Tropical Biomedicine 23(1): 85–96 (2006)

Spatial, environmental and entomological risk factors analysis on a rural dengue outbreak in Lundu District in Sarawak, Malaysia

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Abstract. The objective of this study was to elucidate the association of various risk factors with dengue cases reported in Lundu district, Sarawak, by analyzing the interaction between environmental, entomological, socio-demographic factors. Besides conventional entomological, serological and house surveys, this study also used GIS technology to generate geographic and environmental data on *Aedes albopictus* and dengue transmission. Seven villages were chosen based on the high number of dengue cases reported. A total of 551 households were surveyed. An overall description of the socio-demographic background and basic facilities was presented together with entomological and geographical profiles. For serological and ovitrap studies, systematic random sampling was used. Serological tests indicated that 23.7% of the 215 samples had a history of dengue, either recent or previous infections. Two samples (0.9%) were confirmed by IgM ELISA and 49 samples (22.8%) had IgG responses. A total of 32,838 *Aedes albopictus* eggs were collected in 56 days of trapping. Cluster sampling was also done to determine whether any of the risk factors (entomological or geographical) were influenced by geographical location. These clusters were defined as border villages with East Kalimantan and roadside villages along Lundu/Biawas trunk road. The data collected were analyzed using SPSS version 10.01. Descriptive analysis using frequency, means, and median were used. To determine the association between variables and dengue cases reported, and to describe the differences between the two clusters of villages, two-sample *t*-test, and Pearson's Chi-Square were used. Accurate maps were produced with overlay and density function, which facilitates the map visualization and report generating phases. This study also highlights the use of differential Global Positioning System in mapping sites of 1m accuracy. Analysis of the data revealed there are significant differences in clusters of villages attributable to container density, house density, distance of the house from the main road, and number of *Ae. albopictus* eggs from ovitraps set indoor, outdoor and in dumping sites (Person's Chi-Square=6.111, df=1, $p<0.01$). Further analysis using *t*-test showed that house density, container density, indoor mosquitoes egg count, outdoor mosquitoes egg count, and dumping sites mosquitoes egg count were higher at the roadside villages compared to border villages. A number of potential risk factors including those generated from GIS were investigated. None of the factors investigated in this study were associated with the dengue cases reported.

INTRODUCTION

Dengue fever (DF) and dengue haemorrhagic fever (DHF) are the most common arthropod-borne viral diseases. It is estimated that about 50 million cases of dengue infection occur throughout the world each year and causing 25,000 deaths (WHO, 1999). The World Health Organization (WHO) estimated that more than 2.5 billion people are at risk of dengue infection. In South East Asia, the principal vector of dengue viruses in urban areas is *Aedes aegypti* (=*Stegomyia aegypti*),

whereas *Aedes albopictus (Stegomyia albopicta)* is an important vector in some rural areas. There has been an increasing spread of dengue fever from urban to rural areas due to improved road systems and better socio-economic situations in most of the developing countries in the region. New established agricultural settlements in rural areas could also increase the *Ae. albopictus* population thus spread of rural dengue fever among the rural communities (Chang *et al.*, 1977).

Ae albopictus has been implicated as a vector of dengue epidemics in Asia by many researchers (Russell *et al.*, 1969; Chan *et al.*, 1971). Most recently the dengue virus has also been repeatedly isolated from field collected *Ae. albopictus* in Singapore (Chow *et al.*, 1998). This species is also capable of transovarian and venereal transmission of dengue virus (Rosen *et al.*, 1978; Lee *et al.*, 1997). Chang & Nagum (1986) reported a rural dengue fever outbreak in Lawas district in Sarawak.

One of the main problems faced in dengue epidemiology is the inadequate knowledge on the risk factors and their association among them. This problem is more acute in rural dengue outbreak responsible by *Ae. albopictus* as many outbreaks were not reported or adequately investigated. Even if the outbreak is investigated; there is a lack of a sensitive vector surveillance tool to estimate the vector density in the outbreak areas. Thus vector abundance for both *Ae. aegypti* and *Ae. albobictus* is still expressed as House index, Breteau index and Container index. It has been criticized by Focks (2003) that these indices are of operational value and are of limited use in assessing the transmission risk. Even then, the normal *Aedes* surveillance (house inspection) for *Ae. aegypti* breeding carried out by the dengue team is unable to locate the *Ae. albopictus* breeding sites due to its peri-domestic nature, and this would under-estimate the larval prevalence. The WHO Special Programme for Research and Training in Tropical Diseases (TDR) on dengue recognizes the need to improve current surveillance tools for the development of better indicators to reflect transmission potential. The main objective of this study was to elucidate the association of various risk factors for rural dengue transmission with geo-information using GIS technology incorporation plus the entomological surveillance.

MATERIALS AND METHODS

Study area

This study was carried out at Lundu district following the reporting of a rural dengue outbreak by the Ministry of Health, Sarawak in 1999. Lundu is one of the districts in Sarawak, East Malaysia where the principal vector – *Ae. aegypti* is absent (Chang & Nagum, 1982). The district is located in the Kuching Division, lies between latitude of 2° 1/6' north and longitude of 109° 15' east, bordering Kalimantan, Indonesia to the east. The dengue incidence in Lundu remained minimal until 1998 when there was an increase of 14 cases reported, compared to the year before. In 1999, an outbreak occurred with 57 hospitalized cases reported within a period of three months (Health Department, unpublished report). It would have been more precise and accurate if the study was conducted during or right after the outbreak. However, due to operational constraints, it was not possible to carry out the study immediately. Furthermore, the study involved large amount of manpower and resources that needed funding to carry it out.

Sampling Villages

All dengue cases involving 23 villages reported in 1999 were recruited for the study. Of these villages, seven (Fig 1) were further chosen based on the high dengue incident. In these villages, an overall description of the socio-demographic backgrounds and the basic facilities available and, entomological-serological and geographical profiles are described. Systematic random sampling technique was used for serological surveillance and

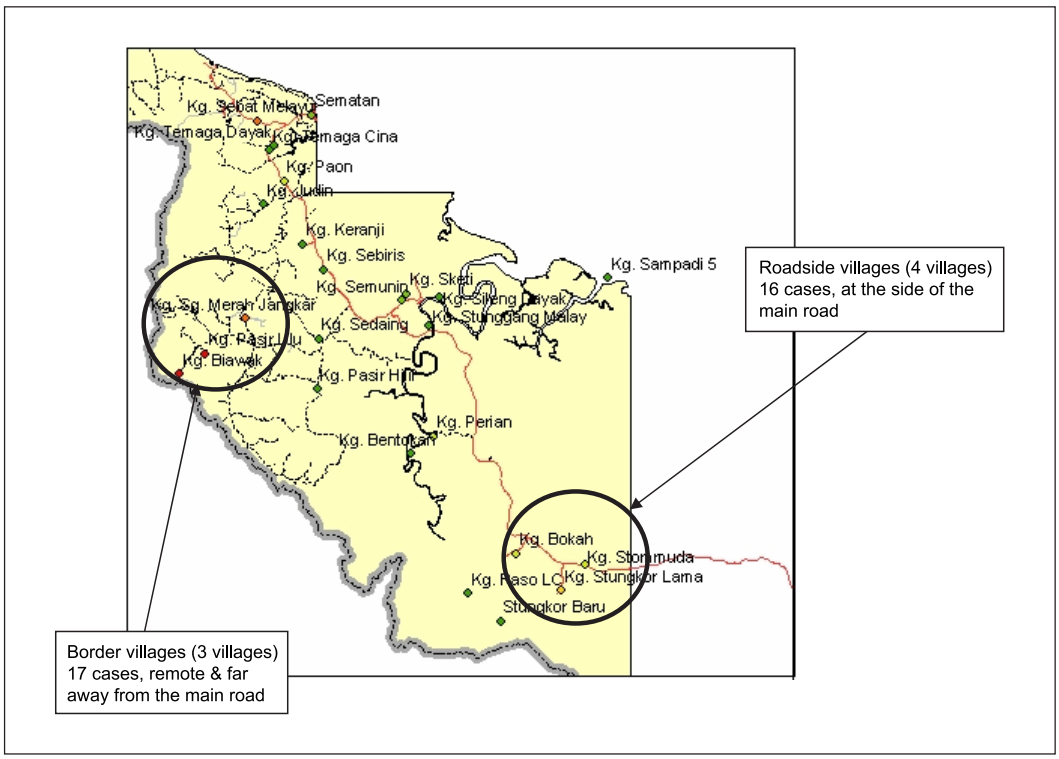

Figure 1. A Lundu district map to indicate the location of all the 23 study villages.

ovitrap studies from the total households in the villages.

The seven villages were further divided into two clusters based on location and human ecology. The first cluster (four villages) was remote and far away from the main road and situated near to the Kalimantan border within the forest fringe (Fig 1). The second cluster (three villages) was chosen on the basis of studies done by Wellmer (1983) and Soper (1967), and more accessible to the main road.

Collection of data

The data was collected through interview (socio-demographic background), observation (Basic amenities), entomological (larval inspection and ovitrap survey), and sero-prevalence survey and GIS/GPS.

Standard ovitrap, the black plastic containers (Fay & Eliason, 1966) were used. The size of the container was 8.5 cm in diameter and 7.0 cm in height. The plastic container was lined with rough, absorbent paper (#76 seed germination paper, Extra Heavy Weight, Anchor Paper Co., Box 65648, St Paul, MN 55165, USA). Traps were set in the morning (9-11 am), the period of minimum oviposition activity and recovered or exchanged for fresh traps at 7 –10 days intervals (Ritchie, 1984). They were placed in open, visible places inside the house, within the house compounds and at the identified dumping sites. During the inspection, the ovipositional substrate (paper) was periodically collected and returned to the laboratory in plastic bags. Samples were kept cool, placed individually in the plastic bag during transportation. In the laboratory, the labeled oviposition papers were dried and examined under the stereo-microscope for the presence of *Aedes* eggs and number of egg per positive trap was counted. The hatched larvae from the eggs were subsequently identified.

Blood samples were collected from the household recruited by venepuncture. IgM and IgG capture ELISA (Cardosa *et al.*,

1992) was used to detect the presence of antibodies against dengue virus, in the virology laboratory at Universiti Malaysia Sarawak. Since the duration of IgM-antibody is transient (60-90 days) in relation to the duration of dengue epidemics, and as this study was conducted within nine months after the epidemic, the prevalence of IgG antibody of the tested samples was also measured.

Geographical Information System was used to generate geographic and environmental data. Topography maps obtained from the Land and Survey Department, Sarawak with the scale of 1:50,000 were used. These maps provide the basic information of the geographical features like road, river, household, dumping sites, other buildings which are essential for locating and plotting larval breeding places. The topographic maps that were used included: Lundu, Gunong Undan, Kampung Pueh and Kampong Biawak maps. To create the spatial database, three processes were used:

1. Scanning and digitizing
2. Data projection and transformation
3. Feature attributes editing

The position of houses and dumping sites in the seven villages in this study were mapped using a Trimble GeoSurveyor Asset GPS instrument, with the accuracy of 1 meter.

Data collected were analyzed using SPSS version 10.01. Descriptive analysis using frequency, means, and median were used. To determine the association between variables and dengue cases reported, and to describe the differences between the two clusters of villages, two samples *t*-test, and Pearson's Chi-Square were used.

RESULTS

Household surveyed

A total of 551 households were surveyed in this study. The highest number of households ranged from 35 in Kg. Stommuda to 135 Kg. Semunin. The mean number of persons per household was 5.9. The majority of the house owners were farmers (54.8) with a small number of households (6.4%) from the border villages engaged in small or medium size businesses. About one third (32.4%) of the total population had more than 9 years of formal education. Most frequent source of water was from gravity fed pipes (86%). In most of the villages, except Kampong Semunin, there were no proper dumping facilities for solid waste deposal. Most of the villagers either discarded their rubbish in the house compound or nearby river, or carried it to their farms to be buried.

A random *Aedes* larval survey was carried out and confirmed that *Ae. albopictus* was the only vector species in the areas as predicted. Out of the 415 houses surveyed, 38 houses were found to have *Ae. albopictus* larvae (average house Index = 9.15%). Of all the villages surveyed, Kg. Semunin had the highest number of houses positive with *Ae. albopictus* larvae (House index=18.8%). The Breteau index ranged from 6.52 in Kampong Bokah to 262.5 in Kampong Semunin (Table 1). The total number of potential breeding sites was 1,521 with a mean of 3.63 (ranged from 1 to 48) per household. The survey showed that discarded tin cans were the most abundant breeding containers for all villages (43.1%) and followed by the plastic cups, pans or bowls (14.8%). These discarded containers accounted for 57.9%.

A total of 32,838 *Aedes* eggs were collected in 56 days of trapping. Yields per positive seed paper ranged from 40 to 230 eggs (Table 2). Larvae/pupae stages were also found in the traps and the numbers were excluded due to mixture of all four larval developmental stages. Eggs from the ovitraps were allowed to hatch and the 3rd and 4th instar larvae were randomly identified to be *Ae. albopictus*.

Dengue serological tests indicated that 23.7% of the total samples were confirmed to be positive on the basis of the results of IgM and IgG antibody responses. Two samples (0.9%) were confirmed IgM positive and 49 samples (22.8%) had IgG responses. The highest number of samples

Table 1. *Aedes albopictus* Breteau[1] and House index[2] by villages

Village	No. of house surveyed	No. of water container surveyed	House Index (%)	Breteau Index
Kampong Biawak	83	184	6.0	16.9
Kampong Pasir Ulu	63	223	1.6	9.5
Kampong Jangkar	55	142	14.6	50.9
Kampong Semunin	32	358	18.8	263
Kampong Stommuda	92	425	15.2	181
Kampong Bokah	46	145	6.5	6.5
Kampong Stungkor Lama	44	44	2.3	6.8

[1] Number of positive container per 100 households surveyed.
[2] Percent household positive with *Aedes albopictus* larvae/pupae.

Table 2. Weekly Ovitrap survey of Aedes albopictus by village

Village	Habitat*	Week								Total no. of eggs counted	Mean eggs per week
		1	2	3	4	5	6	7	8		
Biawak	I	5	0	10	0	72	115	15	179	396	49.5
	O	48	131	207	390	629	746	459	441	3051	381.4
	DS	2	5	50	47	110	25	115	100	486	60.8
Pasir Ulu	I	2	10	10	0	40	70	160	167	459	57.4
	O	52	93	527	106	601	699	492	446	3016	377
	DS	20	18	34	0	50	90	80	20	312	39
Jangkar	I	0	0	10	36	50	59	77	80	312	39
	O	8	310	409	349	899	574	441	447	3437	429.6
	DS	23	45	110	65	242	232	120	260	1097	137.1
Semunin	I	201	258	52	169	175	491	355	327	2028	253.5
	O	37	91	293	516	597	787	812	510	3643	455.4
	DS	55	79	178	386	488	490	758	440	2874	359.3
Stommuda	I	21	3	40	60	83	78	41	89	415	51.9
	O	2	290	409	643	259	563	364	314	2844	355.5
	DS	141	108	111	228	0	83	45	110	826	103.25
Bokah	I	33	22	64	74	146	181	179	174	873	109.1
	O	2	120	539	291	467	428	150	506	2503	312.9
	DS	19	10	102	80	100	88	40	50	489	61.1
Stungkor Lama	I	8	12	7	59	203	55	78	99	521	65.1
	O	108	60	473	295	641	88	473	289	2429	303.4
	DS	36	41	138	45	360	57	82	68	827	103.4

* I (indoors), O (Outdoors) and DS (Dumping sites).

positive with IgG was from Kampong Biawak with 19, followed by Kampong Jangkar (8). As for IgM result, only two positive samples were detected, one from Kampong Pasir Ulu and another one from Kampong Semunin. On the serological results from the village clusters, 67.3% of households in border villages were found reactive to IgG antibody to dengue virus, but only 32.7% in roadside villages, 3.7 times more IgG positive cases found in border villages as compared to roadside villages (Pearson's Chi-Square=15.5, df=1, p=0.000, Odd's Ratio=0.269, 95% Confidence Interval=0.137, 0.529).

From the epidemiological records of the outbreak, 11.8% of households in border villages were found to have at least one dengue case, but only 3.2% of household in roadside villages were found to have at least one case. There were about 4 times more cases found in border villages than roadside villages. We could reject the hypothesis that dengue cases in two clusters of villages are identical at any reasonable significance level (Pearson's Chi-Square=6.111, df=1, p=0.013).

The data on distance (meter) of the houses from the main road and household dumping sites were generated using the function of "Near" analysis under the ArcInfo tool to find the distance of the house from the main road and their respective dumping sites which could contribute to risk of dengue transmission. This was based on the assumption that high vector density and their proximity of vector breeding sites to human host are the two main high risk factors for dengue transmission. Figure 2 shows the mean distance of the houses from the main road, by village. The distance of the village, Stommuda to the road side is 89.9 m while Stungkor Lama village only less than 30 m. Similar results were also recorded on the measurement of houses and dumping site within the village perimeter. The greater mean distance is also in Kampong Stungkor Lama (74.61m) and the lowest is in Kampong Stommuda (Fig 3)

To anlayse the risk factors associated with the dengue outbreak in 1999, five risk factors; container density, house density, egg count per positive indoor ovitrap, egg count per positive outdoor ovitrap, egg count per positive ovitrap at domestic dumping sites were used (Table 3). Risk factors analysis for the two clusters of villages however was identical (P= 0.01).

It also reveals that only container density has a weak relationship with dengue cases reported in 1999 outbreak (Spearman's correlation=0.127, $p<0.01$). Investigations on the relationship between the risk factors and these variables showed strong relationship are house

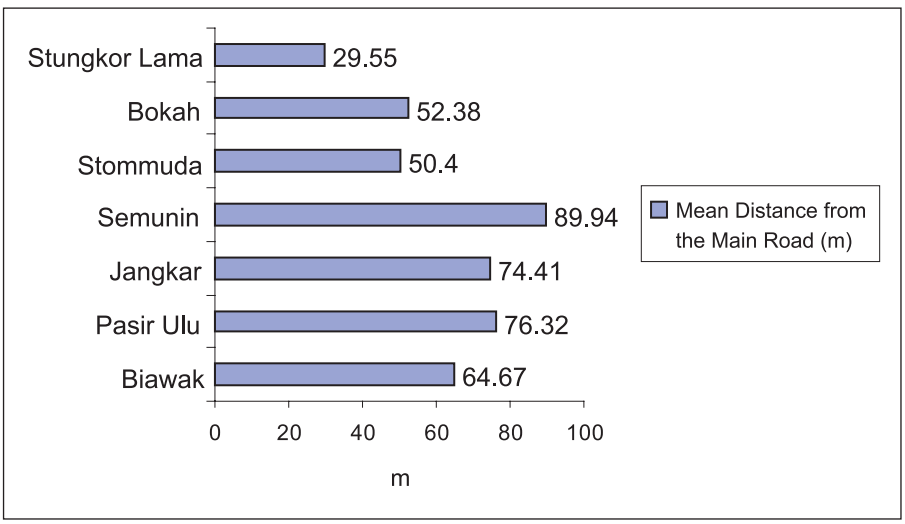

Figure 2. Mean distance (m) of the house from the main road by village.

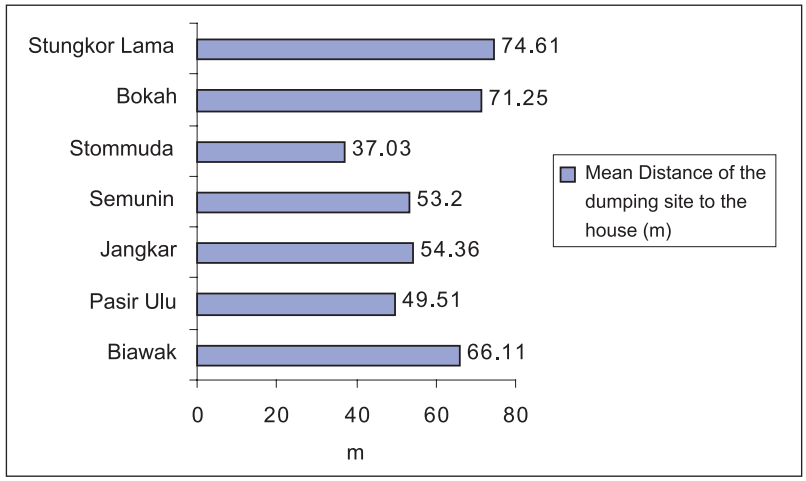

Figure 3. Mean distance (m) of the dumping site to the house by village.

Table 3. Comparison of potential risk factors by clusters of villages

Potential risk factors	Mean	SD	t	df	p
Container density					
– Border	3.5963	3.0955	-4.320	206.624	0.001*
– Roadside	6.0167				
Human Population density					
– Border	11.1338	11.080	0.146	157.327	0.884
– Roadside	10.9367	2			
House density					
– Border	1.8038	1.6283	-5.992	204.359	0.001*
– Roadside	3.6065				
Shading tree density					
– Border	2.6335	2.3311	-1.058	214.956	0.291
– Roadside	3.0214				
Distance of the house to the main road					
– Border	71.4171	79.011	20114	136.338	0.036
– Roadside	51.9249	4			
Distance of the dumping site to the house					
– Border	57.178	62.229	-0.244	184.085	0.808
– Roadside	59.178				
Egg Count per positive ovitrap (Indoor)					
– Border	0.9350	0.6654	-10.89	137.497	0.001*
– Roadside	4.0976				
Egg Count per positive ovitrap (outdoor)					
– Border	9.9185	7.2523	-3.777	212.608	0.001*
– Roadside	14.0166				
Egg Count per positive ovitrap (dumping sites)					
– Border	2.1448	2.9316	-3.879	213.783	0.001*
– Roadside	3.8738				

* Significant at 0.01 level (2-tailed)

Table 4. Relationships between the potential risk factors

Variable	Variable	σ (Spearman's Correlation)	p
Number of breeding site outdoor	House Density	0.264**	0.001
	Egg count per positive ovitrap (outdoor)	0.213**	0.006
Distance of dumping site to the house	Container density	0.318**	0.001
	Human density	0.303**	0.001
	House density	0.432**	0.001
	Shading tree density	0.271**	0.001
	Egg count per positive ovitrap (Indoor)	0.214**	0.001
	Egg count per positive ovitrap (Dumping site)	0.191**	0.001
Container Density	Shading tree density	0.291**	0.001
	House Density	0.624**	0.001
Distance of the house to the Main Road	Human Density	0.201**	0.001
	Shading tree density	0.226**	0.001
House density	Distance of the house to the Main road	0.280**	0.001
	Egg count per positive ovitrap (Indoor)	0.616**	0.001
	Human density	0.929**	0.001
	Shading tree density	0.747**	0.001
	Egg count per positive ovitrap (Dumping site)	0.256	0.001
Human Density	Shading tree density	0.724**	0.001
	Container Density	0.648**	0.001
	Egg count per positive ovitrap (Indoor)	0.478**	0.001
	Egg count per positive ovitrap (Outdoor)	0.536**	0.001
	Egg count per positive ovitrap (Dumping site)	0.239**	0.001
Shading tree density	Egg count per positive ovitrap (Indoor)	0.514**	0.001
	Egg count per positive ovitrap (Outdoor)	0.741**	0.001
	Egg count per positive ovitrap (Dumping site)	0.209**	0.001
Container Density	Egg count per positive ovitrap (Indoor)	0.415**	0.001
	Egg count per positive ovitrap (Outdoor)	0.185**	0.001
Egg count per positive ovitrap (Indoor)	Egg count per positive ovitrap (Outdoor)	0.685**	0.001
	Egg count per positive ovitrap (Dumping site)	0.368**	0.001
Egg count per positive ovitrap (Outdoor)	Egg count per positive ovitrap (Dumping site)	0.375**	0.001

** Significant at 0.01 level (2-tailed)

density and human population density (Spearman's correlation=0.929, p=0.000), house density and shading tree density (Spearman's correlation=0.747, p=0.000), human population density and shading tree density (Spearman's correlation=0.724, p=0.000), human population density and potential container density (Spearman's correlation=0.648, p=0.000), Egg count per positive ovitrap (outdoor) and shading tree density (Spearman's correlation=0.741, p=0.000) (Table 4).

DISCUSSION

This is a retrospective study on a rural dengue outbreak with *Ae. albopictus* as the only vector. The study used entomological, serological and socio-demographic surveys assisted by Geographical Information System (GIS) and analysed using both spatial and statistical analysis (SPSS version 10.01). Data from the above were analysed using relevant tests such as *t*-test and Spearman's Correlation.

Ae. albopictus is relatively more widespread in rural towns and plantations (Chang & Nagum, 1982) in Sarawak. This species is more common in outer urban areas in Penang (Paramaevaran, 1965). In our present study areas, the main socio-economic activities of the villagers are outdoor farming, thus they are frequently exposed to *Ae. albopictus* bites. Furthermore, with the unsanitary conditions due to lack of proper dumping facilities, the presence of village open dumping sites and the high tree shade density close to the village houses further promotes the breeding and harbouring of *Ae. albopictus*. Smith's observation (1956) showed that the flight range of 200 m implied that premises within the indicated diameter area are at risk of dengue transmission. However, recent study done by Lee (unpublished data) in a residential urban area in Batu Caves, Selangor had proved that the diameter was even smaller 100-120 m. With all the distances taken between houses to dumping sites and main roads, it indicated that all the houses are at higher risk of dengue transmission. Study by Rudnick (1986) also showed that crowded, wooden structures promote high density breeding of the *Aedes* vector in Jinjang, Kuala Lumpur.

Twenty years after Chang & Nagum studies (1982), *Ae. aegypti* has not spread to Lundu district probably due to the effective dengue vector control programme implemented in Sarawak thus preventing further spread of this species. Kg. Semunin is situated in a rural town and has the highest *Ae. albopictus* Breteau index (BI) of 262.5 and house index (HI) of 18.8% compared to other study villages. One expects that Kampong Semunin, the only village near to the town with all facilities available, should have a low *Ae. albopictus* infestation rate. Despite of the high vector density, the number of dengue cases recorded from the 1999 outbreak is low. This again reflected the un-reliance of conventional entomological indices that have any relationship to the transmission risk of dengue fever. A few studies have found that there was no simple correlation relationship of dengue cases with HI or BI (Lee & Hishamudin, 1990; Lee, 1996) Again in another study by Lee (1992), similar result indicated that ovitrap was a more sensitive technique than conventional larval survey, especially in low *Aedes* infestation rate areas. The conventional *Aedes* larvae survey of house to house visits could only detect the water storage containers which are relatively visible to the survey teams. The other entomological/ environmental risk factors such as shading condition, village dumping sites and house density are ignored and hence grossly underestimated the transmission risk of rural dengue fever.

The use of enzyme-linked immuno-sorbent assays (ELISAs) for dengue virus antibody detection has been developed during the past many years. It has many of the properties needed for a good screening test, including broad cross-reactivity and high sensitivity (Cardosa *et al*. 1992). From the serological survey, IgG was more prevalent in Kampong Biawak, with 22.79% positive out of 215 samples tested. This indicates that dengue virus probably circulated in the village previously without being noticed. However, there has been no recent dengue infection as no samples tested were positive with IgM. In Kampong Pasir Ulu and Kampong Jangkar, as in Kampong Biawak both belong to the border cluster, had more or less similar IgG positivity rate ranging from 20% to 28.57%. Out of the three villages, two had one positive IgM sample each. This indicates that current transmission of dengue fever was probably recent. The

same findings also were noted from the mean number of potential breeding (11.19) sites. For outdoor ovitrap results, all the three villages reported to have high egg counts with 455.4, 377, and 429.6 eggs per positive ovitrap respectively. On the other hand, the last three villages (Stommuda, Bokah and Stungkor Lama) of the roadside cluster, had a fewer IgG positive samples, compared to others. In this case, Kampong Stommuda has illustrated this.

With respect to the ovitrap results, it was observed that *Aedes albopictus* preferred outdoor ovitraps with a mean egg count of 373.6 per week compared to indoor ovitraps with mean count of 89.35 per week. This is consistent with the study done by Mogi *et al.* (1988) in Chiang Mai, Thailand. If compared to dumping sites ovitraps, outdoor ovitraps still produced higher mean counts. Although, under the circumstances, the village dumping sites will have more discarded containers, which can compete with the ovitrap, thus it is not surprising to note that dumping site ovitraps did not give a high egg count.

There was 6-30% presence of *Ae. albopictus* egg count in the indoor ovitrap. This is because by nature, *Ae. albopictus* is an outdoor breeder and will move in door in the absence of *Ae. aegypti*. Hence, this makes the vector control even more difficult.

The use of seed germination paper has proved successful in collecting the mosquito eggs. For the first time, this type of paper has been used in setting up the ovitrap for *Ae. albopictus* study. However, the type of ovitrap containers used is standard, adopted for *Ae. aegypti* work by Centers for Disease Control (Fay & Eliason, 1966).

There is significant difference in two clusters of villages attributable to container density, house density, and distance of the house from the main road, and number of *Ae. albopictus* eggs from ovitraps set indoor, outdoor, and in dumping sites. Based on cross tabulation test and *t*-test (95% confidence level), there was significant difference in terms of dengue cases in border villages and roadside villages cluster. The former cluster village category had four times more cases compared to roadside village category. Further analysis using two-sample *t*-test to determine which of the risk factors contributed to the difference showed that house density, container density, indoor mosquitoes egg count, outdoor mosquitoes egg count, and dumping sites mosquitoes egg count gave significant result at $p<0.05$. The mean value for these factors showed higher values/counts at the roadside village category compared to border village category. These findings did not match with the 1999 epidemiology of dengue fever outbreak. This apparent paradox can be explained by the fact that *Ae. albopictus* is widely distributed regardless of the remoteness of the village in Lundu district although this species may originate from the forest fringe (Hawley, 1988). Based on the entomological survey using ovitrap along with house to house larval survey with- in the premises areas may yield misleading results if one attempts to use these entomological related risk factors to predict dengue fever outbreak.

This study further elucidated a number of other potential risk factors associated with the dengue cases reported in Lundu outbreak. Nevertheless, none of the factors (house density, container density, human population density, shading tree density, indoor mosquito egg count, outdoor mosquito egg count, and dumping sites mosquito egg count, distance of the dumping site to the house, distance of the house to the main road) were associated with the dengue cases. Our analysis of the above relationship is limited by the preliminary nature of dengue cases in Lundu. Furthermore, the study was done six months after the outbreak, when many of the important risk factors may have been reduced or eliminated due the intensive post-epidemic control measures that include outbreak control procedures and enforcement of laws and legislation. Nevertheless, it is still logical to assume that human behavior is complicated and difficult to change over a short period of

time (Wong, 2000). Especially the operation in eradicating dengue usually last for a month as indicated under the laws and legislation on vector and vector-borne diseases. Risk factors related to dengue transmission are very much influenced by individual and environmental factors. Lack of or improper rubbish disposal facilities in the villages, natural breeding containers such as cocoa and coconut husk within the forest fringe would have contributed to the transmission of dengue.

Despite the lack of association with all the potential risk factors described and dengue cases reported in this outbreak, the addition of GPS and GIS technologies to dengue epidemiology as used in this study affords the possibility of exploring spatial dimensions of disease transmission not easily examined in the absence of these capabilities. Further, the incorporation of these techniques in the long term will help to save the high cost of dengue surveillance. Su & Chang's study (1994) also recommended the use of GIS as long term management of *Aedes* mosquitoes and control of epidemic of dengue disease. By incorporating geo-statistics (such as Krigging) modeling and forecasting of possible dengue epidemics, there will be a proper and efficient use of a decision support system.

Acknowledgemnent. We would like to acknowledge the medical staff at Lundu Hospital who have given so much help and support during the data collection of this study. We also thank Andrew Wong and Goh Hock Chuan for their help in the area of GIS. This study was supported with funding from the short term research grant of Universiti Malaysia Sarawak.

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