ORIGINAL ARTICLE

Spatial-Temporal Pattern of Mosquito-Borne Disease Occurrence Based on Epidemiological Data: A Case Study from Terengganu

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ABSTRACT

Introduction: The trend of several mosquito-borne diseases in Malaysia has shown an increasing pattern over the past few years despite close monitoring and continuous control initiatives by public health authority. The objective of this study is to determine the spatial and temporal epidemiology of mosquito-borne disease in Terengganu from the year 2009 to 2018. Terengganu has been selected because it is geographically unique and experiences two monsoon seasons per year. **Methods:** Weekly surveillance data of mosquito-borne diseases which include dengue fever, malaria, filariasis, Japanese Encephalitis (JE) and chikungunya from 2009 to 2018 were collected from the Terengganu State Health Department. The variables included in the dataset mainly comprises of disease onset, diagnosis, case category, area (district) and site of onset. The data has been monitored spatial and temporal in which to explore the distribution pattern of the disease. The annual average for each type of mosquito-borne disease was determined using time-series and is further analysed by using geographical information system (GIS) tools to form spatial statistical analysis. **Results:** Results indicate that the temporal distribution of the mosquito-borne disease in Terengganu increases slightly despite a fluctuating pattern from the year 2009 to 2018 and there are between each type of mosquito-borne disease. Spatial analysis showed different stratification between seasons as well as the areas that are more susceptible to each disease. **Conclusion:** The results obtained in this present study through spatial and temporal analysis revealed that mosquito-borne diseases show a dynamic pattern in distribution. It can be concluded that the occurrence of the diseases depends on the geographical area and the weather within the region. This study provides public health authorities with a comprehensive assessment that will be useful for surveillance and monitoring, as well as for predicting and managing mosquito-borne disease outbreaks effectively.

Keywords: Mosquito-borne disease, Spatial, Temporal, Public health, GIS

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INTRODUCTION

Mosquito-borne diseases are complex and dynamic. Their emergence and re-emergence (eg: chikungunya, dengue fever, Japanese Encephalitis (JE), malaria, West Nile, yellow fever, lymphatic filariasis and Zika) across continents have brought about large numbers in mortality and morbidity in various subtropical and tropical regions. To this day, mosquitoes have been documented as the vector responsible in transmitting numerous diseases. Out of almost 3,500 species of mosquitoes throughout the world, around 200 species can transmit diseases to humans (1). An increase in the number of mosquitoes is usually associated with environmental factors such as temperature, humidity, vegetation and land-use patterns (2,3). Since mosquito-borne diseases are weather sensitive, a lot of consideration has been given to its implications on the risk of diseases in the future. From a biological perspective, weather variables are one of the more important factors affecting incidences of mosquito-borne diseases, especially as they affect the mosquito's growth, development, as well as the survival rate of pathogens such as viruses and parasites within the mosquitoes (4). The knowledge of the relationship between these factors is a necessity for public health authorities in order to assert some measure of surveillance and control over the vectors, and implementing effective early warning systems (4-6). Therefore, adequate knowledge about the interaction between vector population with human settings is needed (2).

The comprehensive monitoring on the disease occurrence provided by observable data is required, especially for distinctive groups of human population. Based on context, surveillance activities have to be carried out in order to assess, control or treat immediately. Since the threat of mosquito-borne disease cases have been increasing slowly for decades, the Ministry of Health Malaysia have introduced several prevention and control programme such as disease surveillance, vector surveillance, prevention and control, clinical management on diagnosis, and emergency response at both state and national levels, to manage and reduce the burden of these diseases (7). During outbreaks, activities focus on reducing the number of mosquito populations. This effort is not sustainable and is difficult to manage, often due to the high number of habitations within a region as well as the fact that the mosquitoes targeted may be at different stages of development (2). Hence, an early warning system is very crucial in order to manage outbreaks effectively by by allowing authorities to focus on high risk areas (8). Nowadays, the dynamic spatial and temporal patterns of mosquito-borne diseases are easily observable due to the abundance of mosquitoes and their ability to sustain themselves while relying on several environmental factors.

The transmission factors affect the transmission of mosquito-borne diseases and the most important challenge in reducing the occurrence of outbreaks is the enhancement of knowledge regarding the spatial and temporal dynamics of disease transmission (9). Recently, the implementation of Geographic Information System (GIS) tools as a form of disease management mechanism has become a necessity, in line with the advancement of technology (10). The disease mapping done by using the GIS allows it to be carried out in relation to particular localities. Hence, the implementation of GIS as a tool will enhance the monitoring and detection of the occurrence of the disease outbreak especially in the form of mapping (8). The implementation of GIS in the health scope can be beneficial for (i) the mapping of diseases (ii) determining the distribution pattern of the disease within a particular timeframe (iii) identifying risk factors and (iv) the mapping of risk areas (10). The analysis method of mapping locations is integrated into the GIS so that epidemiologists can assess the factors related to the occurrence of the disease (21). Several factors such as time, people, and other dimension of interest as well as weather variables can be integrated together to form epidemiological information of collective factors that influence the distribution of the disease. Other than that, this system also provides an effective tool for visualization and spatial analysis of epidemiological data and environmental factors. This approach is widely used in disease surveillance and identification, the monitoring of high-risk areas, the focusing of mitigating measures and surveillance plans on selected areas, programming and monitoring the incidence recorded (11). These tools are very different compared to those used in traditional disease surveillance which is comprised of a set epidemiological method which monitors disease transmission and how it is transmitting. This approach only analyses the statistics (i.e. the number of cases) for each location throughout a specific timeframe.

The present study aims to assess data through the spatial-temporal approach of identifying high-risk areas that are prone to the occurrence of mosquito-borne diseases and to analyse the dynamic variations of the temporal risk patterns based on monthly data obtained through mosquito-borne disease surveillance over a long period of time (from 2009 to 2018) in Terengganu. Terengganu was selected due to an increase in cases reported on mosquito-borne diseases as well as due to its unique geography whereby it experiences two monsoon seasons per year, a factor which is known to influence the occurrence of mosquito-borne diseases. Based on these criteria, the distribution and dynamics of the mosquito-borne disease cases were analysed and the outcome of the study can be used as risk indicator within a locality, allowing for improvement in mosquito-borne disease surveillance and management.

MATERIALS AND METHODS

This study applied an integrated epidemiological study design to assess the spatial and temporal distribution on mosquito-borne diseases. A retrospective cross-sectional study was conducted from 2009 to 2018 to analyse several information about mosquito-borne disease occurrence in Terengganu. For this study, ethical approval was obtained from Medical Research & Ethics Committee (MREC), National Medical Research Registry (NMRR) ethic approval reference number: NMRR-17-3503-38568. Secondary data from public domains that contain no information on human subjects was also collected from Vector Borne Disease Division of the Terengganu State Health Department and permission to access the data was obtained through a formal application.

The data was used for this study consists of mosquito-borne disease surveillance data (dengue fever, malaria, lymphatic filariasis, Japanese Encephalitis (JE), and chikungunya) with variation in terms of location and time. The surveillance data of different types of mosquito-borne diseases from seven main administrative districts in Terengganu was used. The data is collected through passive surveillance systems over the duration of ten years, from the years 2009 to 2018, which consists of 52 weeks per year. The collection of multiple types of data sets can provide a baseline that will be useful in developing a prediction model in the future for mosquito-borne disease prediction. The information is collected and reviewed over time to allow stakeholders, public health epidemiologist, and health workers to understand the spread and incidence of mosquito-borne diseases and within their respective fields.

Study Area

This study was conducted in eastern coast state of Peninsular Malaysia called Terengganu. It is located between the longitude 103.1324° E and the latitude 5.3117° N. This state is divided into seven main administrative district namely Kemaman, Dungun, Marang, Kuala Terengganu, Hulu Terengganu, Setiu and Besut. The most concentrated area in terms of population is the Kuala Terengganu district. It is located along the South China Sea coast and acts as the city's administrative centre. The total geographical area is 13,035 km and the total population in this state is 1.125 million (2013). 97.25% of the population live in rural areas whilst the remaining reside in urban and sub-urban areas. The major ethnic group is Malay and many of them are farmers. This study will focus on the whole area of Terengganu state.

Data Source, Integration and Management

This study analyses surveillance data of mosquito-borne diseases obtained from the Vector Control Division of the Terengganu State Health Department as secondary data. The original mosquito-borne disease surveillance data was an aggregate of the occurrence of mosquito-borne disease cases based on weekly data of the year 2009 to 2018. This present study only use mosquito-borne disease datasets that consist of cases confirmed through serological test. The variables included in the mosquito-borne disease dataset are mainly dates (onset, diagnosis, case category, area (district) and site of onset). The data processing involved in this study consists of two main parts: the conversion of weekly-based data of mosquito-borne disease into monthly-based data; and the breaking down of perpetual data into discretized data in order for the mining mechanisms to conduct the analysis. The task used to administrate data discretization in unsupervised equal width interval (12). In this study, the trends in distribution of the mosquito-borne disease had been monitored spatially and temporally. Annual averages for each type of mosquito-borne disease was determined using a time-series analysis in order to understand the epidemiological trends on a monthly and annual basis. In order to understand the temporal trends, the cumulative number of cases of five types of mosquito-borne disease were plotted on a graph over the twelve months in the year, across ten years, for all districts. Monthly and annual mosquito-borne disease data were generated and used as responding variables. All data extraction data was done in Microsoft Excel 2015 spread sheet. The linear relationship between the five types of mosquito-borne disease is shown by using the statistic package for social science (SPSS) 20. Overall statistical analysis used a p-value of below 0.05.

As for spatial analysis, after proper data cleaning, the distribution of mosquito-borne disease in Terengganu state for each districts is analysed by using the geographical information system (GIS), ArcGIS 10.6 software in order to form a spatial statistical analysis. The analysis process included buffer creation, map editing, and query development. In this present study, the analysis also includes the use of ArcMap which focuses on creating overlays, buffers and query layers. The map editing process is done by using the toolbar editor to form a geographical map of Terengganu (8). The distribution of each type of mosquito-borne disease is presented for each district over the duration of ten years in order to determine the locations with a high distribution of cases and their concentrated areas respectively. The obtaining of data on mosquito-borne disease cases based on districts within the state is useful in explaining its occurrences and in understanding the specific areas where high number of cases are reported.

RESULTS

Temporal Distribution of Mosquito-Borne Disease in Terengganu

In order to understand the temporal pattern and trend of mosquito-borne diseases in Terengganu, this study has produced a graph of data spanning a continual ten years' period. In Figure 1, the graph shows the temporal distribution of mosquito-borne disease for a

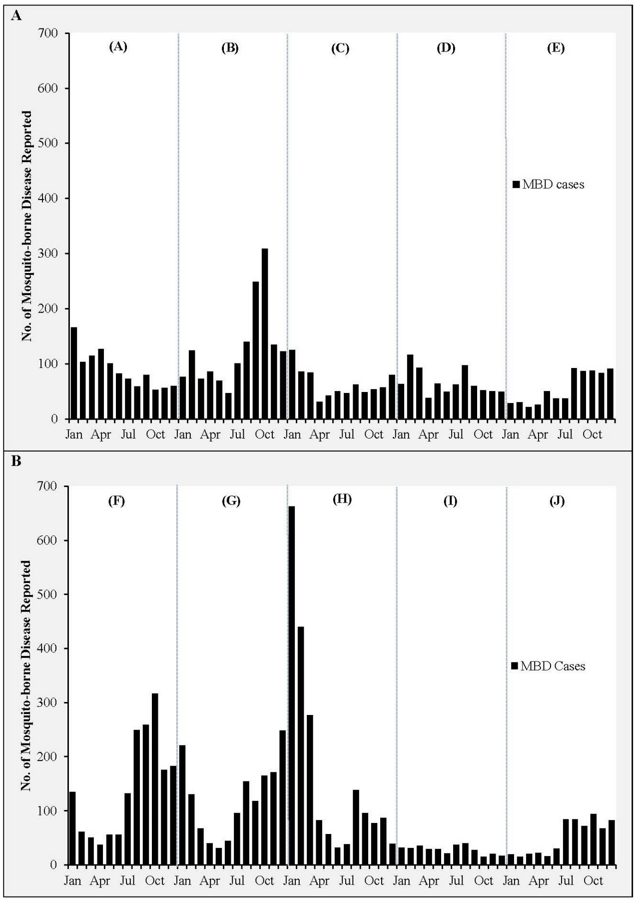

Figure 1: Temporal distribution of mosquito-borne disease in Terengganu; shown in black histogram in the year 2009 to 2018. The graph has been split into two sections namely A and B, which portraying (A), (B), (C), (D) and (E) as the year 2009, 2010, 2011, 2012 and 2013 whereas B potraying (F), (G), (H), (I) and (J) as the year 2014, 2015, 2016, 2017 and 2018 respectively.

continual period from 2009 to 2018. For a better view of the results, the graph analysis has been split into two sections namely A and B, which portraying (A), (B), (C), (D) and (E) as the year 2009, 2010, 2011, 2012 and 2013 whereas B portraying (F), (G), (H), (I) and (J) as the year 2014, 2015, 2016, 2017 and 2018 respectively. The illustration provides a comparison on density of cases between each year based on the cumulative number of cases for all types of mosquito-borne disease.

From the graph of temporal mosquito-borne disease distributions in Terengganu, a few significant patterns may be seen. In general, this study shows that there is a significant increase in reported cases of mosquito-borne diseases in Terengganu over the years. The scheme of monthly cases showed an increasing trend from 2009 to 2018. The number of mosquito-borne disease cases reached an all-time high in the year 2010 for the first section (A) whereas for the second section (B), mosquito-borne disease cases occurred most in 2016. A clear contrast and a gradient among the cases were determined. The worst mosquito-borne disease cases were recorded in January 2016 in Terengganu with an average of more than 600 cases reported. By referring to both sets of distribution trends for each year (A, B, C, D, and E) and (F, G, H, I and J), the pattern is quite similar for the entirety of Terengganu state; it reveals a consistently different seasonal pattern of mosquito-borne disease throughout the year from 2009 to 2018.

Comparison of Mosquito-Borne Disease Distribution in Terengganu

A temporal pattern may also be seen and ascertained within the comparison between each type of disease. The data obtained for Terengganu shows five main types of mosquito-borne diseases including dengue fever, malaria, filariasis, Japanese encephalitis (JE) and chikungunya. The data from these different types are compiled for comparison analysis. The total number of cases were segregated based on the type of mosquito-borne disease and its detailed contribution percentage (%) on an annual basis (10 years) is tabulated. Table I presents the profile of mosquito borne disease cases reported according to each type of disease in Terengganu reported from 2009 to 2018.

From the results obtained, a clear difference distribution among mosquito-borne disease is observed. From the year 2009 to 2018, the trend of mosquito-borne disease cases for the whole of Terengganu showed a fluctuating trend and a significant difference for each year. The results also showed that, the cumulative number of mosquito-borne disease cases for the year 2016 was the highest with 2,028 cases reported. By comparing the total number of cases reported from 2009 to 2018 for each type of mosquito-borne disease, it can be seen that dengue fever was identified to be the dominant disease. It is recorded as the highest annual peak value of all cases at a total of 10,447 (95.0%) cases, followed by malaria with 285 (2.6%), filariasis at 196 (1.8%), chikungunya at 60 (0.5%) and Japanese encephalitis at 7 (0.1%), being the lowest. The highest number dengue cases recorded in the year 2016 which showed the maximum number of cases to be 2,009 contributing to about 99.0% of the total number of mosquito-borne disease cases reported. In contrast, malaria and filariasis cases have been determined to be highest in the year 2011, with 49 cases (6.4%) and 37 cases (4.7%) reported for each, respectively. As for Japanese Encephalitis (JE), the number of cases reported was highest in the year 2017 with 3 cases (1.0%). Chikungunya reached its peak in 2009 with 59 cases (5.5%) reported.

Table I: Distribution profile for each mosquito-borne disease in Terengganu from 2009 to 2018 with their respective percentage (%)

Year	Total Number of Cases	Number of cases (%)				
		Dengue	Malaria	Filariasis	Japanese encephalitis (JE)	Chikungunya
All	10,995	10,447 (95.0%)	285 (2.6%)	196 (1.8%)	7 (0.1%)	60 (0.5%)
2009	1,075	968 (90.0%)	30 (2.8%)	18 (1.7%)	0 (0.0%)	59 (5.5%)
2010	1,534	1,472 (96.0%)	24 (1.6%)	37 (2.4)	0 (0.0%)	1 (0.1%)
2011	761	675 (88.7%)	49 (6.4%)	37 (4.7%)	0 (0.0%)	0 (0.0%)
2012	792	738 (93.2%)	34 (4.3%)	20 (2.5%)	0 (0.0%)	0 (0.0%)
2013	670	600 (89.6)	41 (6.1%)	27 (4.0%)	2 (0.3%)	0 (0.0%)
2014	1,712	1,688 (98.6%)	17 (1.0%)	7 (0.4%)	0 (0.0%)	0 (0.0%)
2015	1,485	1,455 (98.0%)	11 (0.7%)	18 (1.2%)	1 (0.1%)	0 (0.0%)
2016	2,028	2,009 (99.0%)	11 (0.5%)	7 (0.3%)	1 (0.2%)	0 (0.0%)
2017	333	292 (87.7%)	23 (7.0%)	15 (4.5%)	3 (1.0%)	0 (0.0%)
2018	605	550 (91.0%)	45 (7.4%)	10 (1.7%)	0 (0.0%)	0 (0.0%)

In order to offer a better view of the results, the graph analysis has been divided into five parts namely A, B, C, D and E, each representing dengue fever, malaria, filariasis, Japanese Encephalitis (JE) and chikungunya respectively. In an attempt to identify and determine the temporal pattern for each mosquito-borne disease from year the 2009 to 2018, the values of mosquito-borne disease cases were measured based on months and statistical descriptors such as maximum, minimum and average number of cases across the study area is determined. To determine the distinctions in these distributions, a comparison of the profile of the cases is carried out, with data being subsequently classified based on the type of mosquito-borne disease.

Figure 2 shows data on year-by-year mosquito-borne disease cases during the duration of the study for each type of disease separately. Generally, when comparing

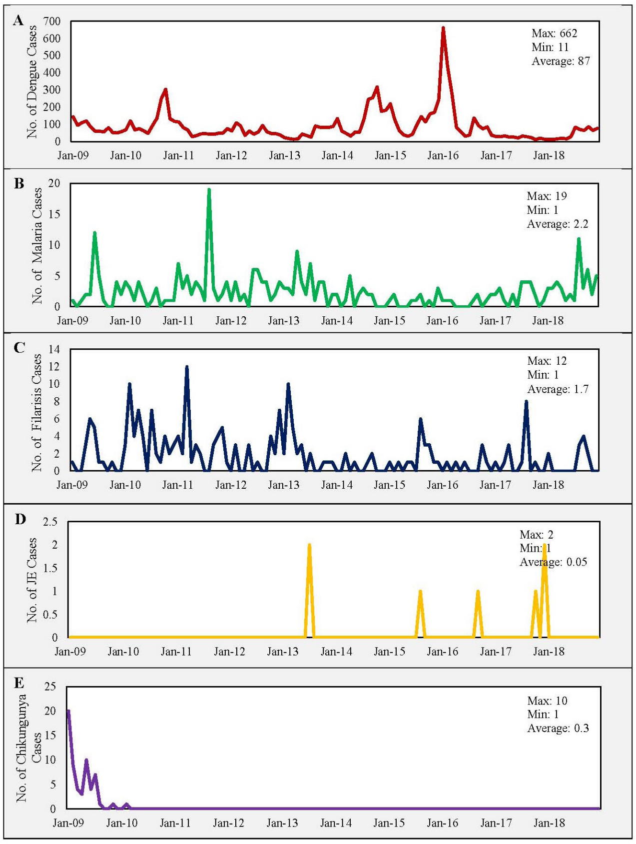

Figure 2: Schematic representation of dynamic pattern on mosquito-borne disease in Terengganu from 2009 to 2018. A: Dengue fever (red line); B: Malaria (green); C: Filariais (blue line); D: JE (yellow line); E: Chikungunya (purple line).

the temporal pattern, each type of mosquito-borne disease showed different trends in distribution of cases based on data plotted monthly from 2009 to 2018. An observation of the trends of dengue cases showed that the cumulative number escalated sharply in the year 2016 compared to the other years. The result shows that the cases recorded were at (min: 11 cases; max: 662 cases; median: 87 cases). However, the trends of cases for malaria showed a contrasting pattern whereby the cases recorded were highest in 2011 with (min: 1 case; max: 9 cases; Median: 2.2 cases). For the filariasis, the density of the cases was also identified at its highest in the year 2011 with (min: 1 cases; max: 12 cases ; Median: 2.7 cases). For the Japanese Encephalitis (JE), temporal pattern and the trends of cases showed an inconsistent pattern (up and down) throughout the entire study period. The data shows no significant changes in the number of cases reported. The highest density has been observed during the year 2013 and 2017 with (min: 1 case; max: 2 cases; Median: 1 case). Lastly, for the chikungunya, the trend of cases is observed to be very high in the year 2009 and the trend showed a dramatic decrease with an ascending gradient for the next year. It can be seen in the results that the cases recorded with (min: 1 case; max: 10 cases; Median: 1 case).

The mosquito-borne disease surveillance data during study period from 2009 to 2018 was further analysed by assessing the linear relationship between the five types of mosquito-borne disease, a bivariate Pearson's correlation coefficient (r) between each pair of the mosquito-borne disease time series data has been calculated based on corresponding weeks. Table II presents the results of the linear relationship between dengue fever, malaria, filariasis, Japanese Encephalitis (JE) and chikungunya respectively. Based on the table, it was found that the bivariate correlation between weekly number of cases for two types of mosquito-borne disease was positive but small in value as the Pearson's is close to 1 (malaria and filariasis; r=0.155; p=0.01). However, for dengue, the correlation in its weekly number of cases with the four other diseases was not correlated when calculated (malaria; r=0.099; p=0.02, filariasis; r=0.030; p=0.49, Japanese Encephalitis (JE); r=0.051; p=0.24; chikungunya; r=0.011; p=0.80). On the other hand, the partial correlation was also not correlated between malaria and filariasis with two other diseases (Japanese Encephalitis (JE); r=0.048; p=0.027; r=0.049; p=0.27; chikungunya; r=0.031; p=0.49; r=0.029; p=0.51). In addition, the corresponding correlation calculated between Japanese Encephalitis (JE) and chikungunya was not statistically significant as well (r=0.017; p=0.69;).

Table II: Pearson correlation coefficient (r) between each type of mosquito-borne disease in Terengganu from 2009 to 2018. Each coefficient is calculated from the weekly number of cases

Mosquito-borne disease	Dengue fever	Malaria	Filariasis	Japanese encephalitis	Chikungunya
Dengue fever	1.000				
Malaria	0.099	1.000			
Filariasis	0.030	**0.155***	1.000		
Japanese encephalitis	0.051	0.048	0.049	1.000	
Chikungunya	0.011	0.031	0.029	0.017	1.000

Spatial Distribution of Mosquito-Borne Disease in Terengganu

Further assessment has been conducted to identify the spatial distribution of mosquito-borne disease in Terengganu. In the present study, the total number of mosquito-borne disease cases had been monitored spatially where information on all the reported cases has been collected from separate administrative district boundaries. The total number of mosquito-borne disease recorded from the year 2009 to 2018 is visualized according to month from January to December by using GIS. The analysis was performed by using colour contouring, the darkest colour indicates high burden of cases whilst the lightest colour indicates low prevalence of cases for each mosquito-borne disease. Figure 3 shows the monthly distribution of mosquito-borne disease in Terengganu from 2009 to 2018. The map is characterised into five fractions namely A (dengue fever), B (malaria), C (lympathic filariasis), D (Japanese Encephalitis) and E (chikungunya) which are coded with the colours red,

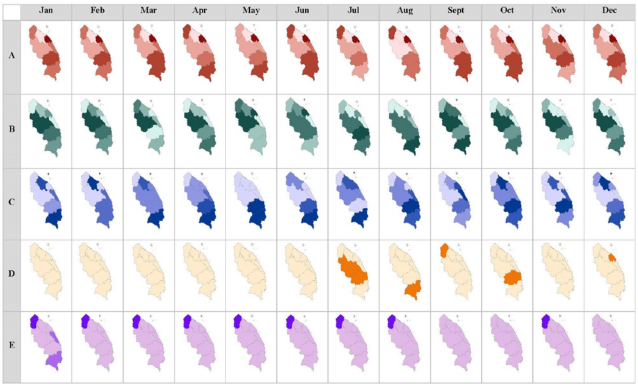

Figure 3: Monthly distribution of mosquito-borne disease in Terengganu from 2009 to 2018. The map is characterised into 5 sections namely A (dengue fever), B (malaria), C (filarisis), D (JE) and E (chikungunya) which are coded with the colours red, green, blue, yellow and purple respectively. Note: The darkest colour indicates high prevalence for each mosquito-borne disease.

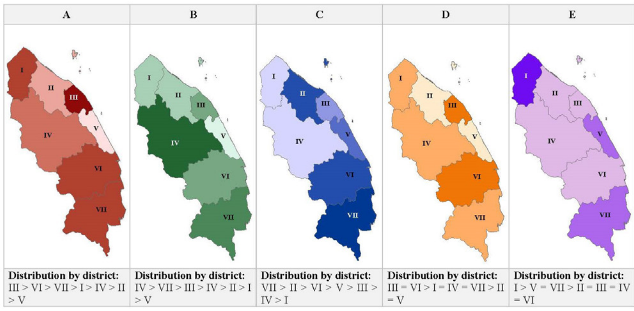

Figure 4: Overall distribution pattern of mosquito-borne disease in Terengganu from 2009 to 2018 which are coding into different colour codes namely; A: : Dengue (red), B: Malaria (green), C: Lymphatic filarisis (blue), D: Japanese Encephalitis (JE) (orange) and E: Chikungunya (purple). Note: Terengganu district are classified into 7 district; (I): Besut, (II): Setiu, (III): Kuala Terengganu, (IV): Hulu Terengganu, (V): Marang, (VI): Dungun, (VII): Kemaman.

green, blue, yellow and purple respectively.

The monthly spatial analysis reveals a clear pattern of emergence and continuance over the 10 years' period for each type of mosquito-borne disease. These map showed clear spatial pattern of mosquito-borne disease occurrence and its stratification on a monthly basis from 2009 to 2018. When summarized over the entire period for each type of mosquito-borne disease, dengue cases showed synchoronise patterns of with monsoon rainfall. This can be seen in how a high number of dengue cases aggregate towards the earlier parts of the year and the end of the year between January to March and October to December respectively. In contrast, the data for malaria shows no significant pattern between months except on August. For lymphatic filariasis, the highest cases also occur at the beginning and the end of the year in March and October, which happens to be the periods of onset for the monsoon seasons. As for Japanese Encephalitis (JE) and chikungunya, the total number of cases generally occur in January and July respectively.

The spatial distribution of mosquito-borne disease in Terengganu was further analysed to identify patterns for the 5 types of mosquito-borne diseases for the whole year from 2009 to 2018. The data analysis of case distribution and pattern by administrative district boundaries has been done to determine which area is more susceptible to mosquito-borne disease and to compare which district showed the greatest number cases among the district. Figure 4 represents the overall distribution pattern of mosquito-borne diseases in Terengganu from 2009 to 2018 which are coded into different colour codes namely; A: Dengue (red), B: Malaria (green), C: Lymphatic filarisis (blue), D: Japanese Encephalitis (JE) (orange) and E: Chikungunya (purple). Terengganu is classified into seven district; (I): Besut, (II): Setiu, (III): Kuala Terengganu, (IV): Hulu Terengganu, (V): Marang, (VI): Dungun and (VII): Kemaman respectively. As can be seen from the maps, there is generally a slight difference in terms of distribution for each mosquito-borne disease based on district boundaries. For dengue, the cases mostly occur within the central zone or the city area of Terengganu, namely the Kuala Terengganu district, followed by Dungun, Kemaman, Besut, Hulu Terengganu, Setiu and Marang. For the distribution pattern of malaria, Hulu Terengganu district was classified as having a high density of cases, followed by Kemaman, Kuala Terengganu, Dungun, Setiu, Besut and Marang district respectively. In contrast, the distribution pattern of lymphatic filariasis showed that the southern zone of Terengganu, namely the Kemaman district, is the area with a higher density of cases, compared to Setiu, Dungun, Marang, Kuala Terengganu, Hulu Terengganu and Besut district respectively. A similar trend was also observed for Japanese encephalitis (JE) where, central zones or city areas showed a high density of cases followed by Dungun, Besut and Hulu Terengganu. For chikungunya, the northern part of Terengganu, especially the Besut district, indicated a massive number of cases followed by the southern parts (Kemaman and Marang). Overall, this study provides information on the risk mapping aggregating activity of mosquito-borne diseases which can help in the prediction of timing, magnitude, as well as the proneness of an area for future outbreaks or epidemics.

DISCUSSION

The outcomes from this study are of a crucial significance to the future of surveillance and control programmes, and the study of the mosquito-borne disease problem in Malaysia. There is still an increasing number of cases reported on mosquito-borne diseases in several districts for certain periods of time despite the close monitoring that has already been conducted in hopes of preventing the occurrence of these diseases, especially in Terengganu. Surveillance is a crucial aspect in prevention and control programme. Although prevention and control programme for the disease already in existence, it remains insufficient without the understanding of the spatial and temporal risk of the cases to help predict the locations of risk and when these pre-emptive steps should be implemented. In order to explore the spatial and temporal distribution of mosquito-borne disease transmissions, the present initiatives go through the incidence rates based on common calculation for a designated area. Generally, this method was used to determine the characteristics of the spatial clustering pattern of all reported cases. The present study analyses the cumulative number of mosquito-borne disease cases annually and monthly from 2009 to 2018 in order to determine the temporal pattern of the disease in Terengganu. The data analysed indicates that cases of mosquito-borne diseases show a pattern that is currently endemic in Terengganu, although the incidence is significantly different each year.

From examining the temporal data, it is revealed that the number of mosquito-borne disease cases reported increase slightly over the years in Terengganu and this pattern showed an increasing trend. Cumulatively, within the ten years' observation, it can be seen that 2016 recorded the highest cumulative number of mosquito-borne disease cases reported compared to the other 9 years and this proves that the occurrence of mosquito-borne disease continues to increase rapidly from year to year. By comparing each type of mosquito-borne disease, dengue was identified as the dominant disease which showed the highest number of cases for each year. This is due to the many factors which contributed to this problem such as the increase in breeding sites for mosquitoes, a result of the recent increase in ecological and environmental modifications due to urbanization (13). From this study, it was found that the trends for each type of mosquito-borne disease within the study area are quite different from year to year and this condition may be influenced by environmental and demographic changes that occur within the region (22). Proper understanding of temporal patterns, behaviour and magnitude of these mosquito-borne diseases is crucial especially for planning effective prevention and control measures (11,23). Early prediction of upcoming outbreaks/occurrence can then be done based on identified trends. A major factor that can influence the distribution, trend and transmission of the mosquito-borne disease outbreaks is the climatic condition such as degree of rainfall, temperature and relative humidity. High volumes of rainfall play an important role in the increased survival of *Aedes* mosquitoes and provides them with more breeding sites; this can affect a change in the trend of dengue fever outbreaks (13).

The results obtained from assessing the data on inter-relation between mosquito-borne diseases showed that there is a difference between each type of disease in terms of transmission dynamics for infection. This might be due to the fact that each type of disease has a different type of mosquito which acts as its primary vector and they have varying carrying capacity of different viruses and parasites (24). These mosquitoes also have different variations in behaviour when it comes to transmitting viruses and parasites. Some differences may be in the choice of breeding habitat, peak biting time, as well as the rate of vector reproduction and mortality rate which can be affected by how the mosquitoes react to changes in the environment. The inter-relation between dengue fever and malaria showed that both mosquito vectors carrying these virus and parasite are extremely sensitive to and are affected by the climate and seasonality (25). The interrelation between malaria and filariasis can be explained by the fact that both malaria plasmodium and filariasis parasites can be transmitted by the same vector, the *Anopheles sp* mosquito (26).

The present study implements GIS tools in order to explain the spatial pattern of mosquito-borne diseases in Terengganu. This method has been used in this study of mosquito-borne disease in order to ascertain and classify high-risk areas, determine the disease distribution patterns, as well as to assess the risk factors of disease transmission. In this study, the maps were generated based on the cumulative number of mosquito-borne disease cases reported in Terengganu for each administrative district. The present study indicates that the distribution of malaria is localised in rural areas; cases are rarely reported in urban areas. Being one of the major parasitic mosquito-borne diseases, malaria cases are transmitted to indigenous peoples, traditional communities, mobile ethnic communities, jungle workers, land scheme settlers, as well as immigrants from malaria endemic countries (14). Recently, *P. Knowlesi* (simian parasitic malaria) has become more predominant in infecting the rural population compared to other parasites because its transmission is not limited to only mosquitoes as vectors, but also includes a wide range of natural hosts, including macaques (15).

In contrast, the patterns seen in cases of dengue fever and Japanese encephalitis (JE) indicates that this type of disease is more predominant in the city and circulates within communities and settlements as well as crowded urban areas. The main factor that contributes to the increasing trend of dengue cases is urbanization and this may influence the case distribution and transmission of the disease (8). Most dengue fever outbreak episodes occur in big cities across the country where the population number is high and there exist massive developing infrastructures which help create locations (i.e. containers) for the *Aedes* mosquito species to breed (13). Land-use plays a significant function in influencing the distribution of dengue fever cases. Most dengue cases occur in urban areas, followed by mixed horticulture areas and also in construction areas (16). This trend is due to the high population density and also the availability of favourable places for these mosquitoes to breed, resulting from human activity itself.

Moreover, this present study clearly shows the importance of geospatial technology in spatial and temporal analysis of the mosquito-borne disease in Terengganu by using the geographic information system (GIS) tools and computation management. In this study, these methods have been applied in order to study distribution dynamics, determine high-risk areas and indicate disease transmission risk factors (17). The combination between the epidemiology field and analytical tools can serve to be important factors in effective surveillance and control of the disease (18, 19). The results obtained from these approaches may be beneficial to the public health management bodies in controlling the disease with the implementation of intervention programmes (20). The present results suggest that necessary preventative action must take into consideration the locations where the mosquito-borne disease is more susceptible and when the disease mostly occurs, such as during the monsoon seasons.

CONCLUSION

In conclusion, the results obtained from this present study shows that mosquito-borne disease prone areas can be determined by determining the pattern of the disease dynamics based on the previous disease occurrences. Risk distribution and dynamics of the disease can be determined by the crucial method of spatial and temporal analysis. This study uses comprehensive assessment in order to provide public health management with the tool to differentiate the distribution and risk patterns of mosquito-borne diseases and also to determine high-risk areas for outbreaks by using integrated temporal and spatial profiles. Despite depending on incidence-rate mapping of cumulative number of cases, the present study revealed a new set of characteristics which can differentiate the mosquito-borne disease cases data into useful information. Hence, it can provide public health management with other options in integrating environmental factors and associated geographic distribution with systematic tools for surveillance, monitoring as well as to predict and manage mosquito-borne disease outbreak effectively.

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