Impact of Climatic Factors on Dengue Haemorrhagic Fever Incidence in Southern Thailand

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ABSTRACT

This study investigated climatic factors associated with Dengue Haemorrhagic Fever (DHF) incidence in southern Thailand, and compared the differential effects of climatic factors on the incidence of DHF in the areas bordering on the Andaman Sea and those on the Gulf of Thailand side of the peninsula. Climatic factors comprised rainfall, rainy days, relative humidity, maximum, minimum, and mean temperatures. The result indicated that the mean temperature, rainfall, and relative humidity were associated with DHF incidence in the areas bordering the Andaman Sea. Minimum temperature, rainy days, and relative humidity were associated with DHF incidence on the side of the southern peninsula Gulf of Thailand.

Key words: Dengue haemorrhagic fever - Temperature - Rainfall - Relative humidity - Thailand

INTRODUCTION

Dengue haemorrhagic fever (DHF) is one of the most serious public health problems in Thailand and in many other tropical countries around the world. The disease affects hundreds of millions of people every year (1,2). DHF is transmitted predominantly by the mosquito (*Aedes aegypti*) adapted to living near areas of human habitation (3,4). Dengue transmission occurs throughout the year in endemic tropical areas, but there exists a distinct cyclical pattern associated with the rainy season (1). In tropical and sub-tropical regions, temperature and rainfall levels enable adult vectors to remain active all year (5). This results in a continuous transmission cycle that makes the disease endemic.

The transmission of dengue viruses is climatically sensitive for several reasons. First, temperature changes affect vector-borne disease transmission and epidemic potential by altering the vector's reproductive rate, biting rate, the extrinsic incubation period of the pathogen, by shifting a vector's geographic range or distribution and increasing or decreasing vector-pathogen-host interaction and thereby affecting host susceptibility (6). Second, precipitation affects adult female mosquito density. An increase in the amount of rainfall leads to an increase in available breeding sites, which in turn leads to an increase in the number of mosquitoes. An increase in the number of adult female mosquitoes increases the odds of a mosquito obtaining a pathogen and transmitting it to a second sensitive host (7). Third, a distinct seasonal pattern in DHF outbreaks is evident in most places. In tropical regions where monsoon weather patterns predominate, DHF hospitalisation rates increase during the rainy season and lessen several months after the cessation of the rains (8,9). This decline may be related to a decrease in mosquito biting activity, a decrease in longevity of female mosquitoes, or both. In Thailand where the vector life cycle is highly domiciliary, temperature and humidity conditions during the rainy season favour survival of infected mosquitoes (10).

There has been an upward trend in the incidence of DHF, an acute and severe form of dengue virus infection, since the first DHF epidemic outbreak in 1958 (11), with a cumulative total of 1,369,542 DHF cases in 2001. Reported that there had been several regular outbreaks in Thailand. From 1992 to 2002, the Southern Epidemiology Department reported 42,692 cases of DHF in southern Thailand including 123 deaths. This indicates that DHF is a major health risk in southern Thailand. Most studies on dengue have been done in the central part of Thailand (12,13,14,15) and on Samui Island, southern Thailand (16,17) where the climate differs significantly from that of the other southern regions of the country.

Southern Thailand is a narrow peninsular that separates two coasts that are under different monsoon seasons: southwest and northeast monsoon. On the Andaman Sea side of the Southern peninsula, the wettest period of the year is from August to September from the southwest monsoon. On the Gulf of Thailand side, the wettest period of the year is from November to January from the northeast monsoon. The impact of climatic factors on DHF in Thailand is probably among the least well understood. A good understanding of the current causal relationship between climatic factors and DHF is essential for a study of the impact of potential climate change on DHF in the future (18,19,20,21). The aim of this study is to investigate the relationship between climatic factors and the incidence of DHF in southern Thailand, and to compare the differential effects of climatic factors on the incidence of DHF in the areas bordering on the Andaman Sea and those on the Gulf of Thailand side of the peninsula.

MATERIALS AND METHODS

Southern Thailand is located at 5° 37'-11° 42' N, 98° 22'-102° 05' E, and covers 70,715.2 km^2. It is bordered on the eastern side by the Gulf of Thailand and on the western side by the Andaman Sea. There are many hills and mountains bordered by the seas. Southern Thailand is composed of 14 provinces **(Figure 1)**. The climate is equatorial and humid with rainfall, high temperature of over 20°C, and relative humidity of 80% throughout the year (11).

Climatic data for southern Thailand over the period 1993-2002 were provided by the Climatology Division of the Meteorological Department. The monthly DHF incidence data over the same period were collected by the Centre of Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health. Climatic data comprised monthly rainfall, rainy days, maximum temperature, minimum temperature, mean temperature and relative humidity.

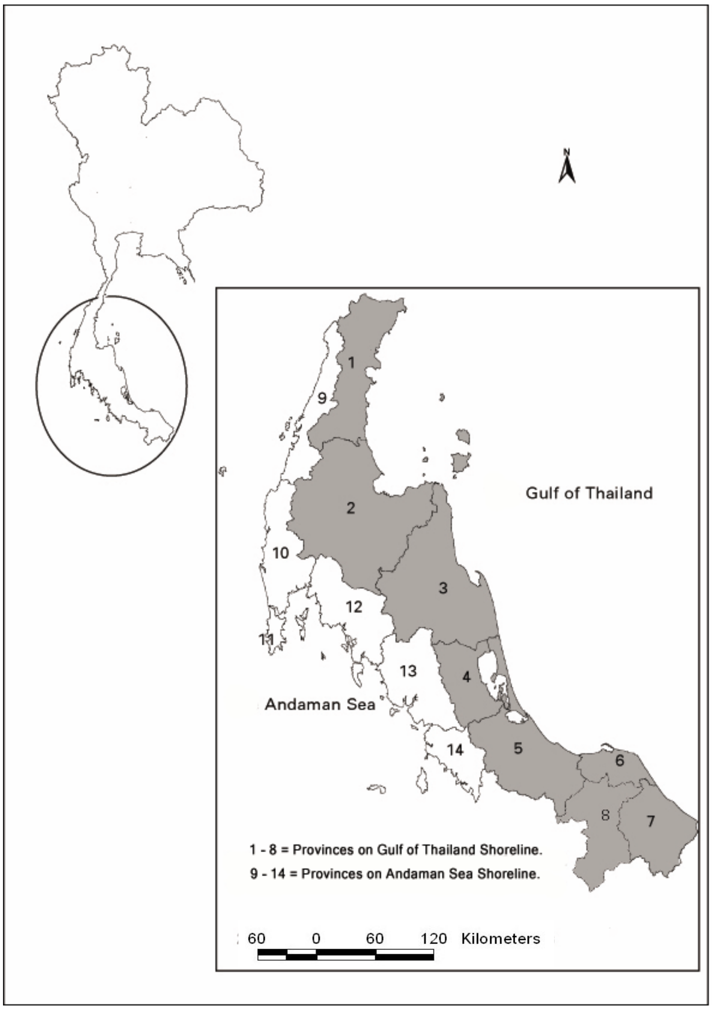


Figure 1. Map of administrative boundaries of 14 provinces of southern Thailand. Shaded area (no.1-8) represents eight provinces at the Gulf of Thailand. Non-shaded area (no. 9-14) represents six provinces at the Andaman Sea.

All variables were tested for normality using the Kolmogorov-Sminov test and transformed when necessary. DHF was logarithmically transformed to achieve normality. Independent *t*-tests were used to test for significant differences in both climatic factors and DHF incidence across two regions. Pearson's correlation coefficient test was used to detect primary association between DHF incidence and climatic factors. Stepwise regression techniques were employed to explore and identify statistically significant climatic risk indicators for DHF.

RESULTS

DHF incidence rates in southern Thailand varied from 0.00-192.73 per 100,000 population. The highest incidence of the disease was observed in July 1995 in Trang Province on the Andaman Sea side with 192.73 cases per 100,000 population. DHF incidence mean rate was 9.91 ± 17.42 with the median 3.09 **(Figure 2a)**. Rainfall varied from 0.00-713.20 mm **(Figure 2b)**. Rainy days were 14.22±7.06 days per month with the range of 0-31 days **(Figure 2c)**. Relative humidity mean was 79.89 ± 3.39% with the range of 72.4-86.0% **(Figure 2d)**. Maximum, minimum, and mean temperatures varied from 29.40-40.30, 13.00-26.60, and 23.90-31.20°C, respectively **(Figure 2e)**.

DHF incidence rates and climatic factors varied on both sides of southern Thailand **(Table 1)**. The DHF incidence rate and climatic factors on the Andaman Sea side showed statistically significant differences from those for the Gulf of Thailand side in all categories **(Table 2)**. DHF incidence per 100,000 population on the Andaman Sea side was lower than that for the Gulf of Thailand side **(Table 2)**. Rainy days, rainfall, mean, maximum temperature, and relative humidity on the Andaman Sea side were higher than those on the Gulf of Thailand side. However, the minimum temperature was lower on the Andaman Sea side than on the Gulf of Thailand side **(Table 2)**.

Table 1. Mean $(\bar{x} \pm \text{S.D.})$ of DHF incidence rates and climatic factors in southern Thailand.

	The Andaman Sea (6 provinces)	**The Gulf of Thailand (8 provinces)**	***t* – test**
DHF Incidence	9.53 ± 16.96	10.20 ± 17.76	$t_{1430}=3.027^{**}$
Rainy days (day)	15.41 ± 7.97	13.32 ± 6.15	$t_{1309}=5.850^{**}$
Rainfall (mm)	204.03 ± 215.14	183.92 ± 177.76	$t_{1373}=5.692^{**}$
Relative humidity (%)	80.85 ± 5.80	79.19 ± 4.17	$t_{1244}=6.504^{**}$
Temperature (°C)			
Mean	27.51 ± 0.90	27.33 ± 1.01	$t_{1630}=3.818^{**}$
Maximum	34.51 ± 1.41	33.72 ± 1.82	$t_{1676}=10.020^{**}$
Minimum	22.03 ± 1.48	22.21 ± 1.57	$t_{1678}= -2.338^{*}$

Table 2. DHF incidence rates and climatic factors of southern Thailand. (*P<0.05, **P<0.001)

Province	$\bar{X} \pm$ S.D.						
	DHF Incidence (per 100,000)	Rainy days (day)	Rainfall (mm)	Relative humidity (%)	Temperature (°C)		
					Mean	Max	Min
The Gulf of Thailand							
Chumphon	8.41 ± 12.52	13.9 ± 7.2	170 ± 136	76.6 ± 3.7	27.0 ± 1.1	34.5 ± 1.5	21.5 ± 2.4
Surat Thani	11.53 ± 20.51	12.8 ± 6.7	136 ± 115	81.1 ± 3.5	26.8 ± 0.9	34.6 ± 1.5	21.2 ± 1.5
Phattalung	10.83 ± 20.27	13.0 ± 5.4	174 ± 149	79.0 ± 3.3	28.0 ± 0.9	32.0 ± 1.5	24.0 ± 1.1
Nakhon Si Thammarat	10.81 ± 19.61	14.0 ± 5.8	219 ± 210	81.0 ± 3.7	27.0 ± 1.0	34.0 ± 1.9	22.0 ± 1.4
Songkhla	12.72 ± 19.53	13.2 ± 6.5	182 ± 200	78.6 ± 3.7	27.8 ± 0.9	33.7 ± 2.0	23.1 ± 0.9
Pattani	7.83 ± 15.28	12.0 ± 6.3	170 ± 177	81.0 ± 3.3	27.0 ± 0.9	34.0 ± 1.4	22.0 ± 1.3
Yala	13.14 ± 19.15	12.7 ± 4.4	180 ± 111	74.6 ± 3.0	27.7 ± 0.9	32.8 ± 1.6	22.6 ± 0.6
Narathiwat	6.31 ± 12.02	14.2 ± 6.3	240 ± 257	82.2 ± 2.8	27.1 ± 0.9	33.8 ± 1.8	22.0 ± 0.9
The Andaman Sea							
Ranong	10.88 ± 14.54	16.6 ± 9.7	358 ± 338	79.7 ± 6.2	27.2 ± 0.9	34.6 ± 1.7	22.0 ± 1.7
Phungnga	8.07 ± 17.43	18.0 ± 8.2	321 ± 250	84.0 ± 4.2	27.0 ± 0.8	34.0 ± 1.4	21.0 ± 1.6
Phuket	7.48 ± 8.59	15.0 ± 7.6	186 ± 131	77.0 ± 5.0	28.0 ± 0.8	34.0 ± 1.2	23.0 ± 0.8
Krabi	13.03 ± 16.27	13.0 ± 7.1	189 ± 150	82.4 ± 5.2	28.0 ± 0.9	34.5 ± 1.3	22.6 ± 1.2
Trang	12.81 ± 27.04	15.0 ± 7.1	191 ± 125	83.0 ± 5.4	27.0 ± 0.8	35.0 ± 1.4	21.0 ± 1.3
Satun	4.89 ± 10.04	16.0 ± 7.1	196 ± 131	80.0 ± 5.6	28.0 ± 0.7	34.0 ± 1.2	22.0 ± 1.2

Pearson's correlation coefficient test was used to detect primary association between DHF incidence and climatic factors **(Table 3)**. On the Andaman Sea side, the significant variables were mean temperature (x_{11}) (t_{597} = 7.77, P<0.001), relative humidity (x_{14}) (t_{597} = 2.73, P<0.001), and rainfall (x_{16}) (t_{597}= 3.55, P<0.01). Therefore, the selected regression model was $y_1 = -6.522 + 0.338x_{11} + 0.180x_{14} + 0.147x_{16}$ (R^2 = 0.15, $F_{3,594}$ = 26.11, P<0.001).

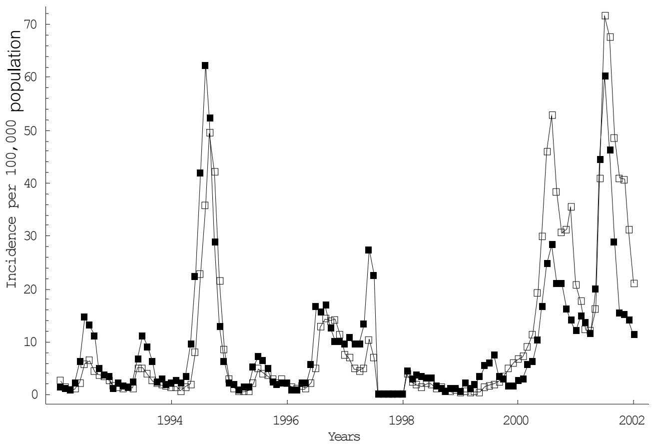
On the Gulf of Thailand side, the significant variables were minimum temperature (x_{23}) (t_{862} = 3.16, P<0.01), rainy days (x_{25}) (t_{862} = 4.03, P<0.001), and relative humidity (x_{26}) (t_{862} = -3.73, P<0.001). Therefore, the selected regression model was $y_2 = 0.072x_{23} + 0.015x_{25} - 0.017x_{26}$ (R^2 = 0.34, $F_{3,838}$ = 144.85, P<0.001).

Table 3. Pearson's correlation coefficient between climatic factors and DHF incidence (n = 1680). RH represents relative humidity. *P<0.05, **P<0.001.

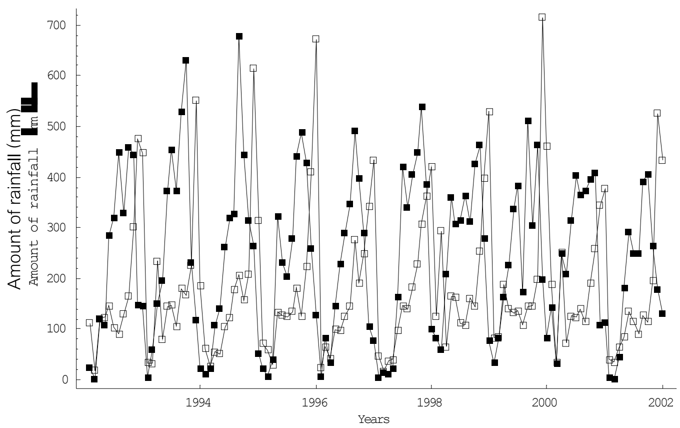
	DHF incidence	Rainfall (mm)	Rainy days	Temperature (°C)		
				Mean	Max	Min
Rainfall (mm)	-0.031	-	-	-	-	-
Rainy days (day)	0.044	0.742**	-	-	-	-
Temperature (°C)						
Mean	0.111**	-0.348**	-0.279**	-	-	-
Max	0.102**	-0.351**	-0.295**	0.559**	-	-
Min	0.109**	0.167**	0.339**	0.548**	-0.039	-
RH (%)	-0.019	0.617**	0.674**	-0.454**	-0.292**	0.060*

DISCUSSION

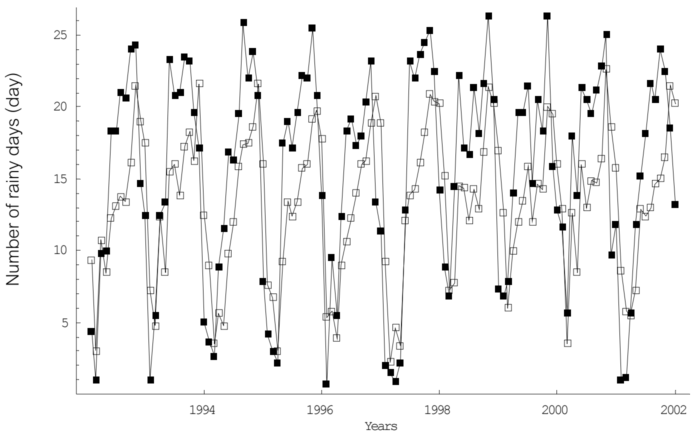
The results of this study indicate that climatic factors may play a part in the transmission cycles of DHF. However, the relative importance of these climatic factors varied with geographical areas. DHF incidence rate on the Andaman Sea side was lower than that on the Gulf of Thailand side. This could be due to different monsoon seasons between these two sides. This result contradicted the findings of the study by (22), which concluded that the seasonal patterns of DHF incidence on the Andaman Sea side and the Gulf of Thailand side were similar. These may be two possible reasons for this difference in findings. First, the data for the two studies were specific to different time-spans. The data for the present study were collected during the period 1993-2002 while those for their study covered the 1978-1997 period. From 1997 to 2002 several significant outbreaks of DHF were reported in southern Thailand. Secondly, the data for the present study were collected from all 14 provinces of southern Thailand, but their data were derived from only four provinces. It is reasonable to assume that the data used in the present study is more comprehensive and representative of southern Thailand.


Incidence per 100,000 population
Years
1994
1996
1998
2000
2002
0
10
20
30
40
50
60
70

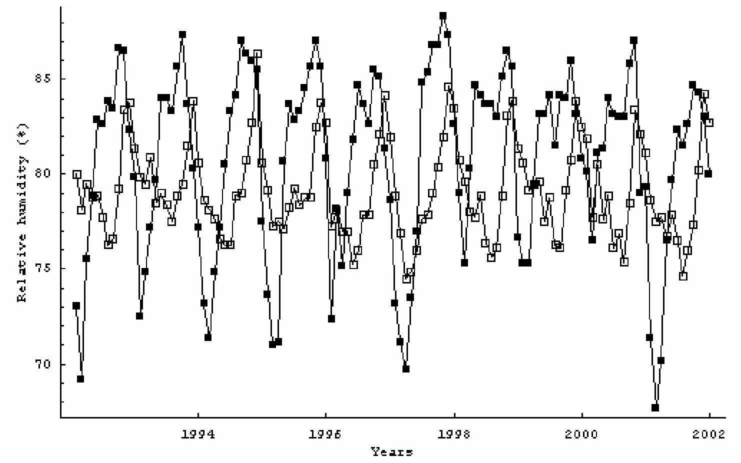
(a)


Amount of rainfall (mm)
Years
1994
1996
1998
2000
2002
0
100
200
300
400
500
600
700

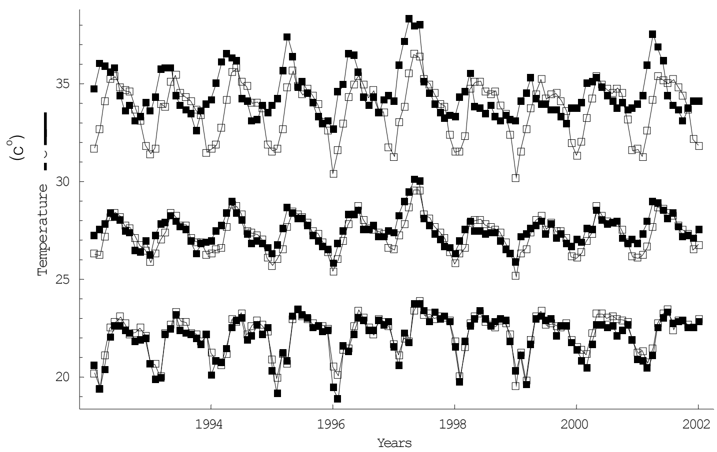
(b)


Number of rainy days (day)
Years
1994
1996
1998
2000
2002
5
10
15
20
25

(c)



(d)



(e)

Figure 2. The average monthly DHF incidence and climatic factors on the Andaman Sea side and the Gulf of Thailand side of southern Thailand during the period 1993-2002; (a) DHF incidence rate per 100,000 population, (b) Rainfall (mm), (c) Rainy days (day), (d) Relative humidity (%), (e) Maximum, mean, and minimum temperature (°C). □ The Gulf of Thailand, ■ The Andaman Sea.

Changes in climate may influence the abundance and distribution of vectors (23,24). Precipitation is an important factor in the transmission of DHF. All mosquitoes have aquatic larval and pupae stages, and therefore require water for breeding (23,24). Rainfall events and subsequent floods can lead to outbreaks of DHF mainly by enabling breeding of vector mosquitoes (24). The timing of rainfall is as important as the amount of rain. The pattern of rainfall may also play a part. Extremely heavy rainfall may flush dormant mosquito larvae away from breeding sites or kill them outright (23). More frequently, lighter rains may replenish existing breeding sites and maintain higher levels of humidity that assist in dispersal and survival of adult mosquitoes (23,24). In this study, it was found that rainfall and rainy days were two important determinants in the DHF transmission in southern Thailand. Rainy days were significantly associated with DHF incidence in both Kanchanapairoj (22) and our studies. According to Kanchanapairoj (22), the number of rainy days was associated with DHF incidence rate on both sides of the peninsula, but our study showed that rainy days were associated with DHF incidence rate only on the Gulf of Thailand side. This divergence may be due to the differential data in terms of scope and timing of data collection for the two studies. The number of rainy days may influence either the life cycle of a mosquito or viral replication rates since a certain number of rainy days are generally favourable for mosquito development. If the number of rainy days were too low, there would not be enough water for mosquito larvae to complete their development.

Warmer temperatures can increase the transmission rates of DHF in various ways. First, warmer temperatures may allow vectors to survive and reach maturity much faster than at lower temperatures (24). Secondly, warmer temperatures may reduce the size of mosquito larvae resulting in smaller adults that have high metabolism rates, require more frequent blood meal, and need to lay eggs more often (11,19,25). Thirdly, environmental temperature has a marked effect on the length and efficiency of the extrinsic incubation periods (EIPs) of arboviruses in their vectors (23,24). This means that mosquitoes exposed to higher temperatures after ingestion of virus become infectious more rapidly than mosquitoes of the same species, which are exposed to lower temperatures (24). Therefore, transmission of arboviruses may increase under warmer conditions as more vector mosquitoes become infectious within their lifespan. Higher temperature may reduce the length of viral EIPs in mosquitoes (15,26,27). At 30°C, the duration of dengue virus EIPs is 12 days compared with only 7 days at 32-35°C (26). Moreover, a 5-day decrease in the duration of incubation period can triple the transmission rate of dengue (28). It was found in this study that mean and minimum temperatures were positively associated with the transmission of DHF in southern Thailand. As minimum temperature increased, the transmission rate of DHF also increased. It is possible that most of the physiological functions of vectors in this area are subject to optimal minimum temperature.

In this study it was found that relative humidity had a positive association with the transmission of DHF on the Andaman Sea side, but a slightly negative association on the Gulf of Thailand side. The disparity may be due to the differences in some climatic factors. The Andaman Sea side has higher temperature, humidity, precipitation, more rainy days, and slightly lower minimum temperature than the Gulf of Thailand side of the peninsula. Relative humidity influences longevity, mating, dispersal, feeding behaviour and oviposition of mosquitoes, and rapid replication of the virus (4,23,29). At high humidity, mosquitoes generally live longer and disperse further. Therefore, they have a greater chance of feeding on infected people and surviving to transmit the virus to other people. Relative humidity also directly affects evaporation rates of vector breeding sites.

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บทคัดย่อ

ศุภวรรณ พรหมเพรา มัลลิกา เจริญสุธาสินี และ กฤษณะเดช เจริญสุธาสินี

ผลกระทบของปัจจัยด้านสภาพภูมิอากาศต่อการเกิดโรคไข้เลือดออกในภาคใต้ของประเทศไทย

งานวิจัยนี้ทำการศึกษาความสัมพันธ์ของปัจจัยด้านสภาพภูมิอากาศที่มีต่อการเกิดโรคไข้เลือดออกในภาคใต้ของประเทศไทย โดยทำการเปรียบเทียบผลกระทบของปัจจัยด้านสภาพภูมิอากาศที่มีต่อการเกิดโรคไข้เลือดออกบนฝั่งทะเลอันดามันและฝั่งอ่าวไทย ปัจจัยด้านสภาพภูมิอากาศที่ทำการศึกษาประกอบด้วยข้อมูลรายเดือนของปริมาณน้ำฝน จำนวนวันที่ฝนตก ความชื้นสัมพัทธ์ อุณหภูมิสูงสุด อุณหภูมิต่ำสุด และอุณหภูมิเฉลี่ย ผลการศึกษาปรากฏว่า อุณหภูมิเฉลี่ยปริมาณน้ำฝน และความชื้นสัมพัทธ์ มีความสัมพันธ์กับการเกิดโรคไข้เลือดออกในพื้นที่ฝั่งทะเลอันดามัน ในขณะที่อุณหภูมิต่ำสุด จำนวนวันที่ฝนตก และความชื้นสัมพัทธ์ มีความสัมพันธ์กับการเกิดโรคไข้เลือดออกในพื้นที่ฝั่งอ่าวไทย

สำนักวิชาวิทยาศาสตร์ มหาวิทยาลัยวลัยลักษณ์ อำเภอท่าศาลา จังหวัดนครศรีธรรมราช 80160