การกระจายและปัจจัยทำนายพื้นที่เสี่ยงโรคมาลาเรียในพื้นที่ชายแดนไทย-เมียนมาร์

Distributions and Predictive Factors of Malaria Risk Areas along the Thai-Myanmar Border

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อบรรยายการกระจายของโรคมาลาเรีย ระบุพื้นที่เสี่ยง และวิเคราะห์ปัจจัยทำนายพื้นที่เสี่ยงโรคมาลาเรียในพื้นที่ชายแดนไทย-เมียนมาร์ 111 อำเภอ จาก10 จังหวัด โดยข้อมูลทุติยภูมิย้อนหลังระหว่างปี 2547 ถึง 2556 จากหน่วยงานที่เกี่ยวข้อง วิเคราะห์การกระจายของโรคมาลาเรียเชิงพื้นที่และเวลาด้วยโปรแกรม Microsoft Excel, GeoDaTM 0.9.5-I และ Quantum GIS (1.7.4) ระบุพื้นที่เสี่ยงโรคมาลาเรียบนฐานอัตราป่วยปรับเรียบโดยวิธี Spatial Empirical Bayesian (SEB) และวิเคราะห์ปัจจัยทำนายพื้นที่เสี่ยงด้วยสถิติ Logistic regression ผลการศึกษาพบว่าอุบัติการณ์โรคมาลาเรียมีแนวโน้มลดลง พบจำนวนผู้ป่วยสูงช่วงเดือนมีนาคมถึงเดือนมิถุนายน และปี 2553 พบจำนวนผู้ป่วยสูงที่สุด พบพื้นที่เสี่ยงสูงของโรคมาลาเรีย 62 อำเภอ โดยส่วนใหญ่คืออำเภอที่มีอาณาเขตติดต่อกับประเทศเมียนมาร์ ปัจจัยทำนายพื้นที่เสี่ยงโรคมาลาเรียอย่างมีนัยสำคัญทางสถิติ ได้แก่ สัดส่วนประชากรอายุต่ำกว่า 25 ปี ความหนาแน่นประชากร จำนวนแรงงานต่างด้าว อุณหภูมิเฉลี่ยและปริมาณน้ำฝนเฉลี่ย($p<0.05$) โดยปัจจัยดังกล่าวสามารถอธิบายพื้นที่เสี่ยงสูงได้ร้อยละ 76.60 ผลการศึกษาจะช่วยในการระบุพื้นที่เป้าหมายในการวางแผนงาน จัดสรรทรัพยากร เฝ้าระวัง และเตรียมการ เพื่อการป้องกันและควบคุมโรคมาลาเรีย

คำสำคัญ: มาลาเรีย การกระจาย พื้นที่เสี่ยง ปัจจัยทำนาย ชายแดนไทย-เมียนมาร์

Abstract

This study aimed to describe malaria distribution, identify the malaria risk areas, and determine the predictive factors of malaria risk areas in 111 districts from 10 provinces along the Thai-Myanmar border. Using retrospective data routinely collected from 2004 to 2013 which obtained from involved organizations. Malaria distributions were analyzed by Microsoft Excel, GeoDaTM 0.9.5-I, and Quantum GIS (1.7.4) software. Malaria risk areas were classified based on the Spatial Empirical Bayesian (SEB) smoothed rates, and the predictive factors of malaria risk areas were determined by logistic regression. The results showed that trend of malaria incidence rates were decreased. Most of malaria cases were reported from March to June and the highest peak was in 2010. There were 62 malaria high risk districts in which majority of them were the connected territory districts with Myanmar. The statistically significant predictive factors of malaria risk areas were proportion of aged lower than 25 years old, population density, migrant workers, average temperature, and average rainfall ($p<0.05$). Those predictive factors could explain the high risk areas by 76.60%. The findings were useful for identification of specific target areas for planning, resource allocation, surveillance, and preparedness for malaria prevention and control.

Keywords: Malaria, Distribution, Risk areas, Predictive factors, Thai-Myanmar border

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Introduction

Malaria is a mosquito borne disease with widespread infection in many regions of the world. According to the World Health Organization's report, 104 countries had malaria infection continuously and 3.4 hundred million of the world's population was at risk of malaria infection. In 2012, 207 million malaria cases were reported worldwide including 670,000 deaths. People living in Africa and age below 5 years experienced 80% of malaria cases and 90% of malaria-related deaths[1].Most countries have malaria programs. Both domestic and international at 5.1 billion U.S. dollars is predicted to drive malaria control programs in 2015[2].

According to the annual report of the Bureau of Epidemiology, Department of Disease control, Ministry of Public Health in 2012, Thai had malaria morbidity rate of 25.20 per 100,000 population and 17 deaths. The majority groups were children 10-14 years old, which were Thai, Myanmar, Cambodia, and Lao PDR (72.64%, 18.58%, 2.36%, and 0.48%, respectively). The top ten provinces for malaria morbidity rate were Tak, Ranong, Mae Hong Son, Yala, Chumporn, Kanchanaburi, Trad, Phang-nga, Chanthaburi, and Prachuap Khiri Khan. The causes were *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae*, mixed infection, and non-identified (42.16%, 35.38%, 0.30%, 1.02%, and 20.13%, respectively)[3].

Goals of national malaria control and elimination strategy in Thai defined by the Department of Disease Control, MOPH, were set that by the year 2016 malaria will be eliminated in 60% of the country, as well as prevented for the new epidemic. The goals were also set that by the year 2016 malaria morbidity rate should not exceed 20 per 100,000 population and mortality rate should not exceed 0.05 per 100,000 population[4].

To control the areas of malaria epidemic as well as decreases malaria morbidity and mortality, it's required clearly understand about distribution of malaria occurrence, risk areas, and predictive factors of malaria risk areas. There are many databases related to malaria incidence which were developed and improved quality continuously and it should be utilized for efficient disease prevention and control. Most of previous studies, malaria data were normally analyzed using individual data, but spatial analyses were analyzed at a large scale, such as national, regional and province level[5-9]which were difficult to identify the specific target areas for implementation. Therefore, the smaller scale should be analyzed to identify more specific areas for efficient disease prevention and control[10]. Thus, this research focused on describing malaria distributions, identification risk areas, and determination the predictive factors of malaria risk areas along the Thai-Myanmar border at district level. Apart from the database of malaria cases, the databases of socio-demographic, population, migrants and control activities, and environmental factors were also utilized. The findings were useful for identification of specific target areas for planning, resource allocation, surveillance, and preparedness for efficient malaria prevention and control.

Materials and Methods

Study areas

The study areas were districts and provinces along the Thai-Myanmar border. In 2013, reported total population was 7,007,918 with a population density ranged between 19.44 to163.60 persons/km^2. The study area include 111 districts located in 10 provinces, namely, Chiang Rai, Chiang Mai, Mae Hong Son, Tak, Kanchanaburi, Ratchaburi, Petchaburi, Prachuap Khiri Khan, Chumporn, and Ranong Provinces (Figure 1). It is divided into three regions: the northern region has four provinces, the central region has four provinces and the southern region has two provinces. In 2012, malaria cases in the study areas covered 57.45% of the cases in the overall country. Regarding the areas, the study provinces covered 43.75% of the provinces having malaria morbidity rates more than 25.2 per 100,000 population.

Data and Data collection

Epidemiological data

Annual and monthly malaria cases at district level from 2004to 2013 for temporal analysis were obtained from malaria surveillance database, the Bureau of Vector Borne Disease, and monthly malaria cases database of year 2013 for spatial analysis were obtained from the Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health.

Socio-demographic data

Number of people by gender and age were obtained from the National Statistical Office, number of registered agriculturist was obtained from the Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, household income and number of house with good housing conditions were obtained from the Basic Minimum Needs database (BMN).

Population, migrants and control activities data

Number of mid-year Thai population and number of migrant workers by district were obtained from the Department of Provincial Administration, Ministry of Interior, number of migrant malaria cases was obtained from the Bureau of Vector Borne Disease, and malaria control activities was obtained from the Office of Prevention and Control Disease, Department of Disease Control, Ministry of Public Health.

Environment data

Maximum, minimum, and average of temperature, rainfall, and humidity were obtained from the Meteorological epartment, land elevation was obtained from the Royal Thai Survey Department, Royal Thai Armed Forces Headquarters, land used for agriculture, forest areas, and number of surface water sources were obtained from the Village's Status Database (NRD2C).

Data analysis

Malaria distributions

Malaria cases and population at district level from 2004 to 2013 were analyzed for malaria distribution. Temporal distribution was shown as a sequence of malaria cases over time by plotting the line graph of rates or cases in Microsoft Excel[5, 6]. Spatial distribution was described using the Spatial Empirical Bayesian (SEB) smoothed rates which were calculated from the annual malaria cases using the GeoDaTM 0.9.5-I software and overlaid to the map using Quantum GIS Wroclaw version 1.7.4 software. SEB smoothing method was used to minimize the phenomenon of the Modifiable Areal Unit Problem (MAUP).The SEB is one type of smoothing method for solving the problem of comparisons of rates in different population sizes or related to problems of variance instability and spurious outliers. In this study, SEB smoothed rates were calculated by spatial weights based on queen contiguity matrix [8, 10-13].

Malaria risk areas

Malaria cases and population at district level in 2013 were analyzed for malaria risk areas. The malaria risk areas in 2013 were classified by SEB smoothed rates into 2 following categories.

High risk areas: areas having malaria SEB smoothed rates 20 per 100,000 population and above.
Low risk areas: areas having malaria SEB smoothed rates lower than 20 per 100,000 population.

Predictive factors of malaria risk areas

The proportion of socio-demographic factors which were male, aged lower than 25 years old, agriculturist household, good housing condition, and household income, population, migrants and control activities which were population density, migrant workers, migrant cases, and malaria control activities, and environmental factors which were temperature, humidity rainfall, land elevation, land for agriculture, forest area, and water resource in 2013 were analyzed to determine the predictive factors of malaria risk areas. The correlations among the determinants were tested and excluded multicolinearity among some factors. The above determinants were analyzed using logistic regression, stepwise procedure, in SPSS Version 18 software.

Results

Malaria distributions

The monthly incidence rates of malaria along the Thai-Myanmar border from 2004 to 2013 were decreased. The rates had been increased in 2010 and had been decreased again from 2011 to 2013 (Figure 2). More of malaria cases were reported during March to June. The high peaks occurred during April to July in which majority of them were found in May. The small peaks occurred during September to December from 2007 to 2013. The highest malaria cases were found in 2010 meanwhile the lowest malaria cases were found in 2013 (Figure 3).

Regarding SEB smoothed rates of malaria in 2012 and 2013, maximum of rates were 12,556.57 and 11,115.03 per 100,000 population and median of rates were 36.40 and 31.10 per 100,000 population, respectively. The districts having SEB smoothed rates of malaria in 2012 and 2013 higher than the goal of malaria control of Thai (not exceed 20 per 100,000 population) were 58.18 and 55.45% of the total districts, respectively. The high rates districts were bordered to Myanmar (Figure 4).

Malaria risk areas

In 2013, risk areas were classified by SEB smoothed rates and it was found that there were 62 high risk districts and 49 low risk districts (Table 1). Almost all of a connected territory districts with Myanmar were malaria high risk areas (Figure 5).

Predictive factors of malaria risk areas

All determinants were analyzed simultaneously using a forward stepwise logistic regression. The results indicated that five determinants were the significant predictive factors for malaria risks area classified by malaria SEB smoothed rates. There were proportion of aged lower than 25 years old, population density, migrant workers, average temperature, and average rainfall. Occurrence of malaria risk area can be explained by those variables by 76.60% (Table 2).

Discussion

Temporal distribution

Overall areas along the Thai-Myanmar border had high malaria incidence. It slowly decreased from 2004 to 2009 and increased again in 2010 which was higher than 2007 to 2009. This was consistent with the Annual Epidemiological Surveillances Reported 2013, Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health[14] and the study of Pinna C.[15]. Those patterns might be due to the suitable breeding sites and environments. The geography of the Thai-Myanmar border was primarily forest, mountain, and valley, so the climate was humid and rainy, and the main occupation of people was agriculture. Many areas had migrant population moving across the border for employment in Thai. Moreover, it might be due to lack of stringent of surveillance and policy enforcement in malaria prevention and control. These enhanced malaria infection and made it difficult to eliminate malaria along the border. Many factors might be contributed to the reduction such as screening of the malaria cases and drug treatment using Rapid Diagnostic Test (RDT) and microscopy which had a high specificity after laboratory confirm test[16], providing of appropriate treatment following the protocol and distribution of insecticide-impregnated bed net[17]. The peak in 2010 led the National Strategic Plan for Malaria Control and Elimination in Thai by Department of Disease Control, Ministry of Public Health, Thailand to set the goal that from 2011 to 2016 malaria will be eliminated in60%of the country, as well as prevented for the new epidemic. The goals were also set that by the year 2016 malaria morbidity rate should not exceed 20 per 100,000 population and mortality rate should not exceed 0.05 per 100,000 population. As a result, reporting and campaigns for malaria prevention and control were improved and increased. For example, Insecticide Residual Spraying (IRS) activity and distributing the Long Lasting Insecticide Nets (LLINs) including budget allocation for malaria control from public and private sectors were improved. Therefore, malaria incidence had been decreased until 2013. In addition, an improvement in the compliance to the new drug for malaria treatment was also the potential for treatment and behavioral change to decrease the malaria distribution.

Consider the seasons, malaria cases often occurred in summer and rainy months (March to June) and after that it decreased, which was consistent with the study of Wangdi et al. which indicated that malaria transmission occurred in the summer months when ambient temperature and humidity was favorable[8]. Most of malaria cases occurred in March which was summer periods. This might be due to the migrants went back to their hometown in the long weekend during the middle of April, and they might be infected the malaria parasite from those places. Thus, malaria might be epidemic in their communities when they came back for agricultural working when rain is begin[18]. The rainy season began on June in which temperatures was as high as 30° Celsius, humidity was above 60% and surface water sources was plenty[4]. This might enabling the breeding sites and growth of the vector. Moreover, the people began to prepare the land for planting in those periods, and they might have a high risk of Anopheles mosquito bites, resulted to malaria epidemics in the later month.

Spatial distribution

More than half of districts along the Thai-Myanmar border had both annual SEB smoothed rates in 2012 and 2013 higher than the goal of malaria control of Thai. Majority of malaria occurred in a connected territory districts with Myanmar, which was consistent with the finding of The Royal College of Physicians of Thai and Bureau of Vector Borne Disease[19].The malaria cases along the border of Thailand showed that proportion of malaria cases along the Thai-Myanmar border was 68.4%, Thai-Cambodia border was 12.8%, Thai-Malaysia border was 8.8%, and Thai-Lao PDR was 5.2%[15]. The highest malaria cases along the Thai-Myanmar border might be due to the suitable geographic and climate for its breeding which was rain shadow zone and humid including the agriculture characteristics that might affect to the condition of breeding site. The differences of malaria epidemics in each areas might be due to differences of working and farming agricultural characteristics, some plating need less water meanwhile the other planting need excess water, this affect to breeding site. In addition, the connected territory districts with Myanmar has both natural border and formal border which enabled illegal migrant workers (nearly 50%) to move across the border for employment in the areas[20]. Duration of staying in Thai of migrants, at the working areas was also the potential factors for malaria occurrence. The rest of the migrant workers were allocated according to the employer defined, for example; planting, farming and villa workers. They might have inadequate mosquito protective equipment and not access to health service including lack of screening, treatment and continuous drug taking[21, 22]. This might result to drug resistant[23]to malaria in those areas. The travelers and soldiers were also the vulnerable groups for malaria because they were people outside malaria transmitted areas which might have no immune to fight against malaria.

Malaria risk areas

There were 62 high risk districts classified by SEB smoothed rates. These areas located in the suitable environment region with tropical climate such as rainfall and humidity[7, 24-26]which facilitated vector multiplication and parasite survival. The majority of people in these areas were agriculturists, (corn and paddy plantation), which also provided aquatic environment for the breeding of mosquitoes[8]. The geographical characteristics in these areas could also be the factors for malaria risk area (forest, mountain, valley and the land elevation above 600 meters from sea level)[25, 27]. Moreover, there are 9refugee camps located in districts of Mae Hong Son, Tak, Kanchanaburi, and Ratchaburi (Table 3) which had approximately 52,000 people in February 2012[28]. The proportion of patients with *Plasmodium falciparum* and *Plasmodium vivax* parasites accounted for over 12% and 65%, respectively[17]which might be the reservoir of malaria including the cross border malaria between Thai and Myanmar people.

Predictive factors of malaria risk areas

The results of logistic regression showed that after simultaneously controlled the effect of other variables, there were 5 predictive factors for malaria risk area classified by SEB smoothed rates. Malaria high risk areas at a district level along the Thai-Myanmar border can be explain by proportion of aged lower than 25 years old, population density, number of migrant workers, migrant malaria cases, average temperature and average rainfall. The rainfall and temperature were the predictive factors of risk areas, it was consistent with the study conducted by Akpala et al. and Woyessa et al., which found that rainfall was a predictive factors of malaria prevalence[27,29]and the study was conducted by Wangdi et al., which found that the temperature was an important predictive factors of malaria for overall districts[7] and the finding of the study conducted by Li et al., which indicated that each 1°C rise of temperature corresponded to an increase of 0.90%in the monthly number of malaria cases. Likewise, a 1% rise in relative humidity and rainfall led to an increase of 3.99% in the monthly number of malaria cases[30]. In fact, the rainfall and temperature were importance factors for survival of malaria parasite. Moreover, risk behavior of population to expose the mosquito such as personal protection and occupation will also increase chance to get malaria. Important factor that enhance the chance to get malaria and can be reservoir of disease was migrant workers or population mobilized. Migration was often cyclical and seasonal movement. When population moves from low malaria transmission areas to high transmission areas, they are more susceptible than the resident population. In the other hand, migration from these high transmission areas to the low transmission areas can expose previously malaria-free vectors to the disease. This cycle of re-introduction threatens progress towards malaria elimination and control[31].Then, based on limited condition of migrant for staying in Thai, migrant workers have to work or to stay in a not good condition places, it make them prone to get malaria. When they are malaria cases, they can distribute the disease to other people because they were unlikely access or delay to medical services and treatment[32].

Conclusion

The SEB smoothed rates showed that malaria incidence rates for all districts from 2009 to 2013 were higher than the goal of malaria control of Thai. The high rates occurred in districts connected with Myanmar from 2009 to 2013 and seemed that the malaria epidemics occurred in those areas every year. In overall, malaria incidence rates were slowly decreasing. Thereafter, the monthly incidence rates had been decreased from 2004 to 2013. Most of malaria cases were reported during March to June. The majority of high peaks were found in May. There were 62 high risk districts and predictive factors of malaria risk areas were proportion of aged lower than 25 years old, population density, migrant workers, average temperature and average rainfall.

There were limitations of this study. The data of malaria vector were not included in the study because the existing data was not available. The epidemiological data, analyzed for temporal distribution, were the reported malaria cases from the Bureau of Epidemiology which obtained from passive reporting, therefore, the cases from active screening and malaria cases in refugee camp were not included. In addition, this was an ecological study, the results should be interpreted with caution and should be aware that the results cannot infer to the individuals.

The findings suggest that the districts with high proportion of population aged lower than 25 years old, migrant workers, average temperature and average rainfall should be the target areas for strengthening malaria control activities. The active screening and early treatment should be planned and implemented in the districts having migrant workers or refugees, as well as patient monitoring and personal protection. The surveillance system for predictive factors of malaria risk areas should be set and managed, especially in the high risk areas, and the data should also be utilized for more efficient malaria prevention and control.

Further studies should investigate on malaria determinants in the high risk areas, develop the guidelines for resources allocation, prevention and control activities, and assess the effectiveness of those guidelines.

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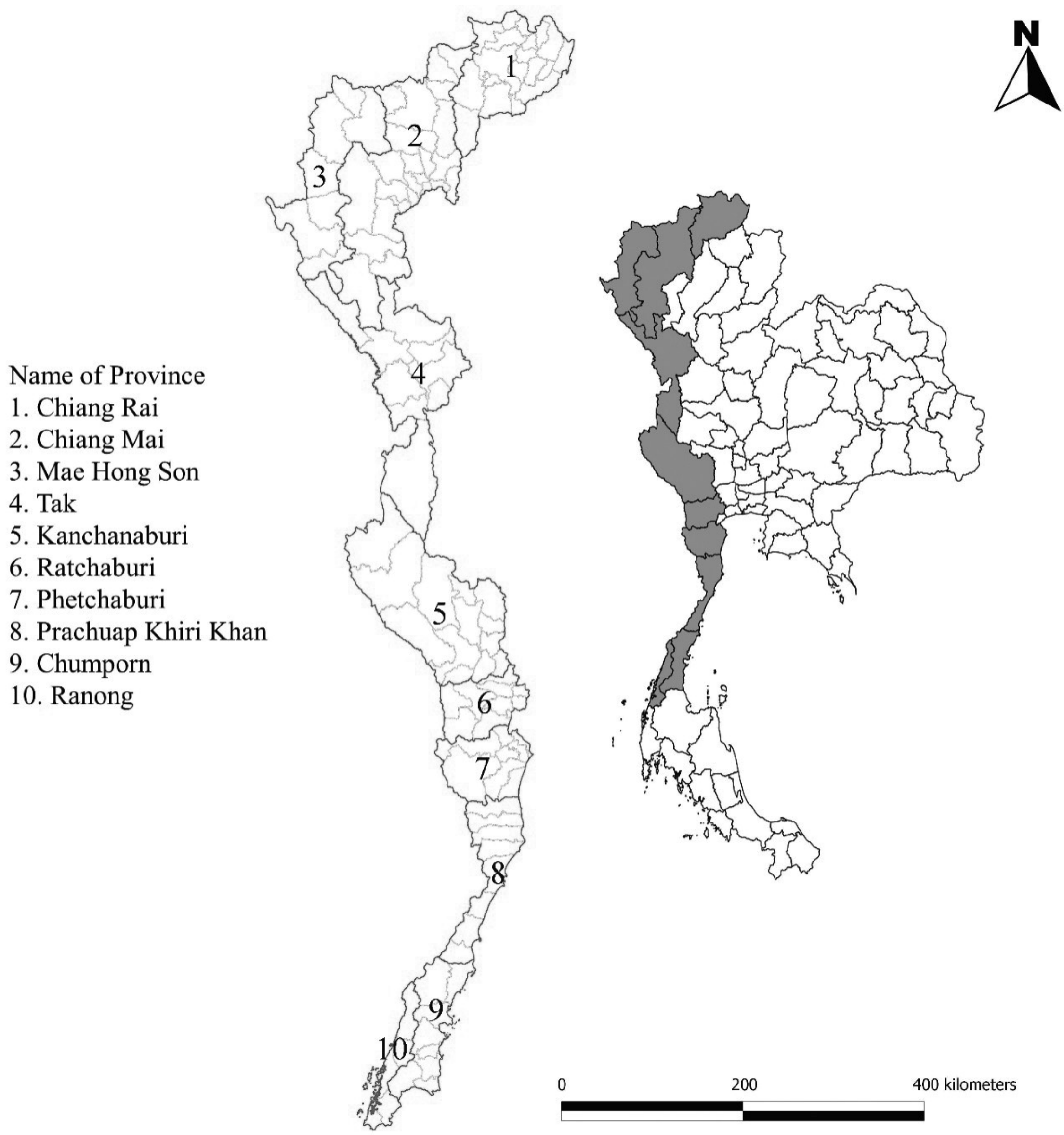

Figure 1 Study areas: The Thai-Myanmar border by province and district

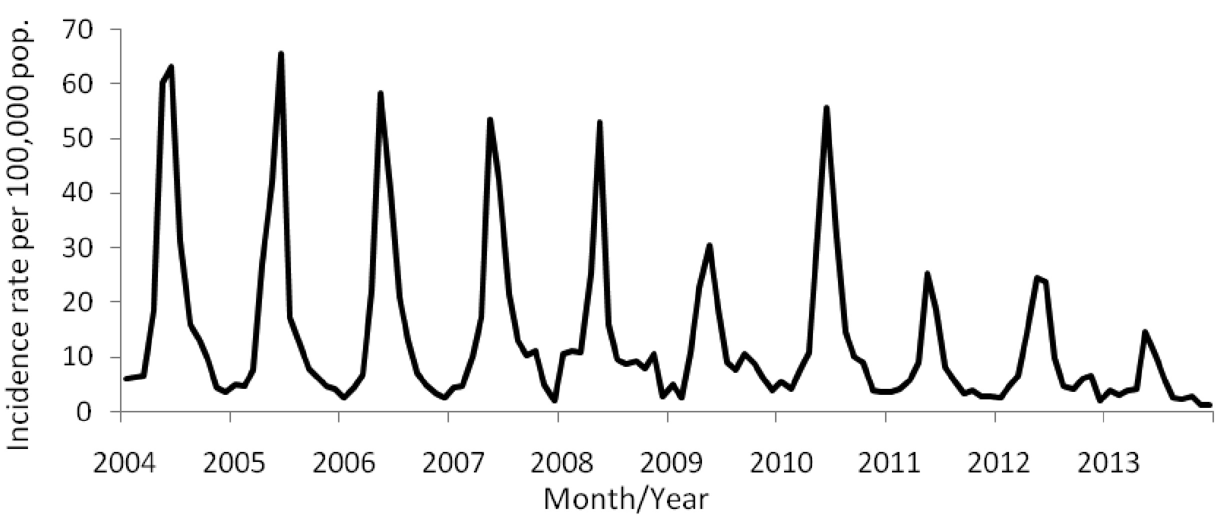

Figure 2 Monthly malaria incidence rates of overall the Thai-Myanmar border from 2004-2013

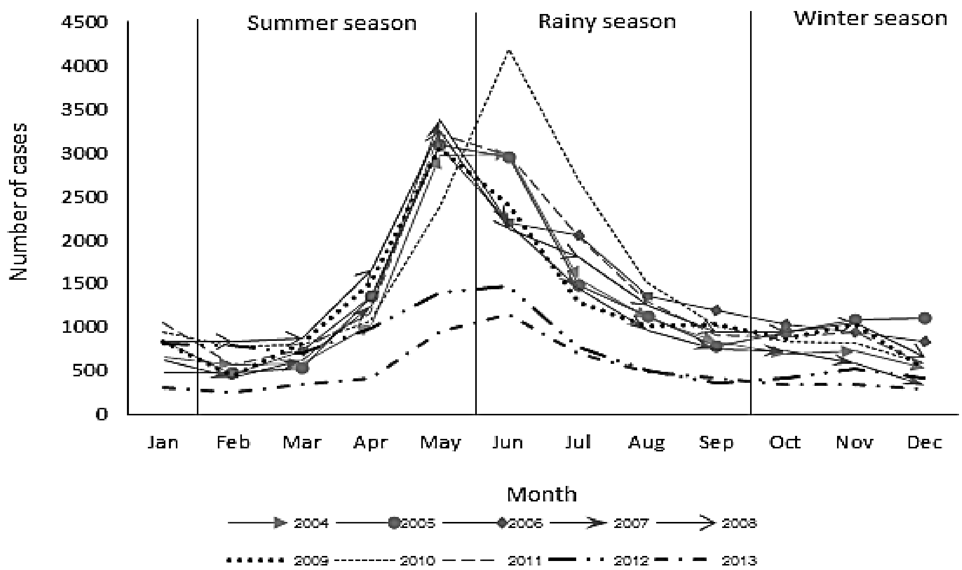

Figure 3 Monthly malaria cases from January to December from 2004 to 2013

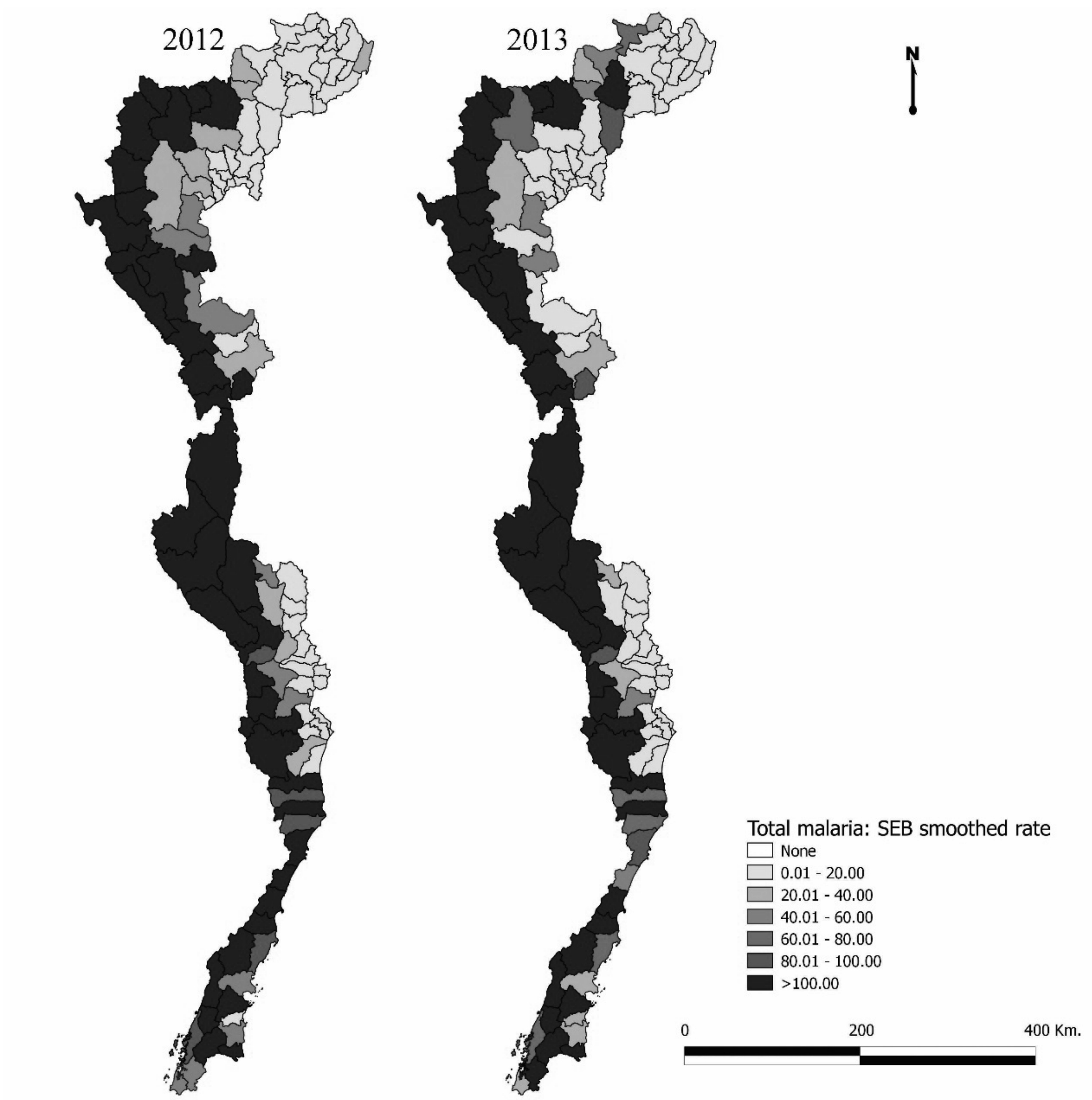

Figure 4 SEB smoothed rates of malaria per 100,000 population at a district level along the Thai-Myanmar border in 2012 and 2013

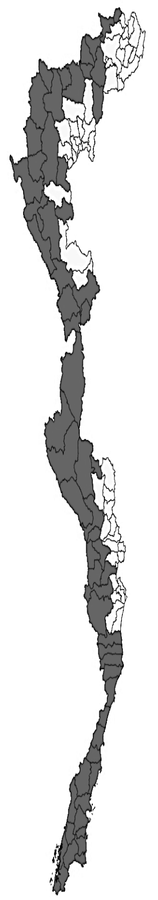

Figure 5 Malaria high risk areas and low risk areas, classified by SEB smoothed rates, in year 2013

Table 1 Malaria high risk areas in 2013 by district

Province	District	Province	District
Chiang Mai	Chom Thong	Ratchburi	Ban Kha
Chiang Mai	Mae Chaem	Kanchanaburi	Muang Kanchanaburi
Chiang Mai	Chiang Dao	Kanchanaburi	Sai Yok
Chiang Mai	Fang	Kanchanaburi	Si Sawat
Chiang Mai	Mae Ai	Kanchanaburi	Thong Pha Phum
Chiang Mai	Doi Tao	Kanchanaburi	Sangkhla Buri
Chiang Mai	Om Koi	Kanchanaburi	Dan Makham Tia
Chiang Mai	Wiang Haeng	Kanchanaburi	Nong Prue
Chiang Mai	Chai Prakarn	Petchburi	Nong Ya Plong
Chiang Mai	Kanlaya Ni Watthana	Petchburi	Kaeng Krachan
Chiang Rai	Mae Sai	Prachaubkirikhan	Muang Prachaubkirikhan
Chiang Rai	Mae Sa-ruai	Prachaubkirikhan	Kui Buri
Chiang Rai	Wiang Pa Pao	Prachaubkirikhan	Thap Sakae
Chiang Rai	Mae Fa Luang	Prachaubkirikhan	Bang Saphan
Mae Hong Son	Muang Mae Hong Son	Prachaubkirikhan	Bang Saphan Noi

Province	District	Province	District
Mae Hong Son	Khun Yuam	Prachaubkirikhan	Pran Buri
Mae Hong Son	Pai	Prachaubkirikhan	Hua Hin
Mae Hong Son	Mae Sariang	Prachaubkirikhan	Sam Roi Yot
Mae Hong Son	Mae La Noi	Ranong	Muang Ranong
Mae Hong Son	Sop Moei	Ranong	La-Un
Mae Hong Son	Pang Ma Pha	Ranong	Kapoe
Tak	Muang Tak	Ranong	Kra Buri
Tak	Mae Ramat	Ranong	Suk Samran
Tak	Tha Song Yang	Chumphon	Muang Chumphon
Tak	Mae Sod	Chumphon	Tha Sae
Tak	Phop Phra	Chumphon	Pathiu
Tak	Um Phang	Chumphon	Lang Suan
Tak	Wang Chao	Chumphon	Lamae
Ratchburi	Chom Bung	Chumphon	Phato
Ratchburi	Suan Phung	Chumphon	Sawi
Ratchburi	Pak Tho	Chumphon	Thung Tako

Table 2 Logistic regression analysis to determine the predictive factors for malaria risk areas

Predictive factors	β	OR	95% CI		p-value
			Lower	Upper	
Proportion of population aged lower than 25 years old	37.298	1.58×10^{16}	6.42×10^{7}	3.88×10^{24}	<0.001
Population density	-0.009	0.991	0.982	0.998	0.039
Number of migrant workers	0.001	1.001	1.001	1.003	0.048
Average temperature	-0829	0.437	0.232	0.822	0.010
Average rainfall	0078	1.081	1.014	1.151	0.016
Constant	0.385				

Chi-square (Omnibus Test of Model Coefficients)=94.079, df=5, p-value<0.001
-2 Log likelihood = 58.274, Nagelkerke R^2 = 0.766

Table 3 Refugee camp in malaria risk areas

Province	District	Name of refugee camp
Mae Hong Son	Sop Moei	Mea La Ma Luang
Mae Hong Son	Sop Moei	Mae La Oon
Mae Hong Son	Muang Mae Hong Son	Ban Mae Nai Soi
Mae Hong Son	Khun Yuam	Ban Mae Surin
Tak	Tha Song Yang	Mae La
Tak	Phop Phra	Umpiem
Tak	Um Phang	Nu Po
Kanchanaburi	Sangkhla Buri	Ban Ton Yang
Ratchaburi	Suan Phung	Tham Hin