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Assessing the Risk of Dengue Fever Based On the Epidemiological, Environmental and Entomological Variables

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Abstract

Dengue fever is an infectious vector-borne disease in Malaysia. Descriptive spatial analysis indicated the DF infection was normally distributed in urban area. As for the environmental attributes, there was no significant difference except for the existence of abandoned houses across the study area. As for breeding index, it was found to be high in all temporal indices in the locality. However, it was noteworthy that there was a significant difference in the preferred breeding containers in all temporal risk indices. As a conclusion, the risk factors for *Aedes* mosquito breeding sites should be considered in carrying an effective vector control.

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Keywords: Dengue; temporal index; entomological; socio-demographic; epidemiological

1. Introduction

Dengue is known as an urban disease and the number of cases reported keeps increasing yearly. The two mosquito species responsible for the transmission of dengue in Malaysia are *Ae. aegypti* and *Ae. albopictus*. It has been long known that both *Aedes* vectors breed primarily in artificial water containers and the mosquitos' lifecycles is closely associated with human activities. Some of the preferential breeding sites are containers such as ant traps, earthen jars, flower pots, drums, concrete tanks, coconut shells and discarded tires (Simard et al, 2005; Paupy et al, 2009). According to Norbert et al, (2010), the

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control of mosquitoes at the larval stage is extremely essential to prevent the episode of the disease outbreak and the common method used to control the larvae is through the application of chemical such as abate. It has been long known that both *Aedes* vectors breed primarily in artificial water containers and the mosquitos' lifecycles is closely associated with human activities.

Urbanization growth, poor or inexistent drainage facilities, chaotic location of dwellings and factories in most towns, influence the mosquito population and affect dengue transmission intensity. The distribution and abundance of mosquito larvae actually reflect the oviposition preferences of adult females and the ability of immature stages to tolerate the conditions that prevail in aquatic habitats. Most of the study indicated that the larval habitat are increasingly rapidly in urban areas (Murrel et al, 2008). Cheong (1967), reported that *Ae aegypti* larvae preferred to breed in ant traps and earthen jars in urban areas and also in tires and flower pots. In relation to preferred breeding sites, Lee and Cheong (1987) found *Ae aegypti* larvae in bucket, basins, bowls and such like containers and concrete tanks while no breeding was detected in ant traps, tires and flower pots. These changes in preference may be the result of the persistent attention of vector control agencies on targeted breeding habitat. Since, there is no curative treatment for dengue, targeted environment with reference to *Aedes* mosquitos' ecology is relevant in combating DF disease.

Most research focuses on the spatial distribution and abundance of *Aedes* vectors, but few studies attend to characterizing the macro and micro environmental differences exhibited by different breeding habitat. The local assessment of the ecological characteristics of *Aedes* larvae can help to improve the environmental management and others control measures by targeting the most productive categories of breeding sites. This can be achieved by using certain parameters which measures the larval productivity which influence the emergence of adult mosquitoes (Yasuoka & Levin 2007).

The utilization of the three temporal risk indices enables the identification of risk area of DF occurrence (Wen et al, 2006). This information provides a clear picture of the epidemic and thus a more detailed representation of the risk. From the spatial and temporal distribution of DF epidemic, several characteristics may be described. Based on dynamic process of the epidemic, some area might have longer epidemic duration while others might have stronger intensity even though the duration is short. This situation might be contributed by the persistent occurrence of dengue cases. Therefore, characterizing dengue vector breeding habitat is important to determine their influence on the distribution and densities of DF cases and thus, explain the variations observed in dengue transmission intensity. This study aims to investigate the physical and environmental characteristics on dengue vectors distribution and densities by using the three temporal indices to identify risk area in hotspot area.

2. Methodology

Vector breeding and disease transmission have close connection to environment, epidemiology and entomology characteristics. Thus, this study was designed to improve our knowledge on the potential influence of these factors on the prevalence of dengue fever. The strategy of this research can be depicted as shown in Figure 1 with the boxes showing the process phases and the arrow representing the flow direction. The phases are described as follows:

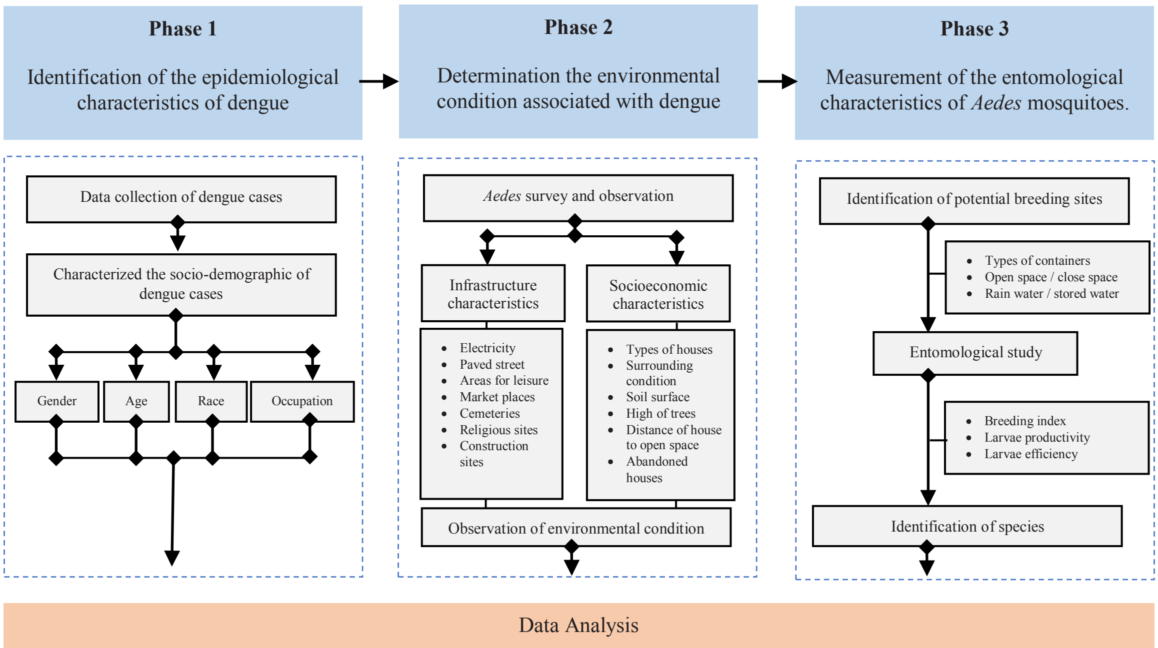

Fig. 1. Phases in carrying the research of the study

2.1. Study area

In this study, Subang Jaya area was selected as the main research site to study the relationship between socio-demographic and the transmission of dengue infection. The selection of this area was justified by several factors. First is it has a high population density in Selangor and has a significant public health implications in relation to the control and prevention of dengue. Besides that Subang Jaya had the highest number of DF cases reported yearly between 2000 until 2010 in the Selangor (Nazri et al, 2009).

Subang Jaya is a city of metropolitan area of Kuala Lumpur. It has a geographic area of 181 km^2. Based on the temperature reading acquired by the Malaysia Meteorological Service Department, the overall temperature is typically warm with bright sunny days and relatively cools in the evening. Temperature typically ranges from 23˚C to 33˚C. Humidity level as generally in range 80% or higher and the annual rainfall recorded exceed 2600 mm. Although some rainfall can be expected throughout the year, period from the December to February is considered as the rainy or wet season. When the rainy season ends, day time will be much warmer and hot but not particularly dry as the humidity level remain high. This period will begin from late January and last up to April. From March to October, both rainfall and humidity are at their lowest levels and temperature is pleasantly comfortable.

2.2. Data collection and management

Epidemiological data on daily DF cases between 2006 to 2010 which include the onset date, place of the notified DF cases, age and sex of patients and laboratory test date was obtained from the Vector Control Unit, MPSJ. (DF is a notifiable disease, positive test results have to be reported by laboratories to the Vector Control Unit, MPSJ). Socio-demographic groups were constructed on the basis of the age, race, and occupation distribution, by using the data of DF cases from year 2006 to 2010. From the result, the demographic pattern of DF cases was further analyzed using ArcGIS version 9.3 in order to obtain the demographic distribution of dengue in Subang Jaya. In addition, to assess the DF risk transmission, epidemiological data on daily DF cases were calculated to three temporal risk indices for each spatial unit and seasonal year which was adopted from Nazri et al (2012).

From the index data, every localities that shows continuous occurrence in every year was prioritized and choose in order to examine their environmental and entomological characteristics. A total of 17 localities have shown a constant occurrence of dengue cases and will directly include as our study site. List of the selected localities is tabulated in the Table 1 shown below.

Table 1. Study localities based on the dengue cases reported from 2006-2010

Temporal Indices	Localities	District
Frequency (α)	PJS 7	Subang
	PJS 9	Subang
	Taman Puchong Perdana	Puchong
	Taman Puchong Indah	Puchong
	Taman Universiti	Seri Kembangan
	Taman Serdang Jaya	Seri Kembangan
Duration (β)	USJ 11	Subang
	USJ 6	Subang
	Taman Kinrara	Puchong
	Bandar Puchong Jaya	Puchong
	Bandar Puteri	Puchong
Intensity (γ)	Kampung Batu 3	Puchong
	Taman Kota Perdana	Puchong
	Taman Subang Mas	Subang
	USJ 14	Subang
	Taman Serdang Jaya	Seri Kembangan
	Taman Sg Besi Indah	Seri Kembangan

A dwellings background survey instrument is developed to gather socioeconomic information of the selected dwellings and adjacent areas (Arunachalam et al., 2010). Localities and dwellings background survey was conducted by using observation approach on the study area. There were approximately 30-40 a house was observed in 16 localities which was selected based on temporal Index. The socio-economic characteristics of the localities also include the type of house, the height of trees, the type of soil surface, the existence of potential breeding sites and sanitation facilities in and around the house, the presence of solid waste near dwellings that could collect rainwater and others were observed (Arunachalam et al., 2010)

A larval survey was conducted according to standard practice by vector control staff from Subang Jaya Municipal Council. In each locality, domestic spaces as well as public (non-household) spaces were inspected. The larval was collected using flow-in technique (C. O'Malley, 1995) due to the suitable for the shallow water as the breeding mostly comprised of shallow water in containers. A total of 5-10 dips were conducted in each and every breeding site found. This is to precisely compute the productivity in each and every breeding site (Fillinger, et al., 2008). The presence or absence of *Aedes* larvae was determined in each container and counted all the larvae to obtain the breeding index, productivity and efficiency of immature of container density which influence larvae production.

3. Result

3.1. Epidemiological characteristics of dengue cases in Subang Jaya

A total of 5200 confirmed dengue cases that had legible and existing address were reported in Subang Jaya Health Office. In order to understand the epidemiological characteristics of dengue cases in Subang Jaya, the demographic analysis was performed. From the results obtained in Table 2, males (56.8%) are more at risk to dengue virus compared to female (43.2%). This distribution is homogeneous from the yearly monitoring analysis. The distributions of incidence cases in the age category are varied. The age group between 15-29 years old has been determined as the highest risk group with about 37.4% reported cases followed by the group of 30-44 years old which 30.4%. The Chinese population had the most number of DF cases with 47.2% followed by Malay population with 34.9%. Mostly the population infected with DF were employed with the percentage of 52.2%. The percentage of student was quite high with 27.1%.

Table 2. Demographic characteristic of dengue cases in Subang Jaya (2006 to 2010)

Socio- Demographic Characteristics		n	%	95% CI
Gender	Male	2952	56.8	56.1-57.9
	Female	2248	43.2	42.6-44.1
	Total	5200		
Age groups	0-14	1027	19.8	19.2-20.7
	15-29	1944	37.4	36.8-38.3
	30-44	1579	30.4	29.8-31.3
	45-59	515	9.9	9.3-10.8
	60-74	126	2.3	1.7-3.2
	Total	5200		
Race	Malay	1813	34.9	34.3-35.8
	Chinese	2454	47.2	46.6-48.1
	Indian	667	12.8	12.2-13.7
	Others*	266	5.1	4.5-6.0
	Total	5200		
Occupation	Employed	815	52.2	51.6-53.1
	Students	422	27.1	26.5-28.0
	Housewives	175	11.2	10.6-12.1
	Others**	148	9.5	8.9-10.4
	Total	1560		

*Noted: * Foreigners; ** Unemployed*

In this study, the incidence cases had been monitored spatially were all the socio-demographic characteristics of DF cases from year 2006 to 2010 was visualized accordingly by gender, age, race and occupation by using Geographic Instrument System (GIS). Therefore the trend of the demographic characteristics cab be easily monitored. The highest numbers to lowest numbers of DF cases was determined by the darkest colour to the lightest colour as demonstrated in the maps below.

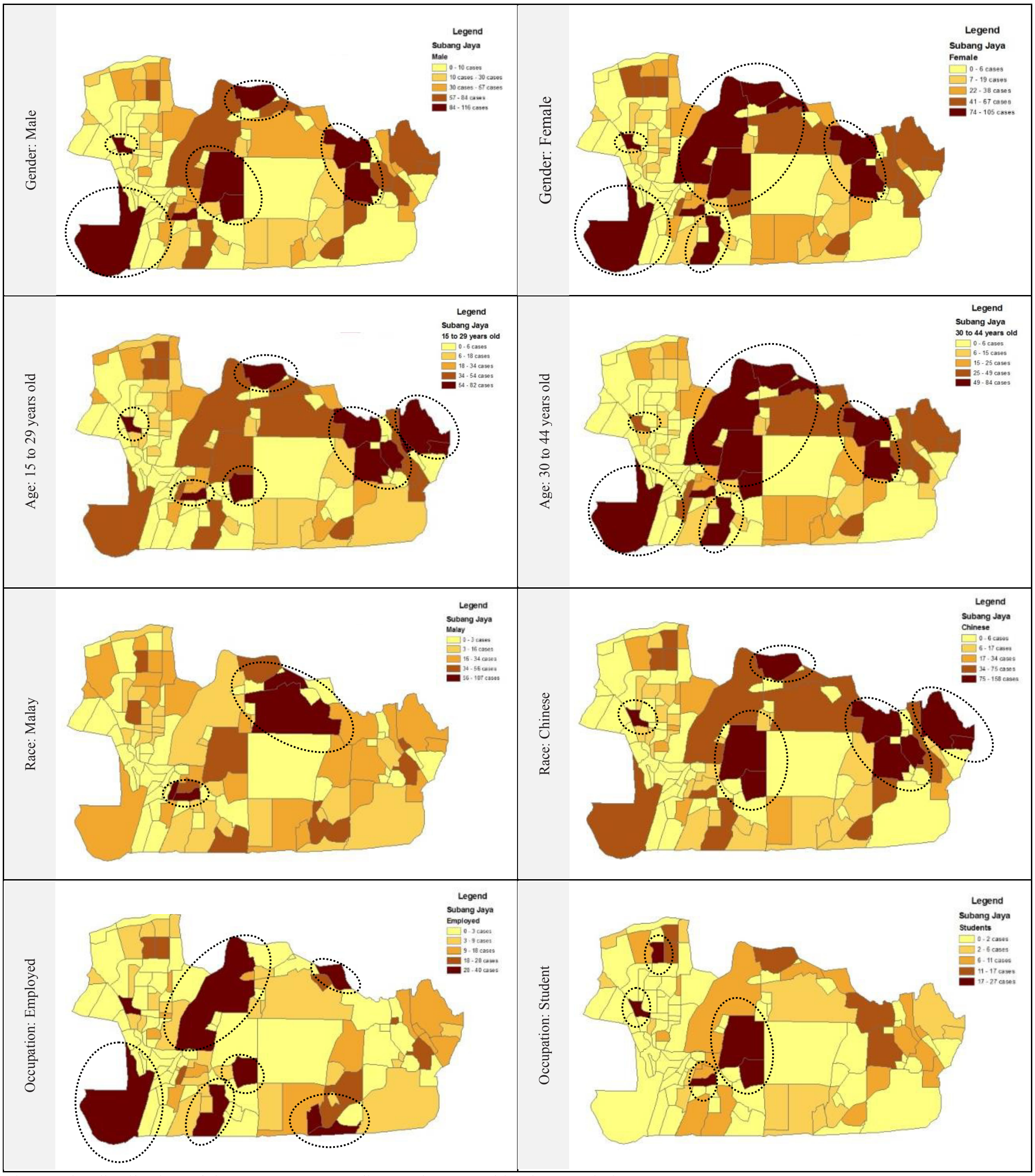

Fig. 2. The distribution of dengue cases according to demographic characteristics, 2006 – 2010.

3.2. Environmental characteristics in different temporal risk indices of dengue outbreak

From the index data, only 16 localities had been selected based on the persistence occurrence of DF cases yearly and was characterized into different temporal risk indices in order explore their environmental and entomological characteristics. As tabulated in Table 3, From the observation of the infrastructural characteristics, the types of house mostly were mixed in all area monitored. All localities are provided with electricity, paved street and market places. The presence of area for leisure such as playground and recreation parks was also observed. For religious sites, all localities were provided with mosque; only few of the localities had temple and church. The present study show that there was no significant difference except for the existence of abandoned houses (***α***: 2.2%, ***β***: 7.0% and ***γ*:** 0.1%) across the study area.

Table 3. Environmental characteristics of different temporal risk characteristics of dengue outbreak area

Environmental Characteristics		**Temporal Risk Indices**					
		Frequency (*α*)		**Duration (*β*)**		**Intensity (*γ*)**	
		n	%	n	%	n	%
Types of house	Bungalow	0	0.0	0	0.0	5	3.3
	Terrace	288	77.8	185	86.4	123	81.5
	Flat/ Condominium	82	22.2	29	13.6	0	0.0
	Village	0	0.0	0	0.0	23	15.2
	Squatter	0	0.0	0	0.0	0	0.0
	Total	370		214		151	
House condition with visible	Garbage dump	125	16.5	60	12.6	31	8.8
	Garden and bulk waste	62	8.2	28	5.9	32	9.1
	Open water container	106	14.0	98	20.5	35	9.9
	Tall trees	167	22.0	86	18.0	52	14.8
	Garden	64	8.4	37	7.7	43	12.2
	Screen window/ door	11	1.4	5	1.0	17	4.8
	Open sewer	224	29.5	164	34.3	142	40.3
	Total	759		478		352	
Soil surface	Paved	54	9.3	0	0.0	14	5.7
	Cement/ Tiles floor	328	56.3	211	58.3	137	55.9
	Grass	117	20.1	95	26.2	53	21.6
	Damp soil	84	14.4	56	15.5	41	16.7
	Total	583		362		245	
Height of trees	<1m	24	14.0	0	0.0	0	0.0
	1-2m	51	30.5	19	22.9	12	25.9
	3-4m	65	38.0	34	41.0	24	44.4
	5-6m	25	14.6	22	26.5	16	29.6
	>6m	2	1.2	5	6.0	0	0.0
	Total	167		83		52	
Distance of house to open and public space	0-500m	291	85.1	214	100.0	151	100.0
	500-1300m	51	14.9	0	0.0	0	0.0
	>1300m	0	0.0	0	0.0	0	0.0
	Total	342		214		151	
Abandoned House		8	2.2	15	7	14	0.1

3.3. Entomological characteristics of Aedes breeding sites in different temporal risk indices

Breeding Index (BI) was calculated in order to evaluate the density of *Aedes* mosquitoes in different temporal index. Besides that, the types of containers were identified across the study area. The density of positive containers and their immature were also calculated. Table 4 showed the BI of *Aedes* mosquitoes based on different temporal risk indices. In Frequency Index (*α*), PJS 7 (BI= 97.6) had the highest BI followed by Taman Serdang Jaya (BI= 83.9).The lowest BI was detected in Taman Puchong Indah (BI= 27.1).Taman Sri Serdang was observed to be the highest number of BI followed by USJ 6 and the lowest was Bandar Puteri for the duration index (*β*) (BI = 89.8, 60.0 and 11.9 respectively). Lastly for the intensity index (γ), Kg Batu 13 (BI= 94.9) was recorded to be the highest number in their BI followed by Taman Serdang Raya (BI= 58.2) and the lowest was in Taman Sg Besi Indah (BI = 44.0). In summary, BI was significantly higher in all temporal risk indices and the densities of larval breeding was in order from greatest to least were Intensity Index (γ) > Frequency Index (*α*) > Duration Index (*β*) (99.1, 92.7 and 72.9 respectively).

Table 4. Breeding Index (BI) of *Aedes* mosquitoes in different temporal risk indices

Temporal Index	Locality	Total number of larvae and pupae (TLP)	Number of dips (ND)	Number of breeding places (BP)	Breeding Index (BI)*
Frequency (*α*)	Taman Puchong Perdana	119	30	6	23.8
	Taman Puchong Indah	166	55	9	27.1
	PJS 9	189	50	13	49.1
	PJS 7	697	100	14	97.6
	Taman Universiti	214	50	10	42.8
	Taman Serdang Jaya	498	95	16	83.9
				Total	324.3
				Average	92.7
Duration (*β*)	USJ 6	360	60	10	60.0
	USJ 11	175	25	4	28.0
	Taman Sri Serdang	481	75	14	89.8
	Taman Kinrara	301	35	6	51.6
	Taman Puchong Jaya	69	35	7	13.8
	Bandar Puteri	79	20	3	11.9
				Total	255.1
				Average	72.9
Intensity (*γ*)	Kg Batu 13	614	110	17	94.9
	Taman Batu 3	236	70	15	50.6
	Taman Sg Besi Indah	264	60	10	44.0
	Taman Serdang Raya	358	80	13	58.2
				Total	247.7
				Average	99.1

As shown in Figure 3, the highest number of Positive Containers (PC) was recorded in Frequency (*α*) followed by Intensity (γ) and Duration Index (*β*) (PC = 63; 52 and 43 respectively). A total of 4,063 larvae were collected across the different temporal risk indices. With reference to the total larvae (TL), it was in line with the PC order (TL = 1385; 1330; 1348 respectively).Plastic and water bottles are the dominant containers found in all temporal risk indices.

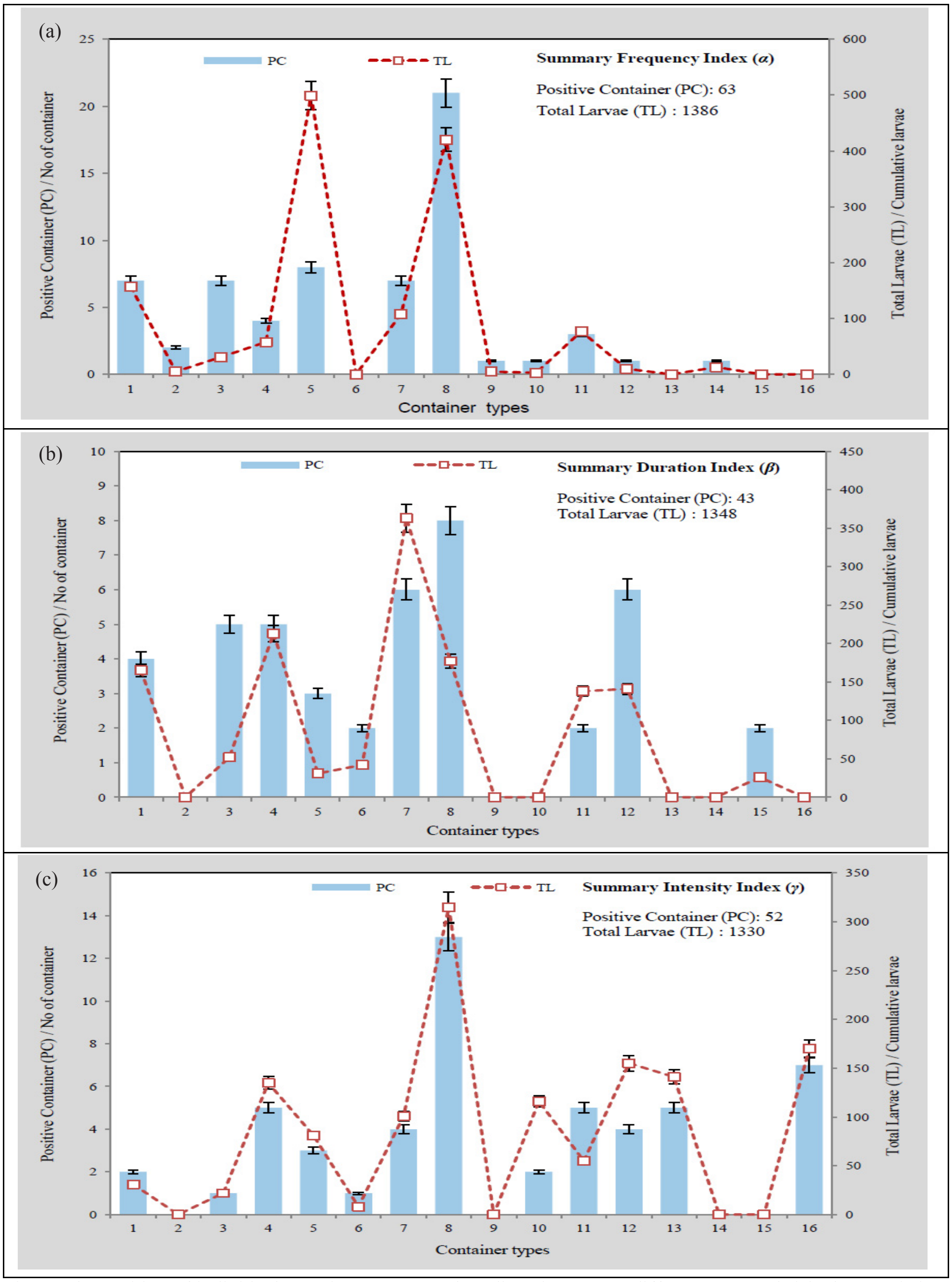

Fig. 3. The position of individual containers as vector breeding sites across different temporal risk characteristics. (a) Frequency Index; (b) Duration Index; (c) Intensity Index. Noted: 1- drums; 2- water reservoir; 3- empty paint cans; 4- drums & bucket; 5- flower vases; 6- earthen pots; 7- tires; 8- plastic bowl & water bottles; 9- plastic bags; 10- aquarium unused, glass jars; 11- Metal pots, tin pots; 12- discarded appliances; 13- dust carrier & garbage bin; 14- ant guard, tray; 15- coconut shell, tree holes; 16- others (pipe, septic tank, gutter, rubber mat).

4. Discussion

The result obtained from this assessment have an important implication for further research, surveillance and control of DF outbreak in Malaysia. Based on the epidemiological analysis, it shows that the pattern of DF outbreak was already circulating in Subang Jaya and most likely influenced by the environmental condition which related to the ecology of *Aedes* mosquito surrounded in the locality. It was found that, the implementation of the temporal risk characteristics (Frequency index (α), Duration index (β) and Intensity index (γ)) (Wen et al., 2006; Nazri et al., 2012) in categorizing the risk of DF outbreak was helpful in determining the detailed characteristics of parameter measured in order to understand the different DF transmission in the locality.

The local assessment of the ecological characteristics of Aedes larvae can help to improve the environmental management and others control measures by targeting the most productive categories of breeding sites. The present study in different temporal risk indices revealed there was a significant difference in the preferred breeding containers in all temporal risk indices. Flower vases was identified as the highest efficiency of container in frequency index due to the abundance of terrace houses which most the floor surface of the balcony was cement thus the dwellers plant their trees in vase. In Duration Index, paint bucket was found to be the highest efficiency among all the key container identified. The dwellers accumulate the used or empty paint bucket after painting their house and used them as container or buckets. They filled them with water for daily purposes or left these containers outside to get filled up with rainwater (Saifur et al., 2013). Most larvae found was at the lids of the paint bucket. As the consequence, the continuous presence of mosquitoes could explain the extended duration of dengue cases in these areas.

The control of dengue vectors has been discussed by several people (Fock et al, 1993; Lu et al, 2009; Oyewole et al, 2009; Troyo et al, 2009) and the control of DF mostly authoritatively presented in WHO (1975). Many methods are available for the control of the dengue vectors, e.g. environmental control, chemical control, biological control, genetic control, human behavioral control and others. Of these method, human behavioral control, environmental control and effective vector surveillance was considered to be the most important in a long-term basis since they have the same resultant effect in order to eliminate and reduce the number of vector breeding sources.

Human behavior control involves changing human behavior to prevent and control the propagation of mosquitoes in premises. Human masses can be motivated to participate in *Aedes* control program through health education and community participation project to clean up compound and removes mosquito breeding sources. The public can also be coerced and forced into carrying out simple preventive and control measures through law enforcement. Health education accompanied by law enforcement are very powerful and effective tools in the prevention of *Aedes* breeding (Aiken & Leigh, 1978). Since DF basically a man-made disease, human behavioral control is undoubtedly the most important and effective measure in the long-term battle against the *Aedes* vectors.

Environmental control is the method to permanently control the DF outbreak through the improvement of the environmental condition (WHO, 1975). The principle involved either the destruction of immature stages or disruption of the mosquito immature life cycle. These can be effectively achieved through a public participation in guided by the health authorities in motivating the public to actively contribute to vector control activities.

Vector surveillance is one of the most important aspects of vector control. It is essential step in the surveillance of vector-borne disease. The purpose of surveillance is to determine the presence of vectors, their frequency of occurrence, abundance, distribution and other epidemiological parameter relating to their vectorial capacity. It is utmost importance to have continuous basic information on the distribution and density of the vectors. Therefore, routine larval surveys in all built-up areas would pinpoint the high

Aedes infestation and routine plotting of DF cases on map would pinpoint the high disease endemic areas. Thus, routine, year-round vector and disease surveillance would enable to identify a priority areas to be periodically mapped out for control.

It must be emphasized that all the above methods, by themselves are not completely effective. An integration of them is necessary in reducing and eliminating the vector breeding sources thus achieve effective control of DF outbreak. Needless to say, a control strategy must be developed well before an outbreak actually occur. Therefore, these integrated methods is needed and should be carried out the whole year round.

5. Conclusion

As a conclusion, the key to effectively control of DF outbreak is to know in advance all the high potential transmission areas which are generally the areas with densest human and vector population. These area would normally coincide with areas of high endemicity of the disease. The result in present study demonstrated a significant different characteristics of all parameter measured across the study area. However, it was noteworthy that there was a significant difference in the preferred breeding habitat. Thus, a risk factor for *Aedes* mosquito breeding sites should be considered in carrying an effective control activities and reducing the transmission of the disease.

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