Spatial and Temporal Distribution of Malaria in Peninsular Malaysia from 1998-2010

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ABSTRACT: Malaria fever is one of two mosquito-borne diseases still being reported in Malaysia. This study aims to visualize the geographical distribution of Malaria cases in Peninsular Malaysia from 1998 to 2010 using Geographical Information System (GIS). The pattern of malaria case distribution in Peninsular Malaysia for the duration between 1998 and 2010 is represented by shaded maps. The total malaria cases were the highest in 1998 but declining since then. Pahang had the highest occurrence of malaria in 2010 (2367 cases) of all states probably due to its high percentage of forest coverage (57.5%) and high rainfall, compared to its low population density. Forest density is statistically found to have the strongest positive correlation with malaria cases. Based on the factor of forest coverage of Pahang compared to other states, Pahang is the most conducive state in Peninsular Malaysia for the survival of malaria vector, *Anopheles sp*. Vector control efforts should therefore be continued to break the chain of transmission between vector and host, without compromising the precious forested area.

Keywords: Forest cover, GIS, Malaysia, malaria fever, mapping, rainfall.

Introduction

Malaria Fever is a vector-borne tropical disease caused by a parasitic protozoon, *Plasmodium* sp. The agent itself is carried by *anopheles sp* especially *Anopheles maculatus*. Malaria is found globally in hot and humid areas where the temperature is just right to ensure the survivability of both the agent and the vector host.

At present, 3.3 billion people live in the areas with risk of Malaria transmission. The endemic areas include the sub-saharan Africa, South-East Asia, Oceania and South America had reported 98% of global malaria deaths. In endemic areas especially African countries, the mortality of children stricken with malarial parasitaemia is high with the highest transmission of Malaria being recorded in the areas of darkest Oceania (Papua New Guinea) and the southern Sahara region of Africa.

While the introduction of DDT had caused the cases to decrease dramatically via vector destruction, malaria remains as a serious third-world disease which is often linked to poverty and low socio-economy development.
Though advancing to become a developed country, Malaysia lies within the global geographic reach of malaria. Historically, the disease of Malaria fever was first recorded as early as the 19th century in Perak, Selangor, Pahang and Negeri Sembilan in the Penisular Malaysia. The outbreak was influenced by the opening of new rubber estates through the clearing of previously thick forests. The building of new roads and settlements for the labourers in early days increased the contact between the vector (*Anopheles sp*) and human hosts. In addition, the unsanitary physical living conditions of human dwellings also provided new breeding grounds for *Anopheles sp* to multiply, increasing the likeliness of contact and subsequent malaria infection. Between 1896 and 1914, there were as much as 297,075 recorded malaria cases in the Federated Malay States (Hassan, 2008).

Malaysia has gone a long way since then, and the disease is in pre-elimination stage according to the ‘Roll Back Malaria’ programme organized by the WHO (World Health Organization) and the Malaria Eradication Programme which started in 1967. In 1980, the programme was renewed and expanded to Sabah and Sarawak in East Malaysia with the name ‘Malaria Control Programme’. The malaria control measures in Malaysia involved Active Case Detection (ACD) and Passive Case Detection (PCD). The former is a proactive screening and intervention for malaria parasites in endemic or malaria-prone areas, which involved blood slide surveys and distribution of insecticide treated bed nets (ITN).

ACD targetted to reach more than 60% of the residents and 95% of houses. PCD is parasitic surveillance based on the received reports of cases. In controlling malaria, the afflicted areas with reports will have focal residual insecticide spraying within ½ mile radius of the locality. The spraying is continued for six months, supplemented with the distribution of anti-malarial drugs to residents to ensure total elimination. For 2010, the residual spraying was reported to protect 25%-50% of the population in high risk areas. The numbers of active foci (focus areas) were 3198, with at least 760,000 people living in the high risk areas (WHO, 2011).

Though Malaria control programme continues, malaria is still resilient and the cases emerge from time to time in. The focus of Malaria control in Peninsular Malaysia was tightened to the middle region between the borders of Kelantan, Pahang and Perak states having large communities of *Orang Asli* (Aboriginals) in the 90's . In Sabah and Sarawak, the situation was more serious, as the disease was still endemic. Sabah used to carry 84.2% (1996) of Malaysia's disease burden for malaria. Sabah started its own Action Plan to control malaria and has successfully decreased the malaria disease burden to 27.9% in 2003 (WHO-Unicef, 2005).

Other than controlling the disease in the deep hinterland, a new threat comes in the form of immigration of illegal workers from malaria-endemic countries. The influx of immigrants could have caused a resurge of malaria cases even in the urban regions of Malaysia, beyond the areas focused in the Malaria Control Programme. The problem of cooperation and access to their dwellings add to the impairment in carrying out the programme (Nazma *et al.*, 2011). More than 50% of parasites detected in these cases were of the species *Plasmodium vivax*, and more than 50% were reported from non-Malaysian residents.

Epidemiological studies and monitoring which involve real-world locations often need a top-down view of situations happening on the ground. The Geographical Information System (GIS) is a powerful tool that may be used in disease monitoring and evaluation of control measures. The spatial distribution of disease cases through time can be sorted out and visualized as maps instead of tables, and with the relation of geographic factors into epidemiology the spread of disease is observed (Lloyd and Yu, 1994). Data from field surveys which are plotted on the map according to their locations on the earth can then be combined with supplementary spatial information such as land use, proximity, orientation, clustering, and other factors which may relate to the causal factors of the outbreak.

In this study, the factors used to supplement the cases data are population density, rainfall and forest cover. Population density represents the availability for infection, rainfall represents the potential for breeding chances, and forest density represents the proportion of the vector's habitat in each state.

Materials and Methods

This study utilized secondary data obtained from archival records at the Forest Research Institute Malaysia (forestry data between years 1998-2010), the Statistics Department of Malaysia (population density), and the Institute of Medical Research and Ministry of Health Malaysia (past malaria case data from 1998-2010). The records were sorted by year and state of Peninsular Malaysia. Forestry data obtained were in the form of total acreage while malaria case data were total yearly case numbers. Note that the case numbers for Malaria in 2004 was unavailable.

The case numbers were then put into the GIS map according to their respective states, and the values of malaria cases were represented with one map for each year. For analyses, the raw data of case numbers, rainfall, forest cover and population were processed and statistically analyzed using Microsoft EXCEL® software. Pearson correlation was used as the input data was non-parametric in nature.

Results

Malaria Cases

During 1998 and 2010, the overall cases of malaria have generally decreased (Figure 1). From a total of 4835 cases in 1998, it dropped to 3493 in the following year but a slight increase in 2000 before gradually decreasing to 757 cases in 2005. In 2006, the cases rose to 853, and then to 1342 in 2008. The cases of malaria beyond this point fluctuated, decreasing in 2009 before increasing to 1204 in 2010.

The numbers of cases for each state 1998-2010 were inserted into a geographical shape file representing Peninsular Malaysia. The shape files are exported into shaded maps ('choropleths') in which the values for the cases are represented in shades from light (low) to dark (high) as shown below (Figure 2a-2l). The state of Pahang had consistently showed the highest intensity of malaria cases between 1998 and 2003. From 2005 to 2007, the states of Perak, Selangor and Kelantan's malaria cases increased, while Pahang's malaria cases decreased. In 2008 Pahang's malaria case intensity returned, with Kelantan's and Perak's staying in the high level.

Environmental Factors

Factors influencing malaria included in this study were forest density (per hectar), population density and rainfall. Tables 1 to 3 show the comparison between all three.

Pahang and Kelantan have the highest forest density of all Peninsular Malaysian states covering 57.5% of their respective total areas. The amount of forest is important as it shows the possibility of contact between humans and mosquitoes, with mosquito habitats largely in vegetated areas. The low density of forest in Kuala Lumpur and Penang is understandable due to its extensive urbanization.

According to the census data, Kuala Lumpur has the highest population density (6891 persons/km2), while Pahang has the lowest. The population density in Pahang was 42 persons/km^2 in 2010.

The table displays the average yearly rainfall values from weather monitoring stations in Peninsular Malaysia. These values represent the average of the local amount of rainfall for the respective state. Stations situated in Pahang and Selangor recorded the highest rainfall, amounting over 2500 mm and the station with the lowest rainfall was Sitiawan, Perak with 1584 mm.

Correlation

To determine the strongest influence on malaria, a Pearson correlation was tested between malaria and selected environmental factors. The data was graphed in a scatter plot (Figure 3). It was found that there is a significant positive correlation between forest density and Malaria cases ($r = 0.528$; $n = 140$; $p < 0.05$). Population density was graphed with malaria cases in a scatter plot, Figure 4. The correlation between population density and malaria cases resulted in population density was not significant ($r = 0.53$ and p-value >0.05).

The case data was plotted against average rainfall values, Figure 5**,** a correlation analysis found that rainfall had a positive correlation with malaria cases with $r = 0.66$ and $p < 0.05$.

Table 1: Forest density of states in Peninsular Malaysia

State	**1998**	**1999**	**2000**	**2001**	**2002**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Johor	0.236	0.227	0.250	0.250	0.250	0.249	0.260	0.268	0.258	0.233	0.247
Kedah	0.366	0.366	0.371	0.370	0.368	0.366	0.366	0.366	0.366	0.366	0.366
Kelantan	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.599	0.594	0.578	0.575
Melaka	0.040	0.037	0.040	0.040	0.040	0.039	0.039	0.039	0.032	0.032	0.032
Negeri Sembilan	0.265	0.331	0.330	0.259	0.258	0.250	0.247	0.241	0.238	0.240	0.242
Pahang	0.544	0.576	0.571	0.570	0.565	0.564	0.563	0.563	0.551	0.575	0.575
Perak	0.509	0.500	0.500	0.500	0.499	0.500	0.500	0.500	0.500	0.496	0.493
Perlis	0.144	0.150	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.137	0.140
Penang	0.070	0.070	0.070	0.070	0.076	0.076	0.076	0.076	0.076	0.076	0.076
Selangor	0.323	0.323	0.305	0.307	0.312	0.305	0.303	0.297	0.314	0.307	0.313
Terengganu	0.516	0.498	0.516	0.513	0.504	0.495	0.501	0.507	0.507	0.505	0.505
Kuala Lumpur	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Source: Malaysia Statistic Department, 2010.

Table 2: Population Density of states in Peninsular Malaysia (per km^2 square)

State	2000	2007	2008	2009	2010
Johor	144	166	168	170	174
Kedah	176	199	202	204	205
Kelantan	90	105	107	109	102
Melaka	389	446	452	458	493
Negeri Sembilan	130	146	148	150	153
Pahang	36	41	41	42	42
Perak	99	112	114	115	112
Perlis	253	282	285	289	282
Pulau Pinang	1,272	1,472	1,490	1,508	1,490
Selangor2	514	600	609	617	674
Terengganu	69	77	78	79	79
W.P. Kuala Lumpur	5,827	6,842	6,926	7,009	6,891

Source: Malaysia Statistic Department, 2010

Table 3: Average Rainfall values from weather stations in Peninsular Malaysia

Station Name	State	Rainfall (mm)
Sultan Ismail Airport (Senai)	Johor	2441.39
Kluang	Johor	2244.85
Lapangan Terbang Sultan Abdul Halim	Kedah	2138.23
Lapangan Terbang Langkawi	Kedah	2059.28
Lapangan Terbang Sultan Ismail Petra	Kelantan	1937.73
Kuala Krai	Kelantan	2196.75
Lapangan Terbang Batu Berendam	Melaka	1678.21
Cameron Highlands	Pahang	2526.21
Lapangan Terbang Sultan Azlan Shah	Perak	2555.71
Lapangan Terbang Sultan Haji Ahmad Shah	Pahang	2543.03
Sitiawan	Perak	1584.60
Chuping	Perlis	1649.21
Lapangan Terbang Antarabangsa Pulau Pinang	Penang	1929.83
Butterworth	Penang	1819.26
Lapangan Terbang Sultan Abdul Aziz ShahAirport, Subang	Selangor	2513.45
Lapangan Terbang Antarabangsa Kuala Lumpur, Sepang	Selangor	1618.78
Lapangan Terbang Sultan Mahmud	Terengganu	2124.88

Source: Malaysia Statistic Department, 2010

Discussion

Among all states in Malaysia, Pahang, has the largest forest density (57.7%) and yearly average rainfall and therefore is conducive for *Anopheles* breeding ground as it has the most intense malaria transmission. This suggests that the amount of forest vegetation in Malaysian states could be used as an indicator of possible malaria risk.

More forest areas mean more potential transmissions – this is shown by the number of cases being numerous in high forested states compared to the low forested states. In Peninsular Malaysia, the *Orang asli* (aboriginal people) still live in many forested areas in Kelantan, Pahang and Perak (Rohani *et al.*, 2010). This is a concern as they have more frequent contact with the *Anopheles sp.* mosquito habitats and increase the chances for malaria transmission.

On the other hand, states such as Selangor and Kuala Lumpur, have greater areas of built environment, have smaller forest areas. Malaria cases were carried by foreign workers from endemic countries such as Myanmar, Bangladesh and Indonesia (Bernama, 2010). The common workplaces for them include fruit orchards, plantations and newly opened construction sites which are near forest areas. Before entering Malaysia, malaria screening is normally conducted on foreign workers but workers who entered Malaysia illegally might have evaded the required screening (Dewi, 2009).

Population density is a vital factor in many transmissible diseases. High population density can ensure more chances of contact between the *Anopheles sp.* mosquito and humans. In Peninsular Malaysia, the consistently high malaria cases occured in the states with low population density. A suggested reason is that the human population in high density areas denotes the level of urbanization, which is not the favoured environment for *Anopheles sp.* mosquitoes to thrive. This factor seems to correlate well to the forest density, with high populated states having low forest densities. For urbanized states such as Kuala Lumpur and Selangor, the malaria cases were mostly recorded from immigrants coming from endemic countries. The states are also densely populated which means that one primary infection can potentially cause a 'chain reaction' outbreak if it is not reported early.

Rainfall also plays a major role in malaria transmission. Frequent rainfall creates breeding areas for mosquitoes whether in their natural habitat or man-made environments. In forest-fringe areas such as quarries, orchards and villages there would be a combination of both natural and anthropogenic water holders which can become potential breeding places. With the presence of such, the *Anopheles sp* can transition and eventually venture out from their natural vegetation habitat to transmit or spread the parasites. This factor was correlated positively with malaria cases in Peninsular Malaysia.

Conclusion

Although the states in Peninsular Malaysia have shown a general decrease in Malaria fever cases, year by year, there is still a potential for malaria resurgence, as long as the environmental factors for malaria such as rainfall and forest cover exist. Both factors which are of natural origin cannot be controlled or eliminated, hence the link between human populations and the malaria vector should be controlled to break the transmission chain. Immigration also comes as a new challenge, in form of untraceable illegal immigrants from malaria endemic countries. This calls for a better pest eradication, medication and disease screening so that Malaysia will successfully 'roll back' malaria for good. It is also hoped that GIS mapping technique will be extensively used in the planning and enforcement stages of wide-scale health programmes so that a clearer look of the situation can be assessed and acted upon.

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