ORIGINAL ARTICLE

Ecological Analysis of Five Years Dengue Cases and Outbreaks in Keningau, Sabah, Malaysia

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ABSTRACT

Introduction: Dengue fever is caused by the dengue virus that is transmitted via Aedes mosquitoes. The lifecycle of Aedes mosquitoes is affected by the local climate (rainfall) which influences dengue transmission. Sabah is one of the states that is laden with a high incidence rate of dengue in Malaysia and the condition seems to have worsened with sudden, multiple outbreaks occurring in the year 2016. **Methods**: An ecological analysis was conducted in Keningau, Sabah to analyse dengue case patterns and distribution over a 5-year period and to exhibit the correlation between rainfall, larval indices, dengue incidences, and outbreaks. **Results:** Significant cross-correlation analysis (CCF) was discovered between rainfall and *Aedes* index at lag number 5 with a correlation coefficient of 0.151 (±0.063) as well as between rainfall and Breteau Index at lag number 5 with a correlation coefficient of 0.143 (±0.063). However, no significant cross-correlation analysis was found between *Aedes* index and dengue incidences. Associations were also seen between larval indices and outbreak cases. **Conclusion:** This study showed an increase of *Aedes* and Breteau Indices to susceptibility level five weeks after rainfall which increases the risk of dengue transmission.

Keywords: Dengue, Correlation, Rainfall, Larval indices, Sabah

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INTRODUCTION

Dengue fever is an infection caused by the dengue virus belonging to the Flaviviridae family, in the genus Flavivirus. The dengue virus is transmitted via the vector Aedes sp. mosquito. The Aedes species known to be vectors in Malaysia are Aedes aegypti and Aedes albopictus. All four serotypes of dengue virus are circulating in Malaysia (1). As for Malaysia, the latest incidence rate of dengue infection in 2018 was 245.3 per 100 000 population with a fatality rate of 0.18% (2). In 1986, Vector-Borne Disease Control Division of the Ministry of Health Malaysia (MOH) came up with a dengue fever prevention and control guideline which has since been updated several times. Dengue outbreak is defined as the occurrence of more than one case of dengue fever in a certain locality whereby the onset date between one case to another is less than 14 days (3).

Studies have been carried out regarding dengue cases and its association with the Aedes Index (AI) or House Index (HI), Breteau Index (BI), and Container Index (CI), but the findings were rather contradictive. Aedes Index is defined as the percentage of premises infested with Aedes larvae over the total number of premises inspected which is also known as the House Index (HI) in certain areas. Breteau Index (BI) is defined as the number of positive containers per 100 houses inspected. Container Index (CI) is defined as the percentage of water holding containers infested with Aedes larvae over the total number of containers inspected. A research done in Kuala Lumpur, Malaysia in 1996 did not show any association between the number of dengue cases with the AI and BI (4). In 2003, a review published by the World Health Organisation (WHO) stated the shortcomings of using Aedes Indices (AI, BI, CI) as a risk assessment and guide for control programmes (5). In southern Thailand, a research conducted in 2008 to study the environmental factors and incidences of dengue fever showed significant association with BI. However, the correlation between dengue incidences and BI is weak with an r value of –0.17 (6). In 2010, an article published based on a research done in Havana City, Cuba stated that the predictive risk for the dengue virus transmission can be determined with the criterion of $BI_{max} \geq 4$ (7). Studies looking at these vector indices and its associations with outbreaks have varying study outcomes. However, the latest study on the association of dengue outbreak and indices done in Malaysia concluded that predicting dengue outbreak by using larval indices was not effective (8).

It is well known that dengue cases are very much influenced by environmental factors. Number of dengue cases correlates with rainfall distribution, especially the frequency of rainy days per month (9, 10). However, there are also other factors associated with the occurrence of dengue cases, such as diurnal temperature range, wind velocity, and humidity which are closely related with precipitation patterns (10-15). Ecological factors have unique interactions with the Aedes mosquito. For example, temperature affects transmission rates of dengue cases by increasing mosquito biting times and mosquito population (13).

In Sabah, 91% of areas receive rainfall that is above 2000mm annually. However, rainfall in Keningau is much lower with rainfall between 1500-1999 mm annually (16). The best way to study the relationship between rainfall and dengue incidences is at the locality that has both rainfall and dry period patterns. So, the rainfall peak can be clearly distinguished from one period to another in the time-series graph. A locality with lower rainfall distribution may have patchy rainfall patterns throughout the year which makes it easy to detect the peak of rainfall distribution in a time series graph. Keningau district has experienced a sudden increase of dengue cases with multiple outbreaks occurring in one year. The aim of this study was to analyse the patterns exhibited by dengue cases and determine the distribution over a five-year duration and its correlation between rainfall, vector indices, dengue cases, and outbreaks seen in the district of Keningau, Malaysia.

MATERIALS AND METHODS

Study Setting

This is an ecological study using the data from Keningau district (Figure 1). The district is situated in a valley with an altitude of 282 metres bordered by the Crocker Range and Trus Madi Range in the Sabah state of Malaysia. It is a part of the interior division of Sabah with an area of 3,532.82 km2 that consists of 43 sub-districts, 245 villages, and an estimated total population of 200,985 in 2010. Initial dengue incidences in Keningau was 6.47 per 100 000 population in 2012 which has since then increased to 275.64 per 100 000 population in 2016 which is about 41-folds within a span of five years. The temperature and precipitation are influenced by the monsoon season that occurs in nearby countries to the Borneo Island where the study area is situated.

Surveillance Data Collection

Data of dengue cases from 2012 to 2016 in Keningau district were retrieved from the Ministry of Health

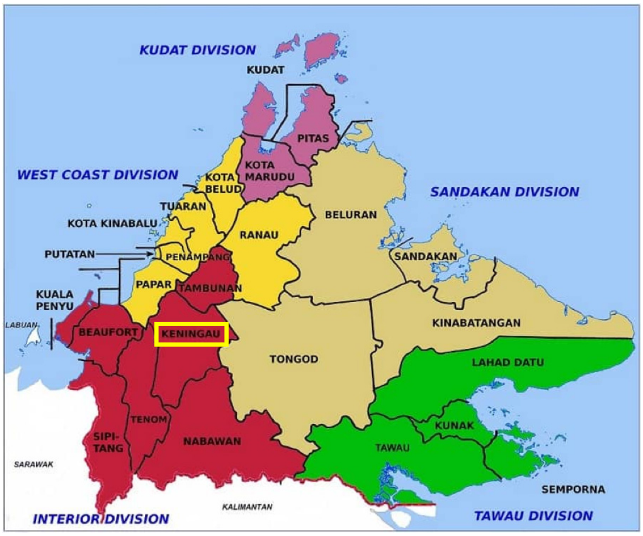

Figure 5: Keningau district (yellow box) as area of study in the map of Sabah, Malaysia.

Malaysia (MOH) eDengue registry system. Based on the newly issued guidelines of dengue case management a dengue case is confirmed by laboratory criteria which includes the demonstration of dengue virus NS1 antigen in the serum (17). All suspected dengue cases detected in health facilities in Keningau are based on clinical features that include a full blood count and notified to Keningau district health office. The notified cases were investigated further to obtain other crucial information such as individual movement to ascertain the source of infection (18). All of the notified suspected dengue cases were confirmed with a serological test (19). After the year 2014, dengue cases were confirmed via a point of care test involving a rapid test kit consisting of NS1 antigen/ IgM and IgG parameters. Only confirmed dengue cases were registered in the eDengue database which included details of investigation and control measures. Some details included in the registry are age, race, location by name and coordinate, AI, BI, CI, and also outbreak status (3). All confirmed dengue cases used for this study were within the five-year timeframe from January 2012 until December 2016. The indices used in the investigation are AI, BI and CI as per the guidelines issued by the MOH Malaysia (20). The threshold for indices value for AI is < 1%, BI is < 5% and CI is < 10% (21).

The daily rainfall data were retrieved from the MMD record that collected data from the station located in Keningau with corresponding coordinates: latitude = 5°21'N, longitude = 116°10'E. All meteorological elements were measured via the automatic weather station and all data of daily rainfall over the course of five years were taken from January 2012 until December 2016.

Data Analysis

This ecological study analyses the number of confirmed dengue cases in relation to the AI, BI, CI, and rainfall patterns. All gathered data were analysed by using Statistical Package for the Social Sciences (SPSS), version 22. Prior Moving Average (PMA) was used on rainfall, incidences, and indexes to smoothen the data. Time series analysis was done to plot the pattern of rainfall distribution, AI, BI, CI, and dengue case incidence by using weekly intervals for five years. The Cross-Correlation Function (CCF) Analysis was done on rainfall distribution over dengue incidences, AI, BI, CI. The associations between a few characteristic variables of the cases and dengue-outbreak status as the outcome were analysed by using bivariate Pearson's Chi-Squared analysis.

Ethical Considerations
This study is registered with the National Medical Research Registered (NMRR ID: and approved for publication by the Director General of Health, Ministry of Health Malaysia (KKM/NIHSEC/800-4/4/1Jld.49(33).

RESULTS

The number of confirmed dengue cases in Keningau district from 2012 until 2016 was 667 cases. The data obtained as per Table I with the majority of dengue cases are among working adults between the ages of 20-59 years old with a mean of 30 years old, and standard deviation of 16.32 years old. The majority of dengue cases occurred in 2016 accounts for about 83% of cases in this study. Most of the residential areas where dengue cases were located are in rural areas which accounts for 77.4% of cases while 65.4% dengue cases in Keningau were single cases. AI has the most cases with a susceptible index compared to BI and CI of which a majority of the cases were less than 1% and 5% respectively.

Most dengue cases were from single cases. However, there were some associations made from the outbreak as shown in Table I. Dengue cases involving patients less than 10 years old had the highest rate in outbreak compared to other age groups. Being female and having residence in town areas showed the highest rate of association with dengue outbreak cases. While the larval indices such as AI, BI and CI with <1%, <5% and <10% respectively had higher association with dengue outbreak cases.

The rainfall distribution patterns in the Keningau district for the 5 years were not seasonal but it should be noted that the peak of rainfall usually occurs during the first half of each year. The dengue incidence was less than 2 cases for every 100 000 population since 2012 till 2015 but increased in number in early and mid-part of the year 2016 (Fig. 2 and Fig. 3). In Fig. 4, there was a significant correlation at lag number 5 with correlation coefficient of 0.151 (±0.063) between rainfall and Aedes Index. Meanwhile, the Cross-Correlation Function (CCF) analysis in Fig. 5 between rainfall and Breteau Index showed that there was a significant correlation at lag no 5 with a correlation coefficient of 0.143 (±0.063). However, the cross-correlation analysis between rainfall

Table I: Analysis of factors and its association with dengue outbreak

Variable	Frequency n (%)	Type of case		Prevalence Odds Ratio	Confidence Interval	Chi-Square (X^2)	p-value
		Outbreak n (%)	Single n (%)				
Age (years)							
<10	41 (6.1%)	21 (51.2%)	20 (48.8%)				
10 – 19	181 (27.1%)	69 (38.1%)	112 (61.9%)			11.23	<0.05
20 – 59	406 (60.9%)	134 (33.0%)	272 (67.0%)				
≥ 60	39 (5.8%)	7 (17.9%)	32 (82.1%)				
Gender							
Female	264 (39.6%)	107 (40.5%)	157 (59.5%)	1.53	1.11-2.12	6.71	<0.05
Male	403 (60.4%)	124 (30.8%)	279 (69.2%)				
Citizenship							
Malaysian	647 (97.0%)	228 (35.2%)	419 (64.8%)	3.09	0.89-10.6	3.51	0.06
Non-Malaysian	20 (3.0%)	3(15.0%)	17(65.4%)				
Address locality							
Town	151 (22.6%)	73 (48.3%)	78 (51.7%)	2.12	1.46-3.07	16.21	<0.05
Rural	516 (77.4%)	158 (30.6%)	358 (69.4%)				
Aedes Index							
< 1%	312 (46.8%)	184 (59.0%)	128 41.0%)	9.42	6.44-13.8	153.43	<0.05
Susceptible	355 (53.2%)	47 (13.2%)	308 (86.8%)				
Breteau Index		206 (40.8%)	299 (59.2%)				
< 5%	505 (75.7%)	25 (15.4%)	137 (84.6%)	3.78	2.38-5.99	34.84	<0.05
Susceptible	162 (24.3%)						
Container Index							
< 10%	650 (97.5%)	229 (35.2%)	421 (64.8%)	4.08	0.93-18.0	4.03	<0.05
Susceptible	17 (2.5%)	2 (11.8%)	15 (88.2%)				
Delay in Diagnosis							
<3 days	354 (63.1%)	137 (38.7%)	217 (61.3%)	1.47	1.07-2.03	5.51	<0.05
≥ 3 days	313 (46.9%)	94 (30%)	219(70.0%)				

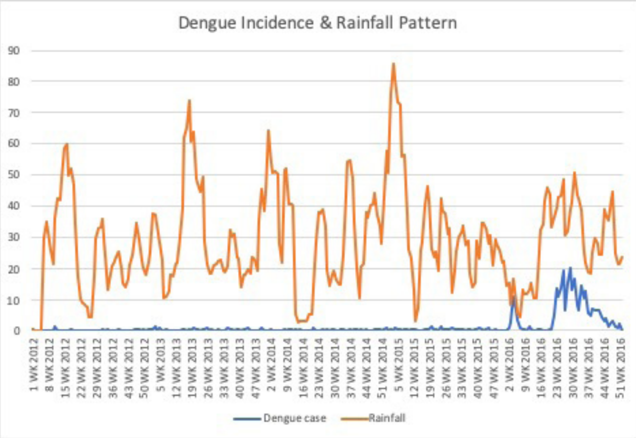

Figure 2: Time series of dengue incidence and rainfall distribution pattern in Keningau for 5 years

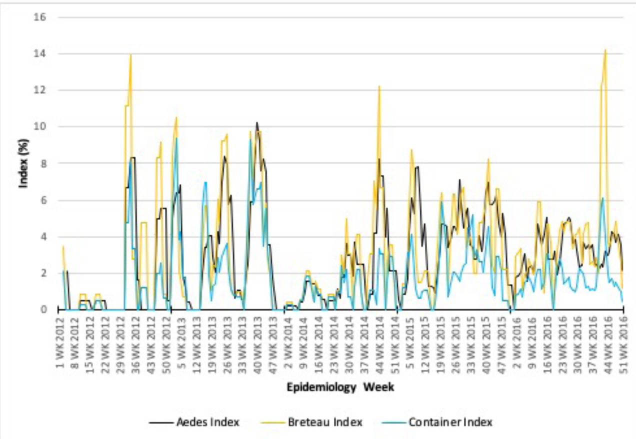

Figure 3: Time series of *Aedes*, Breteau and Container Indices over 5 years in Keningau.

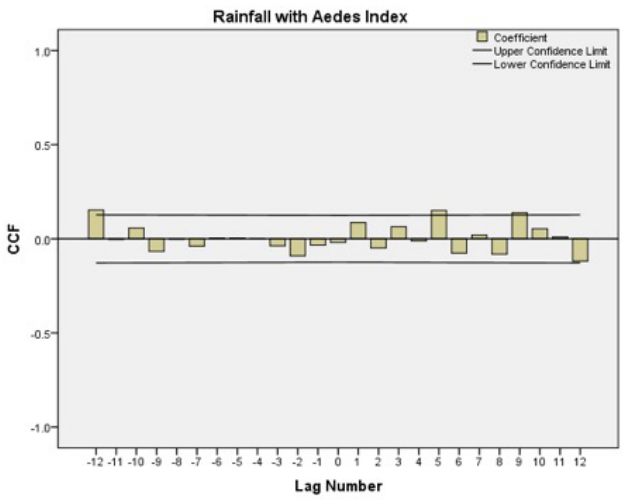

Figure 4: Cross-correlation analysis between rainfall and *Aedes* Index where there was a significant correlation at lag number 5 with correlation coefficient 0.151 (±0.063).

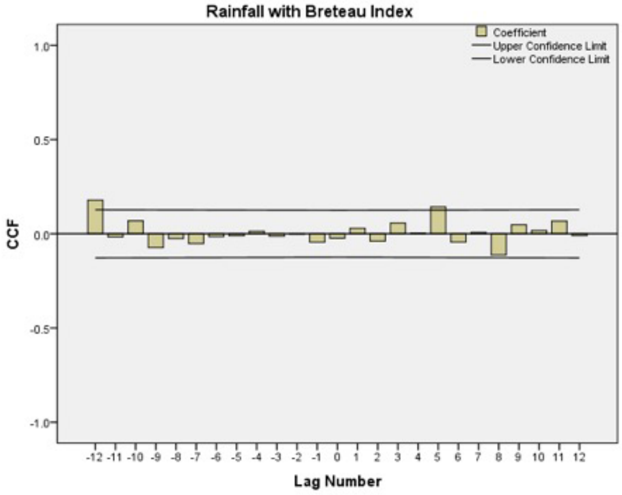

Figure 5: cross-correlation analysis between rainfall and Breteau Index where there was a significant correlation at lag number 5 with correlation coefficient 0.143 (±0.063).

and CI, rainfall and dengue incidence, and AI and dengue incidence were not significant.

DISCUSSION

This study showed a significant correlation between rainfall distribution with AI and BI in the cross-correlation analysis at lag number 5 for both indices. This means that the rainfall will determine the AI and BI susceptible levels within five weeks which increases the risk for dengue transmission. This finding is similar to the study in Vietnam indicating the increase of rainfall associated with increased risk of dengue transmission which is contrary to the study in Sepang (8, 10). A majority of dengue cases occurred in the rural area of Keningau. Some of these areas do not have treated water supply for daily use. Most of these houses use gravity-fed water for cooking or drinking and rainwater for other non-essential activities. Most houses will have a lot of containers for water storage. This is different from the study done in Sepang, where the source of water is treated water that is supplied directly to the residential area.

There is no significant correlation between rainfall and CI which might mean that the number of water containers inspected is abundant, but the number of larvae found is less. Rainfall and Aedes Indices did not directly influence the dengue incidence which contradicted with the study conducted in Sri Lanka in the year 2017 (22). The different findings were possibly due to the complex interactions between agent, host, environment, and vector which include the virus serotypes, sero-prevalence, immunity of dengue in the community, diurnal temperature patterns, wind velocity, and humidity (14, 15).

The majority of dengue cases were among males which is similar to studies in Sri Lanka and Sepang, Peninsular

Malaysia since most males are breadwinners of the family and are involved with outdoor- related occupations during peak biting time; mornings and evenings (8, 23). The majority of cases in this study were among those in the working age group where they are working in rubber plantations starting at dawn which is during the peak biting time for Aedes. Dengue cases among the school aged group is twice as high compared to the study done in Sepang that accounted only for 12% (8). The possible reason for these findings might be due to the differences in prevalence in both populations in which the incidents of dengue cases in Keningau is relatively low in the past. Another possible reason might be due to the time difference of students commuting to school. There is time difference between Peninsular Malaysia and Borneo local real-time ever since the Malaysian Government implemented the use of standard time throughout the country. Most students commute from home to school between 6.00 to 6.30 a.m. Sunrise in Sepang is one hour later than in Keningau where most students are already at school. Besides that, a majority of dengue cases in this study were found to be in rural areas which was not similar to other research in which the majority of cases were found in urban areas (8, 24).

All the susceptible levels for larval indices show lower rate of association with dengue outbreak which is the same findings in Kuala Lumpur, Malaysia in 1996, and Sepang, Malaysia in 2013 (4, 8). This might be because of the on-going dengue prevention and control programmes based on the dengue case notification. When the first dengue case was diagnosed and notified, the dengue prevention and control programme was implemented to the area. The initial search and destroying activities would have high larval indices which resulted in the residents and local authorities cleaning their houses and environment. When the second case was diagnosed and notified in the same area, the subsequent search and destroying activity had lower larval indices findings because the local residents had cleaned their houses and surrounding environment.

This study was conducted in an area with less rainfall distribution that may have reduced the washout effects (16). Although mosquitoes depend on water to breed, the heavy rainfall could cause overflowing and washing out of the larvae from the containers. The complex interaction between agent, host, vector and environment need to be explored in depth to form the accurate infectious model. For example, the temperature gives quite an impact on the vector life cycle which could hasten the dengue case transmission (13). In addition to that, the host factor which gives direction to the natural path of an outbreak, such as the susceptibility of dengue infection in the community is not well studied. In spite of that, the awareness and behaviour related to dengue prevention in the community may give some protective effects on the community.

CONCLUSION

In conclusion, the study in Keningau, Sabah showed an increase of Aedes Index and Breteau Index to a susceptible level following rainfall period of five weeks, which could further increase the risk of dengue transmission and outbreak. Therefore, advocating and intensifying dengue prevention and control programmes should be closely incorporated with the meteorological data.

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