)	688	651	0.11 (50.0)	0.11 (50.0)
Alexandra	3 743	208	1.77 (95.2)	0.09 (4.8)	281	572	0.13 (32.5)	0.27 (67.5)
Cantonment	815	0	0.61 (100.0)	0.00 (0.0)	12	0	0.01 (100.0)	0.00 (0.0)
Macpherson	67	90	0.18 (41.9)	0.25 (58.1)	135	311	0.37 (30.1)	0.86 (69.9)
Tiong Bahru	2 259	655	0.73 (77.7)	0.21 (22.3)	505	150	0.16 (76.2)	0.05 (23.8)

[a] Average number of larvae per housing unit.

Table 6. Density of *Ae. aegypti* and *Ae. albopictus* in houses and in open spaces [a]

Area	No. of *Ae. aegypti* larvae			No. of *Ae. albopictus* larvae		
	House	Open space	% in house	House	Open space	% in open space
Geylang	5 756	54	99.1	1 487	475	24.2
Rochor	15 617	1 137	93.2	1 339	5 121	79.3
Kallang	973	21	97.9	566	65	10.3

[a] All breeding habitats in open spaces were examined, except in the case of large scrap dumps where only a random sample of 10 containers from each dump was examined.

of *Ae. albopictus*, however, was much larger; in the Rochor area, nearly 80% of the total population occurred in open spaces. These large populations of *Ae. albopictus* in open spaces were due to the presence of dumps of rubber tires or tin cans. These types of container are two of the major breeding habitats of *Ae. albopictus* (Chan, Ho & Chan, 1971).

Replicate surveys of Ae. aegypti

A part of Chinatown was surveyed on two different occasions, the first during March–April and the second during November–December of the same year. The premise index and the larval density index of *Ae. aegypti* obtained in the two surveys are shown in Table 7.

Table 7. Replicate surveys of *Ae. aegypti* in Chinatown (Hong Lim I)

Survey date	No. of housing units surveyed	No. of housing units positive for larvae	Premise index (%)	No. of larvae	Larval density index [a]
Mar.–Apr. 1967	737	102	13.8	1 470	1.99
Nov.–Dec. 1967	1 452	196	13.5	2 526	1.74

[a] Average number of larvae per housing unit.

Table 8. Natural rate of dispersal of *Ae. aegypti*

Area	Population status	Housing type	Age of houses (years)	Premise index (%)	Larval density index
Geylang	" donor "	Shop house	50	18.6	1.90
Kallang	" recipient "	Flat	6	2.3	0.20

$$\text{Estimated rate of dispersal} = \frac{\text{population in " recipient " area}}{\text{population in " donor " area}} \times \frac{100}{\text{age of houses in " recipient " area}}$$

$$\text{Rate based upon premise index} = \frac{2.3}{18.6} \times \frac{100}{6} = 2.06\ \%\ \text{per year of " donor " population}$$

$$\text{Rate based upon larval density index} = \frac{0.20}{1.90} \times \frac{100}{6} = 1.75\ \%\ \text{per year of " donor " population}$$

Observation on the rate of dispersal of Ae. aegypti

The distribution and density of *Ae. aegypti* in the Geylang and Kallang areas afford a unique opportunity for the estimation of the rate of dispersal of this species. These two areas, although adjoining each other, are different historically and topographically. The Geylang area comprises mainly shop houses that are about 50 years old, and the *Ae. aegypti* population in this area is, presumably, a stable one. In contrast, the multistorey flats in the Kallang area are relatively new, having been built only 6 years ago. The housing estate is built over a reclaimed swamp adjacent to an old airport where *Aedes* control had previously been carried out to some extent. This area can thus be considered as having been *Ae. aegypti*-free prior to the development of the estate. It is assumed that the present distribution and density of this species in the Kallang area is primarily the result of spread from the neighbouring stable population in the Geylang area, since the latter is the only heavily built-up area in close proximity to the Kallang area.

The rate of dispersal of a mosquito population is defined here as the ratio of the population of the " recipient " area to the population of the " donor " area, expressed as a percentage per year of the population of the " donor " area. The rates of dispersal of *Ae. aegypti* from the Geylang area to the Kallang area, as estimated from the premise index and the larval density index, are, respectively, 2.06% and 1.75% per year of the population of the Geylang (" donor ") area (Table 8).

The Henderson and Alexandra areas are two other areas with a similar type of donor–recipient relationship. The Henderson area is a slum that is believed to have existed for at least 50 years and the adjacent Alexandra area is about 14 years old. The *Ae. aegypt.* population in the flats of the Alexandra area is believed to have originated from the stable population in the Henderson area. When the premise index and the larval density index of this species in the Alexandra area were calculated on the basis of the rates of dispersal obtained from the Geylang–Kallang example, the estimated indices were not significantly different from the actual indices (Table 9).

Measurement of Ae. aegypti *populations*

The premise index, the receptacle index, and the infested-receptacle index have been used by various

Table 9. Estimated indices of *Ae. aegypti* in Alexandra area

Area	Population status	Housing type	Age of houses (years)	Premise index (%)		Larval density index	
				Actual	Estimated [a]	Actual	Estimated [b]
Henderson	" donor "	Slum house	50	29.6		8.11	
Alexandra	" recipient "	Flat	14	9.5	8.7	1.86	1.96

[a] Based on a natural rate of dispersal of 2.06 % per year of " donor " population.
[b] Based on a natural rate of dispersal of 1.75 % per year of " donor " population.

workers to indicate the density of *Ae. aegypti* populations (Tinker, 1967). The receptacle index is the percentage of the inspected receptacles that are infested, and the infested-receptacle index is the average number of infested receptacles per house. These three indices and the larval density index calculated for the 10 areas are compared in Table 10. There is good correlation between the larval density index and the premise index (correlation coefficient $r=$ 0.866), and a very strong correlation between the larval density index and the infested-receptacle index ($r=0.985$), but no correlation between the larval density index and the receptacle index.

Table 10. Comparison of various indices measuring *Ae. aegypti* population

Area	Larval density index	Premise index (%)	Receptacle index (%) [a]	Infested-receptacle index [b]
Henderson	8.11	29.6	15.4	0.76
Geylang West	2.93	24.9	11.7	0.29
Rochor	2.59	14.8	15.6	0.24
Chinatown	2.43	15.9	17.7	0.22
Geylang	1.90	18.6	12.9	0.26
Alexandra	1.86	9.5	61.7	0.15
Tiong Bahru	0.94	5.3	10.3	0.09
Cantonment	0.61	6.8	10.0	0.07
Macpherson	0.43	6.3	5.2	0.07
Kallang	0.20	2.3	2.4	0.02
Correlation coefficient with larval density index		0.866	0.123	0.985

[a] Percentage of the inspected receptacles that were infested.
[b] Average number of infested receptacles per housing unit.

DISCUSSION

The *Ae. aegypti* premise index of slum houses, in the present study, was higher than that reported by Macdonald (1956) for similar types of house in Singapore, but much lower than the index he reported for slum houses in many towns in Malaya (Macdonald, 1956). Our mean *Ae. aegypti* premise index for slum houses was 27.2%, in contrast to the figure of 9.0% that Macdonald reported for Singapore slum houses. However, our mean premise index for shop houses (16.4%) was close to the 15.0% obtained by Macdonald. The premise index of multistorey flats has never been studied in the past because this type of housing has only recently been developed. The lowest mean premise index (5.0%) was found in flats.

Our finding that the *Ae. aegypti* premise index was higher in slum houses than in shop houses was consistent with the data obtained by Macdonald in Malaya. The reasons advanced by Macdonald to explain his finding are equally applicable to the present study, as the types of houses and the habits of the people in the two countries are very similar. The general living conditions and the supply of piped water in slum areas are poor, and the need to store water has resulted in a larger accumulation of containers in and around houses. We have found that there were twice as many containers per house in slum areas as in shop-house areas.[1]

The use to which houses are put is also an important factor affecting the local distribution of *Ae. aegypti.* Commercial houses, in general, have a lower premise index than residential houses even though they are of a similar type of housing. Hong Lim II in Chinatown, which had a premise index of 10.2%, is a highly commercialized area where living space is limited. The houses in this area are generally clean and have fewer unused containers. In contrast, Tanjong Pagar in Chinatown has more residential houses than commercial houses and the premise index of this area was 25.0%. Because of the large number of people living in this area there are more used and unused containers available for mosquito breeding.

Our finding of the mean *Ae. aegypti* premise index for shop houses is of interest. It appears that there had been no significant change in the distribution of this species in the shop-house area in Singapore since the survey by Macdonald (1956) 10–11 years ago. The population of *Ae. aegypti* has probably reached an equilibrium between its natural rate of increase and the effects of human interference. This is possible, as the majority of shop houses are between 50 and 100 years old and human habits, in the absence of any drastic external influence, are not likely to have changed to any great extent.

In order to compare *Aedes* populations between different areas and between different times of survey, we have introduced the larval density index, which

[1] Unpublished data.

is the average number of larvae per housing unit in an area, as a measure of density. Wide differences in *Ae. aegypti* density were found in the surveyed areas but there was general agreement between the larval density index and the premise index. The highest density was found in slum houses and the lowest density in flats, with shop houses occupying an intermediate position. The indoor population of *Ae. aegypti* was generally denser than the outdoor population but in many areas the outdoor population constituted more than 20% of the total population in the area. This species was also found in open spaces far removed from houses, although the population was small.

Replicate surveys of *Ae. aegypti* in one area showed no difference in the premise index or in the larval density index. Subsequent studies, however, showed that the periods selected for the replicate surveys coincided with peaks in the annual population cycle of this species (Ho, Chan & Chan, 1971).

According to the studies carried out by Macdonald in Malaya (Macdonald, 1956) the dispersal of *Ae. aegypti* is relatively slow. We have attempted to estimate, from data obtained in this study, the rate of dispersal of this mosquito from a presumably stable population to an adjacent multistorey flat area. The rate of dispersal, as estimated from the premise index and the larval density index, was approximately 2% per year of the " donor " population. This rate of dispersal may be applicable only to the spread of *Ae. aegypti* from a stable population into multistorey flats. Such flats are characteristically occupied by large numbers of people within a very short period of time, and this is especially true in Singapore where the flat-dwellers, in most instances, have been transferred from demolished slum areas. It is not known how much the population increase in the " recipient " area was the result of mechanical transport of adult mosquitos or of larval stages, or both, by the people when they moved into the flats and how much of the population increase was due to natural increase of the species.

Several indices have been used by workers for measuring *Ae. aegypti* density, e.g., premise index, receptacle index, and infested-receptacle index. Tinker (1967) has shown that the best index for measurement of this species is the premise index. Soper (1967), however, pointed out that the premise index does not adequately measure the density of *Ae. aegypti*, which is affected not only by the number and distribution of infested houses, but also by the number and size of available breeding habitats. We have found good correlation between the larval density index (which is based upon the absolute larval count) and the premise index, and the best correlation between the larval density index and the infested-receptacle index. For practical purpose, the convenient and reliable infested-receptacle index seems to be the most suitable measure of the density of *Ae. aegypti* populations.

Our study of *Ae. albopictus* was the first systematic survey of this species in the urban areas of Singapore. The premise index and the larval density index were also used to show the distribution and density, respectively, of this species. These indices are, however, biased against *Ae. albopictus*, which was often found breeding in dumps of rubber tires and tin cans on vacant land, open fields, and parks. In some areas, the population of *Ae. albopictus* in open spaces was larger than the population found in and around houses.

Our surveys showed that *Ae. albopictus* was present in the urban areas, although it was less widely distributed than *Ae. aegypti*. Large populations of *Ae. albopictus* in houses were found in areas where there were open spaces, irrespective of the type of housing prevalent in the area. In the Macpherson flat area, where the setting was more suburban than urban, the premise index and the larval density index of *Ae. albopictus* were higher than those of *Ae. aegypti*.

In all the areas surveyed, more than 20% of the house-associated populations of *Ae. albopictus* was found indoors. In 4 of 8 areas surveyed, the indoor population reached or exceeded 50% of the total population, showing that this species has become well-established in the domestic environment in the urban areas of Singapore.

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RÉSUMÉ

AEDES AEGYPTI (L.) ET *AEDES ALBOPICTUS* (SKUSE) DANS LA VILLE DE SINGAPOUR: 1. RÉPARTITION ET DENSITÉ

On a procédé de 1966 à 1969 à une série d'investigations dans la ville de Singapour afin de déterminer la répartition et la densité d'*A. aegypti* et d'*A. albopictus*. Ces enquêtes, basées essentiellement sur la récolte de larves et de nymphes, devaient permettre d'étudier l'écologie de ces espèces et d'apprécier leur rôle respectif dans l'épidémiologie du syndrome dengue/fièvre hémorragique.

On a décelé la présence de l'une et l'autre espèces. *A. aegypti* était le plus fréquent, avec une répartition plus uniforme et en rapport avec le type prédominant d'habitation. L'indice de positivité des locaux pour *A. aegypti* était le plus élevé (27,2%) dans les bas quartiers, intermédiaire (16,4%) dans les magasins et le plus faible (5,0%) dans les immeubles à plusieurs étages. Quant à *A. albopictus*, sa répartition ne semblait pas dépendre du type d'habitation, mais on le trouvait avec une fréquence accrue dans les secteurs comportant des espaces dépourvus de constructions et spécialement dans les dépôts de vieux pneus et boîtes de conserve.

L'indice de densité larvaire (nombre moyen de larves par unité d'habitation) était plus élevé pour *A. aegypti* (indice moyen: 1,87) que pour *A. albopictus* (indice moyen: 0,26). On notait une corrélation satisfaisante entre cet indice et l'indice de positivité des locaux. Il apparaît néanmoins que le meilleur moyen d'évaluer la densité d'*A. aegypti* consiste à déterminer le nombre moyen de récipients contenant des larves par maison. Des enquêtes effectuées à deux époques de l'année n'ont montré aucune variation significative des indices de positivité des locaux et des indices de densité larvaire.

On s'est efforcé par ailleurs d'évaluer le taux de dispersion d'une population d'*A. aegypti* depuis longtemps établie dans un secteur et présumée stable vers une zone de constructions plus récentes. D'après les indices de positivité des locaux et de densité larvaire, il semble que ce taux soit annuellement de 2% environ de la population d'origine.

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