SPATIO-TEMPORAL DISTRIBUTION OF MALARIA IN BETONG, SARAWAK, MALAYSIA: A FIVE YEARS STUDY

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ABSTRACT

The emergence of malaria has become one of the major public health problems in Betong, Sarawak, Malaysia. The number of reported malaria cases are increasing continuously in recent years. The aim of this study was to analyse the spatio-temporal pattern based on the yearly malaria surveillance data. Descriptive analysis was done to investigate the malaria incidence by time, person and place. Further analysis was done by mapping all malaria cases reported from year 2013 to 2017 by using ArcGIS software. Distribution of malaria cases were mapped in term of crude incidence. The average nearest neighbour was used to determine the distance analysis between malaria cases while Kernel density was applied to detect spatial pattern of locality for malaria hotspots. Distribution of malaria cases was clustered and random based on distance analysis. Based on spatio-temporal analysis pattern, malaria cases were identified as clusters in Betong and Spaoh subdistricts. It was observed that high risk occurrence of malaria cases were reported in the months of July to October each year. All the socio-demographic variables were associated with the malaria infection. After adjusting the relationship of all potential predictors at $P<0.05$, potential predictors such as gender, ethnicity (excluding the Malays) and occupation had significant association with the malaria infection. Spatial mapping could be beneficial to visualize the distribution of malaria cases for public health prevention.

Keywords: Malaria cases, disease surveillance, GIS tools, Sarawak

ABSTRAK

Kenaikan kes malaria telah menjadi salah satu masalah kesihatan awam utama di Betong, Sarawak, Malaysia. Jumlah kes malaria yang dilaporkan meningkat secara berterusan dalam beberapa tahun kebelakangan ini. Tujuan kajian ini adalah untuk menganalisis corak tempat dan masa berdasarkan data pengawasan tahunan yang diagregatkan. Analisis deskriptif telah dilakukan untuk menyiasat kejadian malaria mengikut masa, orang dan tempat. Analisis lanjut telah dilakukan dengan memetakan semua kes malaria di peringkat daerah menggunakan ArcGis 10.3. Pengagihan kes malaria dipetakan daripada segi kejadian kasar. Purata jiran terdekat telah digunakan untuk menganalisis jarak manakala kepadatan Kernel digunakan untuk mengesan corak tempat kejadian untuk kawasan kelompok malaria. Taburan kes malaria dikelaskan dengan kelompok dan rawak berdasarkan analisis jarak. Berdasarkan analisis masa dan tempat, kelompok malaria didapati di daerah kecil Betong dan Spaoh. Bulan Julai hingga Oktober setiap tahun dikenalpasti sebagai taburan kes malaria yang tinggi. Semua pembolehubah sosio-demografi dikaitkan dengan jangkitan malaria. Setelah menyesuaikan pemboleh ubah yang signifikan pada $P<0.05$, pemboleh ubah seperti jantina, etnik (tidak termasuk orang Melayu) dan pekerjaan mempunyai persamaan yang signifikan dengan jangkitan malaria. Pemetaan malaria memberi manfaat untuk menunjukkan pengagihan kes malaria untuk aktiviti pencegahan dalam kesihatan awam.

Kata kunci: Kes malaria, Surveilans penyakit, perisian GIS, Sarawak.

INTRODUCTION

Malaria is one of the vector-borne diseases caused by *Plasmodium* parasite. Malaria spread through the bite of *Anopheles* mosquito that was infected with the *Plasmodium* parasite. World-wide, malaria disease normally occur in hot and humid provinces. The climate effects such as temperature could influence the endurance of both agent and vector (Kesetyaningsih et al. 2018). Besides that, over million deaths were reported due to malaria, which contributes to global mortality cases. An approximated 216 million cases of malaria were recorded in 2016 and therefore, malaria is as among the significant problems leading to death (William et al. 2012). The calculation was contrasted with 237 million cases in 2010. Meanwhile, about 5 million more cases were forecasted to occur world-wide in 2016 compared with 2015 (World Health Organization 2017). The incidences of malaria in a certain geographical country with certain climate is consistently high, despite the reduction of malaria rates worldwide (World Health Organization 2018). Malaria still persists in rural and isolated areas in most of the states in Sabah and Sarawak (Ministry of Health 2011). According to Malaysia Health Indicators (2014), the highest number of malaria cases in Malaysia was recorded in Sarawak with 1,064 cases which had contributed to 42% of all malaria cases in Malaysia.

Malaysia is one of the countries presently participating in malaria elimination programme and plays an important role towards the success of this programme. Therefore, controlling the outbreaks of malaria in the high risks localities is the main indicator to achieve the goal of malaria elimination programme. Prevention activities for high risk locality can be identified by mapping the location of disease reported (Maude et al. 2014; Yeop et al. 2014). As of today, the incidence of malaria is geographically distributed around the rural areas. Geographic Information System (GIS) is known as a new approach in conducting and assembling the outbreak data related to space and time (Masnita et al. 2016; Wen et al. 2011). Besides that, the pattern of malaria transmissions can be explained effectively by the contribution of GIS tools (Alias et al. 2014; Saxena et al. 2009) and enforcing GIS software provides the result more significantly and offers depth analyses through the field data (Saripah et al. 2019). The geographic term indicates that the locations of the data information can be estimated in the geographical provision which is known as latitude and longitude. Despite the fact that some countries around the world already carried out the spatiotemporal studies on malaria (Maude et al. 2014; Wen et al. 2011; Xia et al. 2015), very few studies on malaria conducted in Malaysia. Past study by Yeop et al. (2014)

using the GIS and spatio-temporal analysis performed in order to determine the spatial and temporal dissemination of malaria incidences. This study was done by analysing the malaria cases that have been reported at the sub-regional level in Perak from 2007 to 2011.Therefore, due to the limited literature published or documented studies temporal and spatial analysis was employed in this study. The spatio-temporal distribution of malaria in Betong was evaluated from 2013 to 2017. Using the data for this interval time, the distributions of malaria were designed using GIS based on space and time analysis. The purpose of this study was to provide helpful information for surveillance of disease, especially malaria in order to deal with the malaria cases in the Betong.

MATERIALS AND METHODS

Study Area

Betong Division is the smallest of the administrative divisions in Sarawak. The total area of Betong Division is 4,180.8 km^2. It has two administrative districts namely; Betong and Saratok. Betong District is further divided into five subdistricts; Betong, Spaoh, Debak, Pusa, and Maludam. Figure 1 shows the five subdistricts under Betong which is bounded by one local authority, Majlis Daerah Betong (Department of Statistics Malaysia Sarawak 2010). According to the information obtained from the Ministry of Health in 2017, Betong District had reported high malaria cases compared to Saratok District. Hence, the study area in this research covers Betong district which has a significant public health implication in relation to prevention and controlling the malaria outbreak.

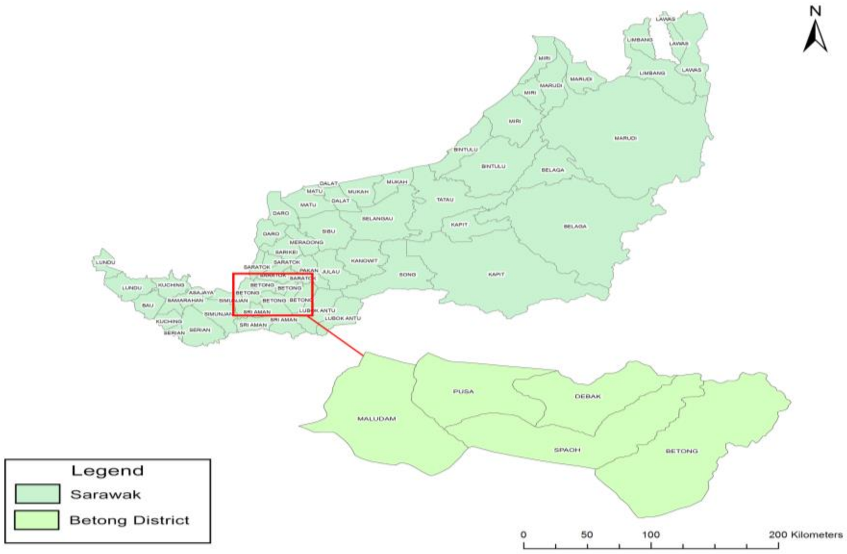

Figure 1. Geographical maps of Sarawak state which comprise thirteen districts and Betong is divided into five sub-districts.

Data Collection and Management

Data of annual cumulative malaria cases registered at the Sarawak State Health Department between 2013 and 2017 were utilized. All the data have detailed information about the malaria cases including the information about the case registration and notification, month, number of cases, day, epidemic week, place of notified malaria cases and laboratory test date.

Data were extracted from VEKPRO system and imported into Microsoft Excel 2013. The geographical coordinates for all the malaria cases were also downloaded from the VEKPRO system. The VEKPRO system was an open access system provided by Vector-Borne Disease Sector, Ministry of Health Malaysia and downloadable only with access with no copyright issues.

Data Analysis

Understanding the epidemiological data for malaria disease is very important in any of malaria study. Descriptive analysis was performed for variables like the sociodemographic characteristics. In this study, the binary logistic regression was used to identify the independent predictors controlling for covariates. Reference categories for categorical predictor are gender (female); nationality (non-Malaysian); ethnicity (Chinese) sector (Debak); age group (<=10 years); and occupation (non-farmer). A final model was created included all those predictors which were significantly associated with malaria risk at the level of P-value <0.05. For spatial analysis, the spatial distribution of malaria incidence was examined using the ArcGIS version 10.3. The incidence rates of the malaria cases between 2013 and 2017 was measured and plotted to visualize the malaria distribution cases. The incident rates were categorized into four classes: class 1 (0.0 per 100,000 populations); class 2 (0.1 -10.0 per 100,00 populations; class 3 (10.1 -20.0 per 100,00 populations and class 3 (more than 20.0 per 100,000 populations). Class 1 also known as malaria free area. Then average nearest neighbour (ANN) and kernel density estimation (KDE) were used to measure the distance between malaria cases in Betong and hotspot analysis respectively.

Using this ANN analysis, the distance between each locality of the cases and its nearest neighbour area were calculated for every year. The outcomes from the ANN analysis showed the pattern of malaria cases and it was divided into three, namely; random, clustered and dispersed. If the average nearest neighbour ratio is less than 1, the pattern exhibits clustering while if the average nearest neighbour is greater than 1, the trend is toward dispersion. For the clustered pattern, the z-score demonstrates in the range <-2.58 to -1.65, while the z-scores range between -1.65 to 1.65 will described the random pattern. The z-score range for dispersed pattern is around 1.65 to >2.58. The observed average distance in the ANN enforced in KDE for hot spot analysis. The purpose of KDE is to measure the density of the malaria cases in the area of study. According to Hazrin et al. (2016), this method is an effective tool to identify high-risk areas within point patterns of disease incidence by producing a smooth, continuous surface that defines the level of risk for that area. It is a better ‘hotspot’ identifier than the cluster analysis.

RESULTS

Overall, a total of 230 malaria cases were notified between 2013 and 2017 in Betong District, Sarawak with Betong sub-district had reported the highest number of cases (n=191 cases) compared to the Saratok District (n=81 cases). Malaria cases in Betong District showed an increasing trend in 2014 but surprisingly the cases declined in 2015 as a result of the implementation control of all *P. knowlesi* infection (Ministry of Health 2017). Sarawak State Health Department emphasized the combination between indoor residual spraying activities and insecticide treated nets for malaria control in order to reduce the zoonotic malaria. However, the reported cases of malaria cases had increased from 44 cases in 2016 to 77 cases in 2017. The increasing trend was likely associated to the presence of relevant environmental factors and the socio-economic condition of the community infected by malaria. The increasing trend of people infected by malaria depicts a perfect example of enforcing the effective control measures that would reduce the effect of malaria to the barest minimum.

Epidemiological Profile of Malaria Cases in Betong District From 2013 To 2017

Baseline socio-demographic characteristic of malaria cases in study area from 2013 to 2017 are demonstrated in Table 1. Based on gender, males had higher risk of malaria infection than females. Those aged between 21 and 60 years old were more prone to malaria infection. While 93.91% of Malaria cases reported among the Malaysians compared to 6.09% non-Malaysian. By ethnicity, Ibans were more prevalent to malaria infection followed by other ethnics such as Malays while Chinese were the least. In further analysis of occupation, the majority of recorded cases were farmers (71.74%) while non-farmers contributed 28.63% malaria cases. The prevalence of malaria infection was significantly higher in Betong compared with Spaoh and Debak, while no cases were reported from both Pusa and Maludam.

Table 1. Baseline socio-demographic characteristic of malaria cases in Betong, Sarawak, n = 230

Socio-demographic variables		**Frequency**	**Percentage (%)**
Gender	Male	178	77.39
	Female	52	22.61
Age Group	< = 10 yrs	4	1.74
	11 – 20 yrs	28	12.17
	21 – 40 yrs	88	38.26
	41 – 60 yrs	81	35.52
	> 60 yrs	29	12.61
Nationality	Malaysian	216	93.91
	Non-Malaysian	14	6.09
Ethnicity	Iban	207	90
	Malay	5	2.17
	Chinese	1	0.43
	Other	17	7.39
Occupation	Farmer	165	71.74
	Non-Farmer	65	28.63
Sector	Betong	191	83.04
	Spaoh	20	8.70
	Debak	19	8.26
	Pusa	0	0.00
	Maludam	0	0.00

Note: Malaria cases notified in Betong district from 2013 to 2017.

From Table 2, the binary logistic regression analysis was utilized to assess the association between categorical variables of malaria infection with the independent variables that includes socio-demographic characteristics like gender, nationality, ethnicity, age group, sector and occupation. After adjusting the relationship of all potential predictors at p<0.05, potential predictor like gender, ethnicity (excluding the Malays) and occupation showed significant predictors with the malaria infection.

Males significantly had higher odd of 1.9 times to get malaria infection compared to females after adjusting the effect of all covariates (ethnicity, sector, age group and occupation). Ethnicity was found to be relevantly contributes with the risky of malaria infection where Ibans had the highest (odd of 16.3) followed by other ethnics (odd of 14.4) after adjusting all the predictors. However, the Malays showed no significant association with the malaria disease. Occupation characteristics indicated that farmers 2.4 times more likely to get malaria rather than non-farmers. Age group and sector did not show any significant association with the infection of malaria after controlling all the indicators.

Table 2. Estimation of crude and adjusted odd ratios for malaria infection (2013-2017)

Variables	**Category**	**Crude OR**			**Adjusted OR**		
		cOR	**95% CI**	**p-value**	***aOR***	**95% CI**	**p-value**
Gender	Male	2.205	1.476, 3.295	<. 0.001[a]	1.943	1.176, 3.210	0.010[a]
	Female	1	-	-	1	-	-
Nationality	Malaysian	0.387	0.146, 1.026	0.056	-	-	-
	Non-Malaysian	1	-	-	-	-	-
Ethnicity	Iban	22.292	2.897, 171.540	0.003[a]	16.337	1.999, 133.486	0.009[a]
	Malay	0.795	0.086, 7.323	0.840	4.465	0.437, 45.671	0.207
	Chinese	1	-	-	1	-	-
	Others	18.308	2.125, 157.711	0.008[a]	14.409	1.537, 135.049	0.019[a]
Sector	Betong	2.167	1.106, 4.246	0.024[a]	1.918	0.921, 3.995	0.082
	Spaoh	0.422	0.182, 0.977	0.044[a]	0.507	0.203, 1.266	0.146
	Debak	1	-	-	1	-	-
Age Group	< = 10 yrs	1	-	-	1	-	-
	11 – 20 yrs	3	0.935, 9.625	0.065	1.054	0.199, 5.583	0.951
	21 – 40 yrs	5.25	1.731, 15.920	0.003[a]	1.117	0.226, 5.520	0.892
	41 – 60 yrs	6.859	2.240, 21.005	0.001[a]	1.232	0.246, 6.166	0.799
	> 60 yrs	6.09	1.842, 20.130	0.003[a]	1.167	0.219, 6.212	0.856
Occupation	Farmer	4.956	3.353, 7.320	< 0.001[a]	2.354	1.482, 3.739	< 0.001[a]
	Non-Farmer	1	-	-	1	-	-

Temporal Distribution of Malaria Cases in Betong District from 2013 to 2017

The majority of malaria occurrences were dominated by the Betong Sector followed by Spaoh Sector and Debak Sector between 2013 and 2017 (Figure 2). However, no cases of malaria were reported in two sectors namely: Pusa Sector and Maludam Sector within the study years. As presented in Figure 2A, a higher incidence of malaria was found in Betong Sector compared to other sectors. The highest notification of malaria cases between 2013 and 2017 was reported in October, 2017. 18 cases of malaria were notified to Betong Health Division during October 2017. In 2014, the cases of malaria decreased during December each year except in 2013. In 2013, the four peaks of malaria increasing monthly during February, June, August and December as shown in Figure 2B.

Spatial Analysis of Malaria Cases in Betong District from 2013 to 2017

The sub-districts of Betong were divided into four classes based on the malaria incident rates as indicated (Figure 3). Class 1 was represented as a malaria free area. Pusa sub-district and Maludam sub-district were categorized as the malaria free area because no malaria cases were notified between 2013 and 2017. Meanwhile, Betong and Spaoh sub-districts showed very high level of malaria incidence rate above 20.0 per 100,000 populations which involves the incidence rates from 2013 to 2017. Besides that, for Spaoh sub-district, it was categorized in class 3 which symbolized as a medium incidence rate ranging from 10.1 to 20 per 100,000 populations in 2013 and 2015 but in 2014, 2016 and 2017 the malaria incident showed a rising of incident rate to the class 4 (20.0 per 100,000 populations). All the sub-district from 2013 to 2017 was not categorized in class 2.

The result of ANN analysis generates three values which are Nearest Neighbour Ratio (R), z-scores and p-value. It was calculated via the analysis of malaria distribution in Betong District, from 2013 to 2017 (Table 3). The results from ANN analysis described that the average neighbour nearest ratio was less than 1. As example, the nearest neighbour ratio is 0.80 with the p-value 0.03. All the p-value and z-score were statistically significant in all 5 years except in 2015. The ANN summary which measures distance analysis indicates that p-value was less than 0.05 excluding the p-value in 2015.

Based on Table 3, these results indicate that the spatial distribution of malaria of all years were in clustered pattern (excluding 2015) which conclude that the significant spatial of malaria incidence occurred at closed distance between the cases. The distribution of malaria in 2015 was categorized as random pattern. The distribution of malaria cases in 2013 to 2017 were further estimated by applying the Kernel Density analysis (Figure 4). The results indicated that the red coloured area was classified as a hotspot area with high malaria cases. In contrast, the green coloured area identified as a hot spot area with low density. Thus, this analysis also presented an area with malaria cases that mostly affected. The hot spot area with the higher incidence of malaria mostly spread in all sub-districts of Betong especially around the Layar area.

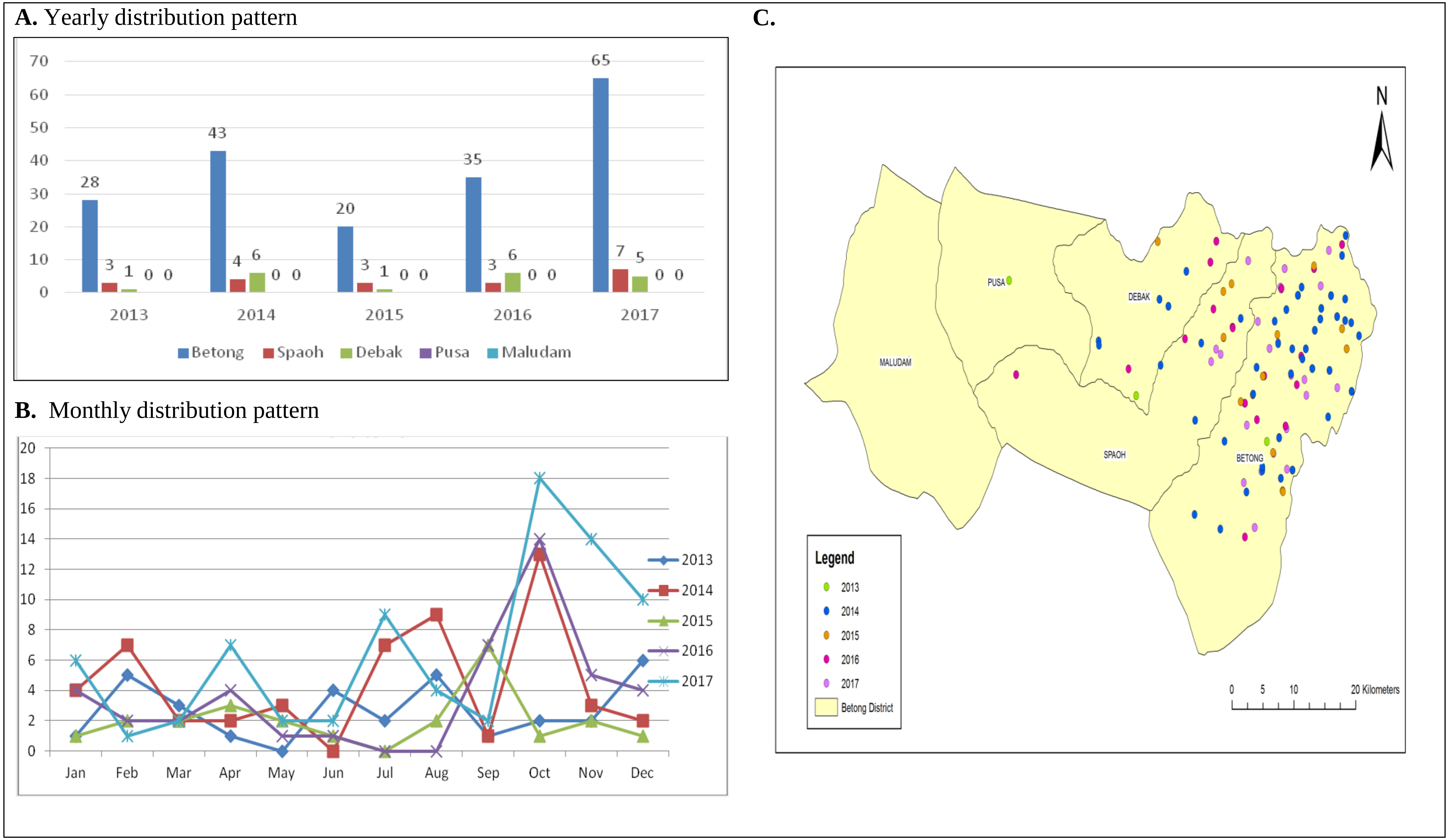

Figure 2. Temporal distribution pattern of malaria cases in Betong, Sarawak, 2013 to 2017. (A)Yearly distribution; (B)Monthly distribution; (C) geographical distribution pattern.

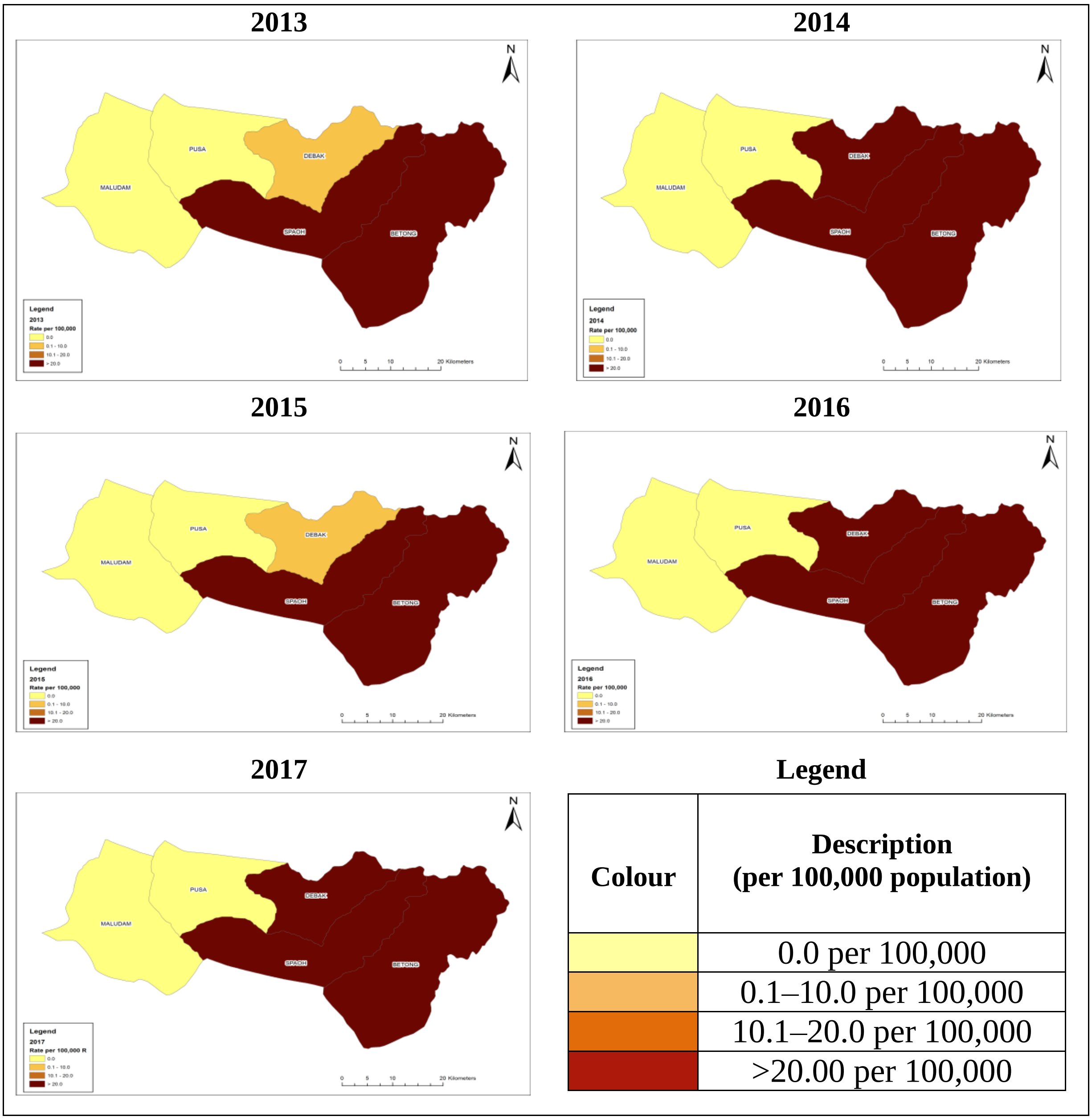

Figure 3. Spatial patterns of malaria incidence rate (per 100,000 populations) at Betong, Sarawak from 2013 to 2017.

Table 3. Average nearest neighbour of Malaria cases in Betong from 2013 to 2017

ANN analysis	**Year observation (2013-2017)**				
	2013	2014	2015	2016	2017
Nearest neighbour ratio	0.80	0.83	0.83	0.47	0.47
z-score	-2.15	-2.43	-1.57	-6.74	-9.65
p-value	0.03	0.01	0.11	0.00	0.00

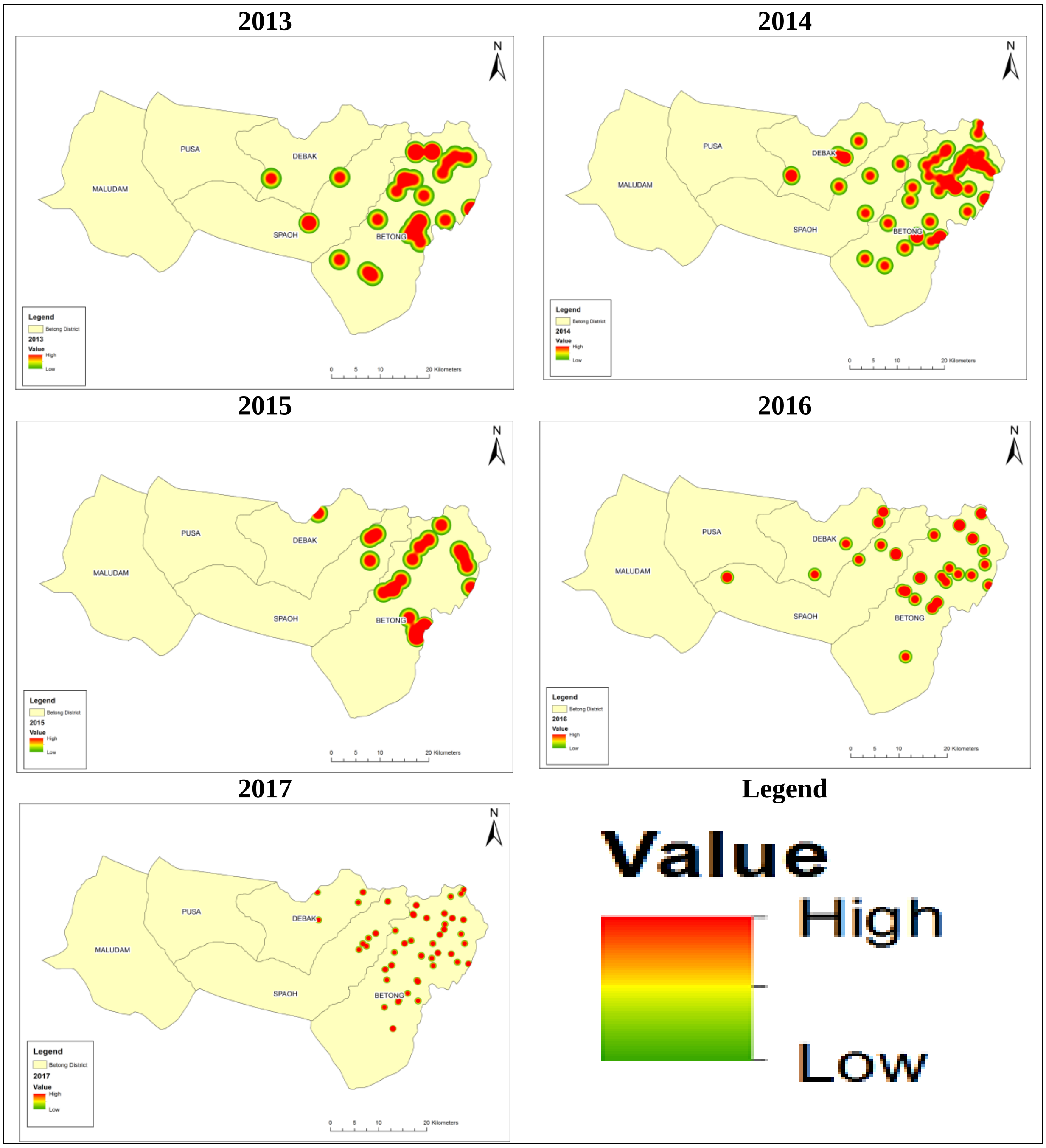

Figure 4. Hotspot identification of malaria cases at Betong, Sarawak from 2013 to 2017

DISCUSSION

In this study, important variables such as the socio-demographic like gender, nationality, age group, ethnicity, sector and occupations are significantly associated with the malaria transmission. Meanwhile, binary logistic regression was applied to assess and confirmed factors that are associated with malaria infection controlling for confounding variables. Based on this study, the socio-demographic characteristics can influence malaria transmission whereby the most at risk to malaria infection includes males and farmers. Males significantly had higher odd of 1.9 times to get malaria infection than females. According to Reuben, (1993), males have a greater occupational risk of contracting malaria than females when they work in risky areas such as mines, fields or forests at peak biting times, or migrate to areas of high endemicity for malaria. However, previous study by Herdiana et al. (2016) reported strong bias of males getting infected with malaria disease. Occupation characteristic indicated that farmers have 2.4 times more likely to get malaria infection than non-farmers. Overall, these findings support previously reported data from Sabah (Barber et al. 2013) where outdoor farming activities increase the risk of infection. The description of malaria transmission would seem to be generalisable to agricultural areas through farming activities that lead to the risk of malaria. The risk of malaria is associated with a range of human interactions within farm, forest, and village environments where macaque hosts and mosquito vectors are present (Grigg et al. 2017).

The spatio-temporal distribution of malaria in Betong District, between 2013 and 2017 was explained by the application and analysis of the data and capability of the GIS application for malaria incidence. It clearly showed that the analysis of malaria incidence can be interpreted by the location using the geographical coordinates of the area as the examples from the studies adopted by Pahrol et al. (2018) and Yoep et al. (2015). Thus, a new and systematic approach especially for health authorities can be performed by applying the application of GIS to develop more plans of action in future. The GIS will guide health authority to prevent and control malaria transmission by identification of malaria hotspots (Qayum et al. 2015) and modelling malaria transmission by adopting the mapping of malaria disease (Samat & Mey 2017).

The temporal analysis showed that the incidence of malaria cases in 2017 was higher compared to the other years. Other than that, majority of the malaria cases occurred in Betong sub-district all years although no reported of malaria cases both in Pusa and Meludam sub-district. The high incidence of malaria occurred from July till October based on monthly analysis for each year. Factors contribute in increasing of malaria cases during that period might coincidentally related to the seasonal fruits harvest season in Betong District. A seasonal fruits harvest season in Betong district occurred between July till October every year. During that season, most of the residents went out to collect the fruits like *durian, dabai, rambutan* and jack fruit. It can be concluded that during fruit collection, they are at risk of getting malaria infection because the macaque which is the source of infection of *P. knowlesi* also get attracted with the fruits during that time. That situation makes people living closer to the macaque habitat and more easily getting malaria infection (Fornace et al. 2016).

The incidence of malaria can be presented whether the patterns were dispersed or clustered rather than random chance by implementing the ANN analysis and the pattern of malaria cases was clustered statistically. Previous study in Banyuma, Indonesia also revealed almost similar spatial clustered pattern of malaria cases (Wibowo et al. 2015). Besides that, precedence study by Vythilingam et al. (2014) showed that distribution cases of malaria in Hulu Selangor sub-districts also statistically clustered. Other than that, these results also consistent with precedence finding that infectious disease spread in cluster spatially in other study (Aziz et al. 2012; Hasim 2018; Hazrin et al. 2016; Rosli et al. 2010). Kernel density was one of the parts of spatial analysis tools that have the capability to locate the hot spot area which is crucial in effective control for vector-borne disease.

CONCLUSION

The implementation of GIS for malaria distribution was described successfully. The GIS technologies and spatial tools could be an effective surveillance to develop the spatio-temporal density of malaria disease. The outcomes of this study showed that malaria distribution in five years in Betong was significantly predicted based on the location itself. By demonstrating the spatial analysis, it provides an opportunity to classify the pattern of malaria disease and this may facilitate the health authorities to improve on monitoring of the potential forecast malaria clusters systematically. GIS analysis could also provide evidence-based sound for prevention and control activities for malaria transmission effectively.

Overall, all the significant findings in this study was significant indicate connection of malaria incidence and spatial alternative to allow the malaria control specifically to be focused at a specific area commonly in cluster areas and high incidence areas. The effectiveness of malaria controls would be effective by utilization of GIS method. In this study, the malaria distribution in Betong was mapped at the sub district level. Therefore, implementation of mapping methods of malaria cases by different layers from the country levels down to village level could provide information for public health team to establish control measures and intervention to control malaria.

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