SPATIAL ANALYSIS ON THE MALARIA DISTRIBUTION PATTERNS AND ITS RELATION TO ENVIRONMENTAL FACTORS AT COMMUNITY LEVEL IN ENDEMIC REGIONS

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SPATIAL ANALYSIS ON THE MALARIA DISTRIBUTION PATTERNS AND ITS RELATION TO ENVIRONMENTAL FACTORS AT COMMUNITY LEVEL IN ENDEMIC REGIONS

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ABSTRACT

Spatial analysis on the malaria distribution patterns and its relation to environmental factors at community level in endemic regions were studied 7 villages in Thailand: Ban Na Bon/Tung Krang, Chanthaburi Province (CT); Ban Mern Darn, Trat Province (TR); Ban Pha Pok Kao, Ratchaburi Province (RA); Ban Rai Phum, Phetchaburi Province (PE); Ban Kao Cha Ang Bon, Chon Buri Province (CH); Ban Tra Kor Neuar, Prachin Buri Province (PJ) and Ban Kao Ta Lard Mai, Chachoengsao Province (CS). The crucial research objective was to study the distribution patterns of malaria incidence in 2004 at community level. The distance between patient houses and breeding sites of vector were investigated to determine possible relationships between environmental factors and the breeding sites of the vector. The environmental factors included: air temperature, wind speed, absolute humidity, sunlight around breeding sites, water temperature, pH, dissolved oxygen (DO), and density rate of mosquito’s larva. Samples were collected in March, July and December 2004. Following this, the relationship between incidence of malaria and behavior taken to protect against infection (mosquito repellent, mosquito coil, impregnated mosquito net and electric fan) was determined. The purposes of malaria eradication at community level in malaria endemic regions are surveillance of risk groups, reduction of environmental risk factors and changing protection behavior of risk groups. Spatial analysis was carried out with ArcView 3.2a and statistical analysis was applied with SPSS and a reliability interval of 95% (p-value < 0.05).

Based on the results, 5 villages CT, TR, RA, PE and PJ had clustered spatial distribution of malaria incidence that the breeding sites of vector had 2-3 kilometers far from patient houses that increase the risk of malaria infection. Only TR had significant clustered spatial distribution of malaria incidence (p-value < 0.05). CH and CS could not be calculated due to insufficient cases (2 and 1 respectively). Regarding the correlation of environmental factors of breeding sites of vector, it was noted that when wind velocity increases, there was a decrease in the density rate of mosquito’s larva in PE. The opposite direction was observed when DO increases in that there was an increase in density rate of mosquito’s larva in CH. When pH increased, there was an increase in density rate of mosquito’s larva in PJ. In terms of the correlation of protection behavior from malaria infection, there was a statistically significant relationship between malaria infection and use of impregnated mosquito net and electric fan in CT (p-value < 0.05; $\chi^2$ = 0.016, 14.418, df=1). In TR, there was a statistically significant relationship between malaria infection and use of mosquito repellent and mosquito coil (p-value < 0.05; $\chi^2$ = 6.975, 5.589, df=1). The study showed that changing protection behaviors can decrease malaria infection.

KEY WORDS: GEOGRAPHIC INFORMATION SYSTEM (GIS)/ SPATIAL ANALYSIS/ MALARIA DISTRIBUTION PATTERNS/ ENVIRONMENTAL FACTORS/ PROTECTION BEHAVIOR/ ENDEMIC REGIONS

103 pp.
การวิเคราะห์ข้อมูลที่ได้จากการวิเคราะห์แบบกระดาษของโรคมาลาเรียและความสัมพันธ์กับปัจจัยต่างๆในเขตที่ระบาดชุมชน (SPATIAL ANALYSIS ON THE MALARIA DISTRIBUTION PATTERNS AND ITS RELATION TO ENVIRONMENTAL FACTORS AT COMMUNITY LEVEL IN ENDEMIC REGIONS)

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ว.ป. (การวางแผนเชิงอคติเพื่อพัฒนาชุมชนและชุมชน)

คณะกรรมการควบคุมวิทยานิพนธ์: บุญลือ นครสี ศรีวราชา, M.Sc., ธนา เลียกุล, Dr.P.H., .Sinharat ภูพิภพพิศุทธิ์, M.Sc.

บทคัดย่อ

การกับมารูเบนการกระจายของโรคมาลาเรียและความสัมพันธ์กับปัจจัยต่างๆในเขตที่ระบาดชุมชน, น้อย 7 หมู่บ้าน ได้แก่ บ้านผักบุบบี้ อำเภอวังระ, จังหวัดน่าน (CT) บ้านแม่เหม้า อำเภอวังระ, จังหวัดน่าน (TR) บ้านหวยหลัก อำเภอวังระ, จังหวัดน่าน (RA) บ้านริมเตียบ อำเภอภูเขาคอย, จังหวัดน่าน (PE) บ้านข้างคงกำนัน อำเภอภูเขาคอย, จังหวัดน่าน (CH) และบ้านยางเขียว อำเภอภูเขาคอย, จังหวัดน่าน (CS) โดยมีวิธีการที่จะมีการวิเคราะห์แบบกระดาษของผู้ป่วยโรคมาลาเรียเป็นปี พ.ศ. 2547 ในระดับชุมชน โดยมีระยะทางระหว่าง 1 กิโลเมตร ที่กลับมาเร็วที่สุดที่มีจุดหมายตั้งอยู่ที่เน้นพื้นที่เฉพาะกลุ่มคนพื้นที่ชุมชน ที่มีความสัมพันธ์กับโรคมาลาเรีย กลุ่มนี้ การวางแผนความหนาแน่นของลูกน้ำยุงพาหะที่มีส่วนอยู่ที่ระดับชุมชน, ด้วยการเรียงด้วยการใช้พลังงานแสงinkel กลุ่มคนพื้นที่ ความสัมพันธ์ของปัจจัยด้านสิ่งแวดล้อมและการลดปัจจัยเสี่ยงต่อการเกิดโรคในระดับชุมชน โดยมีความเกี่ยวข้องกับการลดปัจจัยเสี่ยงด้านสิ่งแวดล้อม ที่ระดับชุมชน, วิธีการวิเคราะห์แบบกระดาษของผู้ป่วยโรคมาลาเรียที่มีการวิเคราะห์ ArcView 3.2a และวิเคราะห์ข้อมูลทั้งหมด

ผลการศึกษาพบว่า พบข้อมูล 5 แห่ง CT TR RA PE และ PJ มีการกระจายของผู้ป่วยโรคมาลาเรียแบบ Clustered กล่าวคือ แปลงดังกล่าวสูงสุดพื้นที่ที่มีการกระจายจากบ้านผักบุบบี้ไปยังบ้านผาภูมิได้ในปี 2547 โดยมีระดับการสมรรถนะ 2-3 ได้แก่ ปีที่ 1 ที่มีผู้ป่วยที่ได้รับการเชื้อโรคหลังจากการกระชุกของโรคมาลาเรียเป็นปี Clustered อย่างมีผู้ป่วยที่สูงสุดสิ่งแวดล้อมที่ p-value < 0.05 สำหรับบ้านผักบุบบี้ 2 แห่ง CH และ CJ โดยมิได้สามารถวิเคราะห์แบบกระดาษของโรคได้เนื่องจากไม่มีจำนวนผู้ป่วยเพียง 2 ราย และ 1 ราย ตามลำดับ ความสัมพันธ์ของปัจจัยด้านสิ่งแวดล้อมในแปลงดังกล่าวสูงสุดพื้นที่ที่สูงสุดที่มีผู้ป่วย PE CH และ PJ ที่มีปัจจัยด้านสิ่งแวดล้อมที่มีความสัมพันธ์กับการกระจายของผู้ป่วยมากที่สุด ซึ่งมีผู้ป่วยสูงสุดสิ่งแวดล้อมที่ p-value < 0.05 โดย PE เมื่อความเร็วเมื่อมีการลดความหนาแน่นของลูกน้ำยุงพาหะมาก สำหรับการลดปัจจัยที่มีส่วนคัดค้านกับการกระจายของโรคมาลาเรียที่บ้านผักบุบบี้ บ้านผาภูมิ, บ้านแม่เหม้า อำเภอวังระ, จังหวัดน่าน (CT) และ TR ที่พื้นที่ที่มีความสัมพันธ์กับการเกิดโรค โดย CT มีพื้นที่ที่มีความสัมพันธ์กับการเกิดโรคมากที่สุด ซึ่งมีผู้ป่วยที่สูงสุดสิ่งแวดล้อมที่ p-value < 0.05 (χ² = 0.016, 14.418, df=1) สำหรับ TR มีพื้นที่ที่มีความสัมพันธ์กับการเกิดโรคมากที่สุด ซึ่งมีผู้ป่วยที่สูงสุดสิ่งแวดล้อมที่ p-value < 0.05 (χ² = 6.975, 5.589, df=1) หากมีการวิเคราะห์พื้นที่พื้นที่นิยมจะสามารถลดการกระจายของโรคมาลาเรียได้}

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<td>4-6</td>
<td>Standard Distance and Standard Deviation Ellipse</td>
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# LIST OF ABBREVIATIONS

<table>
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<th>Abbreviation</th>
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| API          | Annual Parasite Incidence  
  = (new malaria positive cases in one year) x (1000) / population |
| A-temp       | Air temperature |
| CH           | Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province |
| CS           | Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province |
| CT           | Ban Na Bon/Tung Krang, Tubsai sub-district, Pong Nam Rorn district, Chanthaburi province |
| DO           | Dissolved oxygen |
| D-larvae     | Density rate of mosquito’s larvae per 200 dips |
| GIS          | Geographic Information System |
| GISTDA       | Geo-Informatics and Space Technology Development Agency (Public Organization) |
| Humid        | Absolute humidity |
| LUX          | Sunlight around breeding sites of vector |
| PE           | Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province |
| PJ           | Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province |
| RA           | Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province |
| TR           | Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province |
| V-wind       | Wind velocity |
| W-temp       | Water temperature |
CHAPTER I
INTRODUCTION

1.1 Rationale

Nowadays the world is facing the serious challenge from new emerging diseases such as SARS, Bird Flu, Dengue and also the old ones such as malaria. Malaria is the infectious tropical disease that limit of between latitude 64° north to latitude 32° south. This boundary is covering area that below 400 meter (MSL) such as Dead Sea until higher 2600 meter (MSL) such as Kenya (Looareesuwan et al., 1990). Malaria remains one of the major public health problems in many countries. Globally malaria clinical cases are reported 300-500 millions and 1.5-2.7 millions deaths annually (Srivastava, n.d.). At present, there are about 2,600 millions in people more 100 countries where located as above areas. There are about 2,200 millions that inhabit in malaria prevention and control area and 400 millions that inhabit in malaria non-control area. In 1983, malaria has been estimated to ill 200 millions and to kill 2 millions especially the children in Africa recorded more than 1 million deaths per year (Looareesuwan et al., 1990). So these countries have to provide a lot of budget for malaria control program.

Thailand is confronting with malaria; it is important public health problem in the past and present time due to many populations be ill and dies caused by this disease. Malaria mortality rate and malaria morbidity rate in fiscal year 2004 meet patient 30,612 cases, it reduce from a fiscal year 2003 a number of 7,299 cases or reduce 19.25% and reduce continually from fiscal year 2000. Annual Parasite Incidence (API) per 1,000 populations reduces from fiscal year 2003 equal 0.63 in excess 0.51. API in a fiscal year 2004 as an assign in the end of year 2006 should not be over 1.00 per 1,000 populations. API is reducing because of the vector control strategy have been increased for excerpt the cycle of disease and prompt rapid diagnosis and properly treatment (Department of Disease Control, Disease Prevention and Control Office, 2005).
From the study of epidemiology of malaria infection (Wanchaiwong, 2002), they found that malaria is an endemic. Almost malaria is found in a dense jungle and border area where the stream and geography supported to malaria outbreak due to *Anopheles* vector preferable breeding sites. The characteristics of malaria outbreak, almost it is found in rainy season between May to July in every year for the north and the central of Thailand. In the northeast and the south of Thailand, there are malaria epidemic during November to December. These different in each part of Thailand are effected due to influence of the rainy season. So the vector had a different abundance follow any season. The characteristics of malaria disease could be transmitted to the patients by any sex and age group and particularly, in labor group and male. Male may have more expose to the mosquito biting than female. There have occupation factor such, keeping something of forest, cutting a tree, forest destruction. The occupational factor is related to the malaria infection in Thailand, such about exploiting, orchard farmer, para-rubber in the eastern part, and the southern part. These people who have settle their house nearby or easy to explode to the mosquito vector biting. In 2004, the malaria cases were reported and they were mostly found at the Thai-Myanmar and Thai-Cambodia bordering areas. Top ten provinces of Thailand with highest malaria cases such as Tak (7,147 cases), Kanchanaburi (2,211 cases), Yala (1,903 cases), Mae Hong Son (1,659 cases), Prachuap Khiri Khan (1,621 cases), Chanthaburi (1,524 cases), Chumpon (1,485 cases), Chiang Mai (1,413 cases), Trat (1,016 cases), and Ubon Ratchathani (979 cases) (Department of Disease Control, Disease Prevention and Control Office, 2005:2-3) were reported (Figure 1-1). During the study was processed according to the data of the fiscal year 2004, in 2006 the most prevalent of human malaria parasites contributed in both Thais and foreigners. Even though the malaria patients were reduced in each year, but it can not be eradicated from Thailand. The migrant Myanmar and Cambodia who work in Thailand have malaria parasites in their blood, so those will cause significant malaria morbidity to other Thai people, especially, in Tak, Sa-Keao, Trat and Chanthaburi. Top five provinces of highest malaria infection in 2007 are Ranong, Yala, Mae Hong Son, Tak and Songkla, respectively. These provinces are found high prevalence for both falciparum and vivax infection.
Malaria cause by mosquito vector is mainly public health problem and easier to transmit to human being. The elimination and eradication strategies are difficulty implemented (Lek-Uthai, 1999). However, this study purposed to apply geographic information system (GIS) as a tool to collect data by spatial record. Spatial analysis is a one function that can explain or link a relationship of phenomenon include the factors about physical, biological, and socio-economic (Chou, 1997). The emphasis of spatial analysis is to measure properties and relationships, taking into account the spatial localization of the phenomenon under study in a direct way. That is, the central idea is to incorporate space into the analysis to be made (Câmara et al., n.d.). In case of point pattern analysis, to answer questions about the distribution of locations, whether they are clustered, distributed randomly or regularly. Point pattern analysis is used to identify whether occurrences or events are interrelated or not (Saraf et al., n.d.). At present, GIS was popular used popular in public health field. The usefulness of their method is worldwide to the disease control measurement (Srivastava, n.d.).

This study was focused on the assessment and estimating the distribution patterns of the disease occurrence at community level. So geographic information to apply to data collection was done. Spatial analysis could explain the relationship of malaria distribution and environment factor at community level in endemic regions.
1.2 Objectives of the study

1.2.1 General objective

1.2.1.1 To study the malaria distribution patterns using a distance between patient houses and breeding sites of vector.

1.2.2 Specific objectives

1.2.2.1 To explore a relationship of environmental factors in breeding sites of vector.

1.2.2.2 To determine a relationship of a protection behaviors from malaria infection at community level in endemic regions.

1.3 Hypothesis

1.3.1 Malaria distribution patterns, clustered pattern, related to a distance of breeding sites of vector.

1.3.2 Environmental factors of breeding sites of vector associated with density rate of mosquito’s larva.

1.3.3 Protection behaviors from malaria infection correlated with infectious malaria at community level in endemic regions.

1.4 The expected results

1.4.1 To guide for prevention and protection households that located in malaria risk areas, it causes from distance between a patient houses and breeding sites of vector.

1.4.2 To model for reduce environmental factors, it supported to increase a density rate of mosquito’s larva in breeding sites of vector.

1.4.3 To make suggestion to change a protection behavior from malaria infection in risk group from no.1.4.1
1.5 Scope of the study

1.5.1 Study area

This research were studied 7 villages where a perennial transmission area (A1) including; Ban Na Bon/Tung Krang, Tubsai sub-district, Pong Nam Rorn district, Chanthaburi province (CT), Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province (TR), Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province (RA), Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province (PE), Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province (CH), Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province (PJ), and Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province (CS) (Figure 1-2).

Figure 1-2 Map of study village’s position in study area
Figure 1-2 Map of study village’s position in study area (continue)
1.5.2 Scope of content

This research analyzed data according to objectives comprised of 3 parts;

1.5.2.1 Spatial analysis on the malaria distribution that use data about distance between the malaria incidence and breeding sites of vector

1.5.2.2 Relative analysis of environmental factors of breeding sites of vector. Total 8 factors which following: air temperature, wind velocity, absolute humidity, and sunlight around breeding sites of vector, water temperature, pH, DO, and density rate of mosquito’s larva were investigated. Samples were collected in March, July and December 2004

1.5.2.3 Relative analysis of 4 protection behaviors from malaria infection at community level in endemic regions such as the usage of mosquito repellent, mosquito coil, impregnated mosquito net, and an electric were evaluated.

1.6 Limitation of the study

1.6.1 Limit of content

This research was studied at a household level. A target population was malaria positive cases in 2004. Then the data was separated into 7 villages and to strain a data for error reduction by statistically analysis.

1.6.2 A budget

Geographical information, coordinates of houses in study areas was collected. GPS receiver as a tool was used for survey of point by point through these houses. Nevertheless, this method had spent more times and made high expense. However, the researcher who used an aerial photograph for points marking those coordinated houses and to compare with the no scale map of villages marking from Vector-Borne Disease Control Unit.
1.7 Conceptual framework

This study was surveyed for malaria incidence at community level with expectation to use for management the endemic malaria. A concept about surveillance of risk groups, reduction the environmental factors that supported to increase a density rate of mosquito’s larva in breeding sites of vector, and to change behavioral characteristics of risk groups to malaria infection were considered (Figure 1-3).

1.7.1 Prevention and protection households, where they were located in malaria risk area such environment to be born from a risk due to possible of receive agent from vector. Under this condition, the distance between houses and water bodies those were breeding sites of vector. Geographic Information System for the pattern analysis is applied to study the relationship of the distance between incidence of malaria and water bodies in which they were the vector breeding sites.

1.7.2 Reduction an environmental nature, it was supported the increasing of numbers of vector breeding sites in water bodies. The eight environmental factors such as air temperature above the station, wind speed above the station, absolute humidity above the station, sunlight around a breeding sites, water temperature, pH, DO, and density rate of mosquito’s larva were studied.

1.7.3 Changing risk behaviors to malaria infection from no.1.7.1, the relationship of risk behaviors of malaria positive cases at community level in endemic regions was studied.
Figure 1-3 Conceptual frameworks

*Independent variable*
Factor in a distance between patient houses and breeding sites of vector.

*Dependent variable*
Incidence of malaria

Malaria distribution patterns:
Regular, Random, Clustered

*Independent variable*
Breeding sites of vector

*Independent variable*
The 8 Environmental factors were investigated such as
1. Air temperature
2. Wind velocity
3. Absolute humidity
4. Sunlight
5. Water temperature
6. pH
7. Dissolved oxygen (DO)

*Dependent variable*
8. Density rate of mosquito’s larva

*Independent variable*
The 4 protection behaviors from malaria infection such as
1. The usage of mosquito repellant
2. The usage of mosquito coil
3. The usage of impregnated mosquito net
4. The usage of an electric fan
1.8 Definitions

1.8.1 Malaria distribution patterns. It meant that the study of point patterns distribution that is phenomenon of malaria cases, it was considered from the principle of possibility of spatial distribution. This principle has 3 main forms such as random distribution, Poisson theory shown that areas of malaria distributions are shown similarly normal distribution. Regular distribution pattern, this will be a random reduced pattern, and it is not related to the Poisson theory. The cluster distribution pattern is diverted according to the Poisson theory as well. Such this relative in group clustered will be occurred. The other factors would be affected or relative to the etiology of malaria infection, they will be the distance between the water bodies of vector breeding sites.

1.8.2 Endemic regions at Community level. It indicated that the area of endemic occurrence is located. The annually endemic of transmission is usually reported. For this study, A1 is area that transmission annually or over 6 months. There were Ban Na Bon/Tung Krang, Tubsai sub-district, Pong Nam Rom district, Chanthaburi province (CT), Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province (TR), Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province (RA), Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Petchaburi province (PE), Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province (CH), Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province (PJ), and Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province (CS).

1.8.3 Environmental factors. It showed that 8 factors of the environmental factor related to vector breeding sites, such as air temperature, wind velocity, absolute humidity, sunlight around breeding sites of vector, water temperature, pH, DO, and density rate of mosquito’s larva were investigated.

1.8.4 Factors of Behavior (Individual factor). It meant that malaria patient behavior is an important risk behavior to malaria infection, there are 4 characteristics such as apply a mosquito repellent to exposed skins, the usage of mosquito coil to protect from a mosquito bites, the usage of impregnated mosquito net, and using an electric fan. The survey had shown whether the patient infected with malaria have the following behavior.
CHAPTER II
LITERATURE REVIEWS

The literature review for this study is comprised of a concept, theory, and relevant research for a based and direction which following:

1) Malaria
2) Geographic Information System
3) Statistical analysis in geographic
4) Relevant research

2.1 Malaria

2.1.1 Epidemiologic of malaria

2.1.1.1 Concepts in epidemiologic of malaria

Lohsoontorn (1997) mentioned that there are three important concepts or factors related with Malaria Epidemiologic triad. These three factors are agent, host and environment. The factors relate with malaria incidence and malaria distribution in those community.

From the perspective of the epidemiologic triad, the host, agent, and environment can coexist fairly harmoniously. Disease and injury occur only when there is interaction or altered equilibrium between them. But if an agent, in combination with environmental factors, can act on a susceptible host to create disease, then disruption of any link among these three factors can also prevent disease.

Dr. John Gordon has compared the relationship among the three factors; agent host and environment as playing a fulcrum board. Agent and host in the different side of environment are the fulcrum in the center of fulcrum board. Their relationships are divided into 2 types as follow.
1) In equilibrium status between this three factors, there is no Malaria in the community.

\[
\text{Agent} \quad \text{Host} \\
\text{Environment}
\]

2) At disequilibrium status between the three factors, Malaria occurs in the community.

Disequilibrium status may occur when there is an spread out malaria, the portion of sensitive to malaria, children and older people, increases and the change of environment is suitable for malaria distribution.

Agent, host and environment also have both positive and negative affect to public health of community. However, the three factors has the relationship with Malaria incidence in the community.

2.1.1.2 The composition of malaria epidemiology (Looareesuwan et al., 1990)

There are three factors related with malaria incidence; mosquito, people and environment.

- Host factor
  - Every people, even male or female, young or old people can be malaria patient. However, children who was born in the endemic malaria, has immune for malaria because they received IgG antibody from mother through after birth. The IgG antibody will gradually decrease after 3-6 months. After this stage if children have infected by malaria but not treated, later they were malaria patient. In opposite, if those children were usually cured, they will have the malaria immune. When they were infected, they have no malaria symptom even if the blood checked show the malaria pathogen.

  - Malaria immunity: people can gradually acquire immunity to malaria through natural exposure to malaria parasites. They will acquire both humeral and cellular immunity but this immunity will limit only with specific parasite’s species and stage.
The immunity will be maintained if they continuously expose from malaria parasites over time. The immunity will decrease or disappear if person is not infected by malaria. The evidence which can be explained this concept is that when person who live in endemic area move out from this area, they become sick. Another case is people residing in malaria-endemic regions when they were infected, their symptom were not severe such as people living in Africa. The malaria is in their blood but they were asymptotic parasitaemia. Whereas People live in normal area with no malaria endemic, population’s malaria immune is low. As a result, when they were infected, they will severely sick or even sick by other incident diseases.

- Pregnant: pregnant women with malaria infections have higher incident symptom than that of general people. In stable malaria area, the first pregnant woman infecting malaria will seriously sick and her blood is full of malaria pathogen. This symptom is less serious in the woman who already has been pregnant. Malaria infection in pregnant woman normally is found at 4-5 months of pregnancy. The common incident symptom of infected pregnant woman is hypoglycemia, pneumonia, ashy. Surely, her mortality rate is higher than normal one. Moreover, fetus also gets the effects such as abort, dead, and is lower weight than normal infant. After birth’s weight is lower than that of normal infant. Number of malaria pathogen in the afterbirth is higher in that of blood.

In unstable malaria area, the probability to have incident symptom of the first pregnant woman and the woman who has been pregnant is the same. Abortion rate is high in first quarter pregnancy. Incident symptom rate is high in the last quarter pregnancy. At this stage the baby may be born premature or its weight is low. While mother has hypoglycemia symptom. Hypoglycemia symptom is found about 50% of infected pregnant woman.

- Malaria in children: Children infecting malaria in hyperendemic area and holoendemic area have high mortality rate in the first 2 years. In Africa, for example, children were died by malaria more than one million per year. In under endemic area, however, number of children sickened by malaria is not different from adult.
- Duffy negative genotype: person with duffy negative blood group (Fy^a, Fy^b) will not be infected by Vivax malaria because merozoite has no receptor therefore it can not go through red blood corpuscle. For example, African living in the southern part is not infected by Vivax malaria because they have duffy negative blood group.

- Sickle cell hemoglobin: Some of African with hemoglobin gene HbS will be relatively protected against severe disease and death caused by *Plasmodium falciparum* malaria. In laboratory test found that falciparum malaria pathogen can not be grown in hemoglobin SA or SS media. Because red blood cell was destroy by malaria due to the sequestration and cytoadherence between red blood cell and inner wall of capillary. This evidence is consistent with epidemiology evidence which found that African who have S hemoglobin will not be infected by severely malaria specially brain malaria.

- Other erythrocyte factor, epidemiology hypothesis state that the prevalence of hemoglobin-related disorders and other blood cell dyscrasias, such as heterozygote B-thalassaemia, alpha thalassaemia, and fetal haemoglobin are thought to provide protection from malarial disease. Haemoglobin E may provide protection from brain malaria. G6PD enzyme deficiency may prevent from seriously sick. Native people in Papua New Gini with hereditary ovalocytosis rarely sick from Vivax malaria and Marie malaria because faciparum malaria can not go in to hereditary ovalocytosis.

- Nutritional factor: Malnutrition African children were seriously sick by malaria more than normal children. Their symptoms such as convulsion, malaria enter their brain.

- Agent factor

  - **Vector:** Malaria is transmitted from man to man by the female anopheles mosquito. There are more than 400 species of anopheles mosquito. 67 species can be naturally sporozite. But only 30 species have been found to be the vectors of malaria in human. There are 6 species found as malaria vector. The anopheles vector can be categorized as follow.

    1) Primary vector plays very important role for malaria endemic in forest, rubber tree garden, and orchard. Examples of primary vectors are as follows.

      - *Anopheles dirus* is the most important vector for malaria endemic in Thailand. Anopheles dirus are found in pond with shadow. Anopheles mosquitoes like
to have human blood as their food. During the day time, they will stay outside the house, at shrub, hallow of tree, quiet and dark places with high humidity and near their living area. In evening, they will fly toward human house. They start biting by late evening and the peak of biting activity is 18.00-04.00 hrs. *Anopheles dirus* type D was found in Mynmar border. They bite human outside the house. The researchers suspect that anopheles associate with faciparum pathogen which is resistant to Clorovin.

- *Anopheles minimus*, this mosquito normally were found around foothill, living in rill or capillary water. They prefer to stay in the house. Biting time is 18.00-22.00 hrs. They can be the good vector of faciparum and vivax.

- *Anopheles maculatus* is the vector normally found in southern part of Thailand and Malaysia. They live in forest. Their breeding site is the rill with enough sunlight. They mostly bite animal and biting outside houses. *Anopheles maculates* bite human during 18.00-21.00 hrs.

2) Secondary vector is the anopheles mosquito which is fewer roles for malaria endemic.

- *Anopheles sundaicus* is the vector found in coastal area and island in the eastern and southern part of Thailand such as Rayong, Chantaburi, Trad. They bite human outside the house and breeding in blackish water.

- *Anopheles aconitus* is found in forest, paddy field, orchard and coconut garden, breeding in rill, capillary water. They prefer to bite animal and bite outside the house. *Anopheles aconitus* is abundance in rainy season.

- *Anopheles pseudowillmori* is in the same group as *Anopheles maculates*. It is the vector of *Plasmodium faciparum* and vivax in Mae-sod district, Tak

There are other mosquitoes that are suspect to be the malaria vector such as *Anopheles culicifacies, Anopheles philippinensis, Anopheles campestris*. The female mosquitoes bite their victim in the night and lay their egg throughout their life cycle. Total number of their egg through out their life cycle is about 1,000 eggs. They stay not more than 2 meters form the ground. The adult mosquitoes hide themselves behind cupboards, clothes, curtains and other dark and cool corners during the day and come out to bite at night. Once they bite human, their body will rise up.
Three important factors associate with malaria endemic.

1) Mosquito’s density, the area with high mosquito’s density has high probability for malaria distribution. However, the population density is also to be taking into account to calculate the ratio between mosquitoes per people.

2) Mosquito’s biting behavior: some species of mosquito has high frequency of biting such as *Anopheles gambiae* in Africa. The average bite is 0.5 time/day/person. *Anopheles culicifacies* in South Asia prefer to bite animal every 3 days. They bite human only 10%. Therefore the distribution opportunity of malaria for the first case is higher than the later.

3) Mosquito’s age: Malaria will be grown to sporozoite stage in 10 days inside mosquitoes thus mosquito will be able to be malaria vector at the 10 day age. Mosquito with longer life cycle is the better vector such as *Anopheles gambiae* and *Anopheles arabiensis*.

- **Parasite:** Malaria pathogen can be grown from single cell protozoa. For example *Plasmodium* sp. found are more than 12 species. 22 species are found in primate: human and monkey. 9 species are found in rat, bat and mammal. And more than 70 species are found in bird. However only 4 species malaria pathogen cause malaria disease in human: *P.falciparum, P.vivax, P.malariae* and *P.ovale*. Some malaria in animal may cause malaria disease in human such as *P.knowlesi, P.simium* and *P.cynobolgi*.

1) *Falciparum* malaria was abundance in Africa, South America, Asia, North Western India and Srilanka both in tropical and subtropical region. *Falciparum* rarely found in cold region because mosquito can not well grow in the temperature below 20 C. Sporozoite spend 3 weeks to be mature.

*Falciparum* malaria is the most serious malaria among 4 types. After it goes into human body, it will grow at liver and release merozoite from liver about 3-20 times of other malarias. Its incubation stage is shortest compare among others. Merozoite can go through every stage of red blood cell. Number of merozoite in schizont is higher than other malarias. Numbers of malaria pathogen grow very quick in patient’s blood. Incurrent symptom is commonly found. The sickness is serious and the patient may die. Gametocyte will be found in blood after 8-15 days of symptom.
Faciparum is now resistant to various medicines such as Chloroquine, Sulfadoxine, pyrimethamine even Quinie. It also reduces the efficiency of new medicine: Mefloquine. If person has been infected by Faciparum malaria, they will not be relapse because there is no hyponozoite in liver’s cell. If faciparum malaria is found in blood, the hypothesis is the patient has recrudescence or reinfection by mosquito after has been cured.

2) Vivax malaria is found in tropical and temperate zone. After biting, sporozoite from mosquito will go to liver and develop to be primary issue schizonts. If schizonts stay in cytoplasm of liver’s cell for a long period, it is called “hypnozoite”. Hypnozoite is the cause of relapse. The relapse period of vivax malaria is not predictable. It can be 2-3 months from the first time. In tropical or temperate zone, gametocyte can be found in the fifth days of infection. Merozoite of vivax malaria and ovalae malaria will go into first stage of red blood cell only. Therefore only 1-7 % of vivax malaria will be found in blood.

3) Ovalae malaria is usually found in Africa especially in the western part of continent. Ovalae malaria also is found in Southern part of China, Mynmar and Southeast Asia. Only 8 patients are found in Thailand. Ovalae malaria patient may relapse again because there is hypnozoite is in liver’s cell.

4) Malariae malaria is found both in temperate and boundary area especially in Eastern Africa and Western India. Malariae malaria has longest infection period. The reports indicated that longest infection period of Malariae malaria is 35 years. The clinical symptom is not severe, low pathogen in blood; 1-4 %. If the patient is not been cured, malariae will stay in blood for many years. Malariae malaria will not be relapse because there is no hypnozoite. Founding malariae malaria in blood implies that there is recrudescence. This malaria causes malaria in Chimpanzee. It is believed that Chimpanzee is the reservoir of this malaria.

Strain variation means the same malaria species but differently response to the entomology and medicine. For example, malaria in Africa grows well in anopheles mosquito living in Africa region but not grow well in Mediterranean mosquito. Faciparum malaria in different geography is differently responding to medicine in test tube and human. The mortality rate of Aotus monkey by injection of 8 different faciparum malarias is different from 24-89%. Mortality rate is different
because of the different in *faciparum* malaria species. The new detection techniques; monoclonal antibody helps to define the malaria species.

Antigenic variation means the same malaria species in different location has different antigen. Using Lymph of Western African to cure malaria patient in Eastern African is not well recover. The study found that antigen of *faciparum* malaria in different area is different. Although there is sick stage of malaria, antigen also difference.

- Environmental factor

Environmental factors, physical, biology, and socio-economic play important role for malaria. These factors including temperature, humidity, ecology and socio-economic factors and political factors are interactive. Sporogony growing rate is different at difference temperature. For example, *faciparum* malaria and *vivax* malaria can not grow below 19 °C and 16 °C respectively. *Vivax* malaria takes 55 days at 16 °C to grow to sporogony stage. But it takes only 7 days at 28 °C. However, at 33 °C these two malaria species can not grow at all. As a result, in the country where the temperatures lower than 16 °C, *vivax* malaria will not be found. *Faciparum* malaria also can not be found in the country where temperature is lower than 19 °C. Humidity also affects in Anopheles life cycle. The mortality rate of *Anopheles Gambiae* at humidity 65% is 5 % per day. If the humidity is only 55%, 50%, 35 %, the mortality rate is increase to 10%, 15% and 50% respectively.

Lek-Uthai (1997) mentioned about the change of environment affecting to malaria vector by dividing into 2 types as follows.

1) Naturally Environmental Change; the environmental factors such as

*Temperature*: mosquito is the cold-blooded animals. Therefore, the mosquito physical even its metabolism associated with temperature. If temperature low, mosquito’s metabolism also low and at the same direction if temperature high, mosquito’s metabolism also high. Optimum temperature for mosquito’s living is 25-27 °C. The mosquito’s metabolism will stop when temperature is lower than 10 °C or higher than 40 °C. Certainly, the mosquito’s mortality rate is high. Metabolism Human blood is needed to nourish mosquito’s eggs and Anopheles lays their egg every 4 days. Environmental change affects on mosquito’s life cycle especially mosquito’s laying. If environment is not suitable for mosquito’s breeding then the malaria incidence
reduces. Human, warm-blooded animal breathe in O₂ and breathe out CO₂. Mosquito smells CO₂ which will be produce by the human respiratory process.

**Humidity:** Humidity is the factor defined the mosquito’s distribution and mosquito’s age because humidity effect to mosquito’s breathing. Mosquito living in the forest is less tolerance to humidity than mosquito living in house. In summer, humidity is less resulting in shortens mosquito’s life. The number of malaria patient also reduces.

**Rainwater:** If there is rain but not heavy rain, this is suitable for mosquito’s breeding. In contrary, if there is continuously heavy rain then this is not suitable for mosquito’s breeding because water of mosquito’s breeding site is turbid. In Sri Lanka, when water in the river is dry a lot of swamp is created leading to the increasing of *Anopheles culicifacies* breeding site. This is lead to the increasing of opportunity to be infected by Malaria. Thus any factors may not effect in exact direction but that factor has to be suitable for mosquito’s spreading.

**Light:** Light has affected on look for food behavior of mosquito and spawning. Most of Anopheles mosquito hunt for blood in the night but some species hunt for its food both in the day and night. For example, *Anopheles Jisim* lives in house. But in Thailand there has no this type of mosquito, hunting for food both in the day and night. Some mosquito species start hunting their prey a half an hour after sunset and female mosquito spawns its egg. In early morning, before sunrise mosquito start looking for its shelter. Light density and humidity affect on their choosing to live inside or outside houses. Mosquito in temperate zone has longer period of day time. As a result their hibernating period is longer. When the day time is shorter than the night time, mosquito will earlier look for food, thus increasing the risk of people to be bite by mosquito and leading to the increasing of malaria patient.

**Wind:** Wind has affected on the malaria distribution. When there is light wind mosquito can fly through the wind. If mosquito smells CO₂ from human or animal then it can fly to bite its prey. If there is strong wind mosquito can be swept to other places.

**Food:** Certain food is needed for mosquito’s growth. If there is plenty of food and mosquito can eat various kind of food their distribution is definitely good lead to the increase of malaria incidence.
Natural enemy: Enemy affect on the number of mosquitoes. Mosquito’s enemies are giant mosquito larva, dragonfly larva, fishes. These enemies eat mosquito larva. Bacteria also affect on slightly reduce the number of mosquito larva.

Day and night time: The places where night time is longer than day time has high risk of malaria, because most of mosquito bites its prey during night time.

2) Changing causes by human

These are the example of environment change by human affected on changing of ecosystem.

Rochanapremsuk (1990) cited by Lek-Uthai (1999) studied the control of malaria vector by changing of environment. The study was carried in Rayong province. The case-control technique was set up in two villages. The malaria incidence in the two villages was very high even if the officials have spray in to eliminate mosquito vectors every year. The Anopheles minimus is the malaria vector in these two villages. Destroying breeding place by remove aquatic plant and other barriers along the river allow well water flow has been done. After a month, number of mosquitoes has been reduced. From the blood checked found that there is no malaria patients. However after 2 months malaria infection has been increased. The destroying of breeding place has been done again. The result shows that malaria infection has been decreased. The study concludes that environment affects on malaria incidence but not only one factor will play a role on malaria distribution.

The example of unintentionally event is cutting the forest for agriculture or for logging, cutting trees for new plantation. Cutting the tree may reduce breeding site of some mosquito species such as Anopheles dirus but increase breeding site of Anopheles maculates or other species. Activities in Gem mine also increase breeding site of Anopheles dirus. Dam construction reduces Anopheles minimus but may increase other species.

2.1.2 Malaria life cycle (Looareesuwan et al., 1990)

All malaria species have two categories of life cycle; sporogony malaria living in mosquito and schizogony malaria living in human.

2.1.2.1 Sporogony

When female anopheles mosquito bites the malaria patient, mosquito will get malaria male and female gametocyte. Gametocytes stay at its gut. Then each male
gametocyte develops to 4-8 exflagellation gametes. Each exflagellation gamete fuses with female gametes and form into a zygote. This transforms into an ookinete which penetrates the gut wall and becomes an oocyst. The ookinete is oval shape while oocyst is round shape. The oocyst divides asexually into numerous sporozoites which reach the salivary gland of the mosquito. One oocyst of faciparum malaria comprises of one thousand sporozoites. On biting a man, these sporozoites are inoculated into human blood stream. The sporogony in the mosquito takes about 8-16 days depending on malaria species and thereafter the mosquito remains infective for 1 - 2 months.

2.1.2.2 Life cycle in human (Schizogony)

The schizogony is divided into 2 stages as follows.

- In liver; this phase starts with the inoculation of the parasite into the human blood by the bite of a female anopheles mosquito. Within half an hour, the sporozoites disappear from blood because some sporozoites are killing by phagocyte. The rest sporozoites reach the liver through kupffer cell and invade the liver cells. Within the liver cells, the sporozoite develops to merozoite. Then thousands of extra erythrocytic merozoites are released from each liver cell. The time taken for the completion of the tissue phase is variable, depending on the infecting species; (8 - 25 days for P. falciparum, 8 - 27 days for P. vivax, 9 - 17 days for P. ovale, 15 - 30 days for P. malariae). In case of P. vivax and P. ovale, some sporozoites may go into cytoplasm of liver cells within 40-48 hours they become round spot in cytoplasm. They can lie dormant for months or years and on reactivation they cause clinical relapse. At this stage they are called as hypnozoites. When they develop in cytoplasm there is no inflammatory reaction then malaria infected people has no symptom. Number of merozoite in schizont depends on malaria species.

- In Red Blood Cell; this stage divided into 2 stages, asexual cycle and sexual cycle. Mature schizont in liver cells released merozoites. Almost merozoites attach into the red blood cell in liver sinusoid. Some merozoites were destroyed by phagocyte. The period starting from biting time until malaria was found in blood is called as pre-patent period. The period from biting time until patient is cold with high temperature called incubation period. Within the red blood cell, the asexual division starts and the parasites develop through the stages of rings, trophozoites, early schizonts and mature schizonts; each mature schizont consisting of thousands of
erythrocytic merozoites. When trophozoites are dyed by wright stain, their nucleus is round red shape, cytoplasm is ring blues shape. Therefore this stage is called ring form. When tropozoite is growing, cytoplasm increase like ameba, it is called amoeboid form or growing tropozoite. For its growing, it utilises amino acids from hemoglobin. The remained haemozoin is brown spot in cytoplasm of red blood cell. The brown or black spot is the indicator for quantity of malaria. The brown or black spot is called stippling. In faciparum malaria dyeing by wright stains techniques, these brown spot become triangle which is called Maurer’s clefts. In vivax and ovalae it is called Schuffner’s dot while in malariae it is called Zieman’s stippling. At the end, RBC ruptures and each schizont releases 6-36 merozoites. The merozoites will go into other RBCs and growing which cause febrile paroxysm in malaria patients.

When schizont ruptures and merozoite go to RBCs, some merozoite may grow to gametocyte. The gametocyte will not divide but getting bigger. Gametocyte of faciparum is banna shape but in some malaria species gametocyte may has round shape. In every malaria specie, female gametocyte or macrogametocyte is blue cytoplasm but nucleus is red. Male gametocyte or microgametocyte cytoplasm is light blue, nucleus is pink. Nucleus’s microgametocyte is bigger than those of macrogametocyte.

2.1.3 Biology of Anopheles mosquito (Lek-Uthai, 1999)

2.1.3.1 Life cycle

The mosquito goes through four separate and distinct stages of its life cycle: called complete metamorphosis: Egg, Larva, Pupa, and Adult.

- Egg: Eggs are laid one at a time or attached together to form "rafts." They float on the surface of the water. Female Anopheles mosquitoes need blood to nourish their eggs. Female mosquito lays its eggs within 3-4 days after mating with male mosquito. Most eggs hatch into larvae within 2-3 days.

- Larva: The larva lives in the water and comes to the surface to breathe. Larvae molt their skins four times, growing larger after each molt. After molting, larva is called instar. In the fourth molting larva is called fourth instar. The larvae feed on microorganisms and organic matter in the water. During the fourth, molt the larva changes into a pupa. This period takes 13-15 days.
- **Pupa**: The pupal stage is a resting, non-feeding stage of development, but pupae are mobile, responding to light changes and moving (tumble) with a flip of their tails towards the bottom or protective areas. This is the time the mosquito changes into an adult. When development is complete usually within 2 days, the pupa’s skin splits and the adult mosquito emerges.

- **Adult**: The head of adult get out from cephalothorax. The newly emerged adult rests on the surface of the water for a short time to allow itself dry and all its body parts becomes harden. The wings have to spread out and dry properly before it can fly. Blood feeding and mating does not occur for a couple of days after the adults emerge. In the proper environment, mosquito’s adult can stay a life until 2 months.

**2.1.3.2 Mosquito habit**

Anopheles mosquito lives in the forest area, mountain and plane area. Breeding site of Anopheles mosquito is variety such as wetlands, ponds, marshes, and swamps, with shading and enough light. They enjoy living in clear water and like it even better if it is not too deep, so that they can eventually lay their eggs there. Most mosquitoes disperse less than two kilometers; some move only a few meters away from their original breeding place, others can fly some 5 or 10 kilometers, and a few species will disperse up to 50 kilometers downwind from the larval habitats. The adult female returns to a water habitat for a brief period to lay each batch of eggs. Within their lifetime both adult male and female will feed on nectar and plant fluids, but it is only the female that will seek a blood meal. When female the mosquito bite the human, the female will probe the skin for a blood capillary then inject a small amount of saliva containing chemicals which prevent the host's blood from clotting. Then it will draw host’s blood 1.3-3.9 micro-liter per time. Female will bite its host every 2 days and the biting rate will increase when the weather is hot. Mosquito biting time is after sunset to 2 am. After engorging on the host's blood, the female will find a resting place to digest her meal and develop eggs before flying off to deposit them in a suitable aquatic habitat. There is some Anopheles mosquito bite its host outside houses or suddenly flying out from houses after biting.
2.1.3.3 Characteristic of *Anopheles* larva

Larva has a well-formed head and lack legs. A pair of spiracles is located at the end of the abdomen. Larvae use spiracles to breathe air from the water. To protect the water to go in, lipid film is produced from perispiracular glans around the spiracles. This film protects water to go in but allow lipid to go in. Therefore oil is used to kill larvae. Larvicide is mixed with insecticide such as DDT or Temephos.

Larva grows through four development stages call instars when environmental conditions are suitable. Larva will develop to pupa with 7-10 days depends on the temperature. In winter larva may stay at this stage for months. Larva molts to grow bigger. Its head rapidly grow in geometry pattern from one instar to another instar. The instar’s head growth rate is consistence with Dyar’s Principle. In *Anopheles sergenti*, the width of the instar head increase 50% of each molting. Average size of 4 instars is 170,260,395, and 600 µm. The growing is linear pattern with 1.524 times of head size in each molting. Each molting means the increasing of volume to 3.5 times. In the first 3 instars its collar will be longer except in the fourth instars. The size of head and size of collar are defined the fourth instar. The abdomen will get longer along instar stages. The mature fourth instar molts to be pupa.

2.1.3.4 Characteristic of pupae

Mosquito pupae are active when compared to other insect pupae. Pupae move in a somersault fashion through the water. Pupae breathe through tubes located on the thorax and will remain at the water surface unless they are disturbed. This non-feeding stage can be completed in as few as 2-3 days.

2.1.4 Malaria transmission (Sudatip, 1998)

1) The most naturally common transmission is when human has been bite by *Anopheles* Malaria vector.

2) Baby has been infected by Malaria from its mother through the afterbirth. This is very few cases but it will occur in the malaria abundant area. The incubation period is shorter than the first case. Certainly baby and mother will have the same malaria pathogen.

3) Blood donation is also one of causes of malaria infection. The blood donor normally has a little malaria pathogen in the blood and has no malaria symptom.
2.1.5 Malaria situation in the fiscal year 2004 (Department of Disease Control, Malaria Division, 2004)

The monitoring practices in the fiscal year 2004 was that indirect and direct searching for malaria patients, nursing malaria patients, registration, patient’s biography checking, follow up and eliminating potential breeding sites. Annual blood examination Rate or ABER was 5.11%. Slide Positive Rate or SPR was 0.99%. Annual Parasite Incidence or API (number of patients per one thousand people) was 0.51. From the fiscal year 2002-2004, most of malaria patients were infected by \textit{P. vivax}. However, malaria patients have continuously reduced. This was a good direction for the malaria control program.

2.1.5.1 Mortality rate of malaria patients

The Bureau of policy and strategy, Office of Secretary General, Ministry of Public Health reported that in the year 2004, number of people died by malaria was 230 people. This figure increased from the year 2003 to 26 people. Mortality rate was decreased by 12.74%. The mortality rate per one hundred thousand people increased from 0.32 in the year 2003 to 0.36 in the year 2004. It was estimated that by the end of the year 2005, mortality rate will higher than the expectation by 0.30 per one hundred thousand people. The Case Fatality Rate: CFR increased from 0.53% in the year 2003 to 0.75% in the year 2004. The CFR has gradually increased from the year 2003.

2.1.5.2 Malaria incidence

Malaria Infection Rate per one thousand people or (API) decreased from 0.63 to 0.51 in the fiscal year 2003 and 2004 respectively. This figure was lower than expectation for the year 2005 which was not exceeding 1.0 API. The new patient in 2004 was 30,612 people reducing from 2003 by 7,299 people or reducing by 19.25%. API has gradually decreased from the year 1990. The blood checking of new expected patients was 3,089,959 person reducing from the year 2003 by 249,113 person or 7.46%. In conclusion, Malaria incidence has been reduced because the measures to control \textit{Anopheles} mosquito vector and the immediate searching for malaria patient and cure them.
2.1.5.3 Malaria pathogen species

From the fiscal year 2000-2003, *P. falciparum* was less than *P. vivax*. During the fiscal year 2004, patients infected by *P. falciparum* were less than those of *P. vivax* by 17 people. However, when comparing in percentage patients who were sick by these two malaria pathogen was equal with 49.7%. While *P. malariae* was found only 0.11 and only 0.51% was the patients who were infected by both *P. falciparum* and *P. vivax*. The proportion of *P. falciparum* and *P. vivax* was 1:1. It was interested to note that these two malaria pathogen which had increased since 1999 were gradually decreased. But *P. vivax* was reduced less than another one. Therefore, control strategies should focus on *P. vivax*.

2.1.5.4 Malaria patient distribution

Malaria patients were mostly found in border provinces. For example in 10 provinces of the Thai-Myanmar border, 17,909 patients were found accounting for 69.6% of all patients in the country. In 6 provinces of the Thai-Cambodia border, 3,971 patients accounting for 15.4% were found. In 4 provinces of the Thai-Malaysia border, 2,516 patients accounting for 9.8% were found. In 10 provinces of the Thai-Laos border, 1,339 patients accounting for 5.2% were found. Totally 25,735 patients were found in 30 provinces of border area accounting for 84.1% of all patients in Thailand. In the year 2004 number of patients in border area was reduced by 5,896 people from the previous year. It was accounting for 18.6% of API. API of the 30 provinces in border area was 1.22 which was less than 2.8, target value of the year 2006.

Malaria patients by age and sex, the report of Epidemiology Bureau indicated that in 2003 male patients was 65% while female patients was 35%. The proportion between male and female patients was 2:1. 75% of patients were working age (more than 15 years old). 19% was children and students group (5-14 years old). Patients below 5 years old were 6%. It was implied that infection rate in the houses was higher than in 2002 whereas in general number of patients has been reduced.

Malaria patients mostly found in June and December by 5,749 people and 3,636 people respectively. This pattern was same as the last year, but the number of patients was less than the same months of last year.
2.1.5.5 Province with a lot of malaria patients

Malaria patients in Tak province were highest with 7,147 patients or 30% of all patients in Thailand. 10 provinces with a large number of patients were Tak, Kanchanuburi, Yala, Mae Hong Son, Prachuap Khiri Khan, Chantaburi, Chumphon, Chiang Mai, Trat and Ubon Ratchathani. In 10 provinces, 20,958 patients or 68.5% of all patients were reported. However, this number of patients has been reduced by 20.1% compared to the year 1993.

Table 2-1 Top ten provinces of Thailand with highest malaria cases, 2004

<table>
<thead>
<tr>
<th>Provinces</th>
<th>Number of malaria cases</th>
<th>Changing</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tak</td>
<td>7,147</td>
<td>decrease</td>
<td>-3,131</td>
<td>30.5</td>
</tr>
<tr>
<td>2. Kanchanuburi</td>
<td>2,211</td>
<td>decrease</td>
<td>-448</td>
<td>16.8</td>
</tr>
<tr>
<td>3. Yala</td>
<td>1,903</td>
<td>decrease</td>
<td>-1,148</td>
<td>37.6</td>
</tr>
<tr>
<td>4. Mae Hong Son</td>
<td>1,659</td>
<td>decrease</td>
<td>-270</td>
<td>13.9</td>
</tr>
<tr>
<td>5. Prachuap Khiri Khan</td>
<td>1,621</td>
<td>Increase</td>
<td>253</td>
<td>18.5</td>
</tr>
<tr>
<td>6. Chanthaburi</td>
<td>1,524</td>
<td>decrease</td>
<td>-1,104</td>
<td>42.0</td>
</tr>
<tr>
<td>7. Chumphon</td>
<td>1,485</td>
<td>Increase</td>
<td>428</td>
<td>40.5</td>
</tr>
<tr>
<td>8. Chiang Mai</td>
<td>1,413</td>
<td>decrease</td>
<td>-319</td>
<td>18.4</td>
</tr>
<tr>
<td>9. Trat</td>
<td>1,016</td>
<td>Increase</td>
<td>108</td>
<td>11.9</td>
</tr>
<tr>
<td>10. Ubon Ratchathani</td>
<td>979</td>
<td>Increase</td>
<td>367</td>
<td>59.9</td>
</tr>
<tr>
<td>Total</td>
<td>20,958</td>
<td>decrease</td>
<td>-5,264</td>
<td>20.1</td>
</tr>
</tbody>
</table>

2.1.5.6 Provinces without malaria

In fiscal year 2004, there were 18 provinces integrated malaria control program with provincial public health; Bangkok, Nontaburi, Pathumthani, Angtong, Ayudhaya, Singburi, Nakonpatom, Samutprakarn, Samutsakorn, Samutsonkham, Chainat, Pijit, Mahasarakam, Phuket, Pattani, Udontani, Khonkaen, and Payao. In these 18 provinces, 425 malaria patients were found. The malaria patients reduced from the year 2003 by 111 patients account for 20.7%. 
2.1.5.7 Conclusion

Malaria incidence has been gradually reduced after the malaria epidemic during the fiscal year 1997-1999. Number of Thai malaria patients has been continually reduced until now. However, the mortality rate still lower than expected value. In 2006 the expect value was 0.3 but the real value was still higher and the API was also the expected value 1.0. In current situation, the re-organization of public sector and the transformation of mandate and responsible of malaria control organization create the gap which may increase the risk of malaria incidence as it was happen in the past. Consequently, there was the need to have an effective, long-term method of malaria control in the special area, emphasize on the monitoring system in high risk area and educate people on the preventive method from malaria infection.

2.2 Geographic Information System: GIS

2.2.1 Meaning and definitions

There are many researchers provide the definition of Geographic Information System. This is some of definitions.

Sooksing (2004) mentioned that Geographic Information System is the database system responsible for data management in the form of spatial data. Each data type refers to coordinate location and digital data. This system integrates the analysis procedure of computer technology, geographic information and database system. Therefore, GIS is the database system, which refer to the coordinate location on the digital

Pattanakiat (2003) mentioned that Geographic Information System is a tool or method which has been developed to collect data, analyze data and display the real data by referring data in form of the geo-reference or coordinate system for difference purposes. The data in the same coordinate can be display as text or picture which systematic link.

GISTDA (2004) mentioned that Geographic Information System is the use of computer process which are hardware, software and geographic data to enhance efficiency of data accumulation, data improvement, calculation and data analysis to display all format of information that refer to geographic location. Moreover, this
system uses computer capacity for data accumulation and the use of spatial data to explain global surface. The system employs geographic characteristic to link with difference kind of data such as primary data and secondary data. The information obtained from GIS will be used to support any planning and decision making that related to the location.

GIS can display real characteristic area. The data will be set in layer then will be overlapped to show the real information. In addition, GIS can determine weight mathematics condition of each layer to formulate the new layer which is the spatial information. This information can explain the results of any influence factors in the studied area.

In conclusion, GIS capacities are as follows.

1) Location, Determined location of interested area which can be identified as name, post code or coordinate points.

2) Condition, Enable to find the facts according to the defined conditions such as to find the forest area in rich of nutrient soil and located 10 km from the village.

3) Find the changing of area in a certain period of time.

4) Pattern, What is the spatial pattern of the studied evident? For example, whether living nearby the nuclear is the cause of cancer patient, the study on the living pattern of people who suffer from cancer with the relation of nuclear plant location.

5) Modeling, In order to predict the situation when there is a change of interested factors and this prediction needs the spatial data and information in line with scientific concepts. For example, there are many factors, which affect land degradation. Those factors included quantity of water, soil, land slope length of area, and type of cover crop. If these factors change, GIS modeling can be used to predict the land degradation’s quantity.

2.2.2 Evolution of GIS (Burrough, 1986 cited by Pattanakiat, 2003)

During 1960s, the world's first true operational GIS have been developed. There is a new concept to use mapping for resources assessment, land assessment, and land planning. There is a need for multidisciplinary integration. At that time, there are two concepts of the multidisciplinary integration in GIS. First concept emphasizes on the map’s accuracy and picture’s quality. The second concept emphasizes on spatial analysis. From these two concepts, the GIS development has been developed in many
countries such as the United States, Canada, Europe and Australia. GIS also has been
developed by many institutes such as Harvard’s Laboratory for Computer Graphics,
New York State Land Use and Natural Resources (LUNR), Canada Geographic
Information System (CGIS). The computer technology is crucial for GIS development.

GIS has been developed by multidisciplinary integration in the complementary
direction. As a result, GIS is a tool that allows users to create interactive queries,
analyze the spatial information, edit data, maps, and present the results of all these
operations.

GIS is different from computer mapping because GIS allow the user to analyze
in interactive modeling without the experiment in the real situation. This GIS
qualification will not cause any bad effect to the real area before making decision.

A decision making process always relates to the geographical information, GIS
helps solve many problems. GIS can explain the relationship of identified factors that
is the essential information to make decision. Computer in GIS also save a lot of time
for analysis.

Currently, GIS was applying in resource and environmental management such
as finding suitable area for specific crop, planning and management for National Park,
urban planning. Furthermore, GIS can be integrated with remote sensing data which
always be updated, thus increasing the capacity of GIS for resource management.

2.2.3 Composition of GIS (Sooksing, 2004)
The essential GIS composition comprise of five components as follows.

2.2.3.1 Human resource

Officers have to have knowledge on computer and GIS. Officers have to have
enough time to work on computer and active to find the new knowledge. The human
resource in related with the task are need since GIS works in the multidisciplinary
concept.

2.2.3.2 Hardware

Computer is the most important hardware, while GPS, scanner, digitizer and
printer is complementary. But these instruments will enhance the GIS capacity.
2.2.3.3 GIS software

GIS software is capable of integrating, storing, editing, analyzing, sharing, searching, analyzing and displaying. There are many GIS software i.e. ArcView, Arc/InFo, AutoCad, MapInfo, Erdas, Idrisi, Ilwis etc.

2.2.3.4 GIS data

In Thailand, GIS data come from maps of Royal Thai Survey Department and Satellite map from Geo-Information and Space Technology Development Agency: GISTDA. The data is vector file with a scale 1:50,000. The government sector is generating the standard data of Thailand so that every sector can use the same data and to solve the redundancy of data input with difference format because data input is the high cost process. The government sectors that posse the GIS data such as Department of Land Development, Department of Environmental Quality Promotion, and Forestry Department etc.

2.2.3.5 Compute Methodology

The examples of GIS questions are why the population’s income of this district is lower than other areas, why rice’s yield of this district is higher than other areas, how to increase farmer’s income. These questions are all related with the area. So that GIS is the best methodology to answer these question because there are many data and factors to be used in the GIS analysis such as household maps, land used map, water bodies map, road map, climate map, population data, occupation information, soil data, education data, and market information.

2.2.4 GIS data characteristics (Pattanakiat, 2003)

2.2.4.1 General GIS data characteristics can be categorized into two characteristics as follows.

1) Spatial characteristics, the spatial features are as follows

   - Point features; Point is the representative of data such as village’s location. Point is the smallest unit of data. The point has no direction and there is no area.

   - Linear features; there are many kinds of linear, linear represent only a dimension that is the length. In GIS, linear can represents road, river or others.

   - Area features; this type of data will line into order with closed linear so that this type of data can be calculated the area size. The linear shape can form to
convex, concave, area with a hole. This characteristic will describe the data area such as forest area.

2) Attribute characteristics; the change of characteristic in identifies the natural evident by studied area at specific time, this could be a continuous or separate characteristic such as height contour, population number, and type of land cover. The level of data is defined into three levels.

- Nominal level; simply level which use numbers or symbol to identified
- Ordinal level; compare the difference into smaller, bigger, and equal
- Interval-Ratio level; how much the difference of ordinal level will be defined

2.2.4.2 Structure of GIS data

1) Vector structure; linear and point use to identify the geographical characteristic. Linear feature characteristic comprises of arc linear, which links among points. Arcs form the polygon. Process of vector structure is, X and Y defined the location then generalization occurs. The outputs can be shape, scale and information.

2) Raster structure; comprises of grid cells or pixels, size of grid or pixels depend on user or resolution. In each grid comprises of number which represents the data took to draw the map. Row and column define location and direction. A grid replaces a point while grids replace linear into the defined direction. Attribute is replaced by the quantity and relation scatter to the nearby grid. Raster structure is easy to keep, compute and display by computer.

2.2.5 Geographic database (GISTDA, 2004)

Database is the center of GIS, which is difference from cartography and computerized mapping. GIS links with database management system. Geographical database comprises of spatial or graphic database and attribute database.

2.2.5.1 Spatial database: point, line and area or polygon; this database is keep in X, Y for example location of meteorology station, location of water quality measurement station which keep as a single form. Examples of linear data are road and river branch. Linear data is keep as continuous form. Water borders, Forest borders and soil type borders are examples of area data. Area data is keep as many X, Y coordinates with the same start and end points. Spatial database is categorized into two categories.
1) Vector database; X, Y coordinate database is keep to represent map feature. Point, line and area in GIS software may have vector database or topological vector. Topological vector represents the relation between vectors both size and continuity. Topological vector also represents border of island in the picture or shows that the border is on the left or right of line.

2) Raster database; data is keep in table or grid both in row and column. Area comprises of tiny grids. Position is defined by position of row and column grids. Each grid area is clearly separate. Each grid has grid value or picture point value. Picture from satellite is keep as a raster structure, which comprises of many picture points or grids. Each picture point has a value, which come from the reflected energy of the world surface.

2.2.5.2 Attribute database; the database can be in number or quality, which represent relation of spatial data. There are many database management systems for GIS such as dBase and Oracle. The database management system will compute to display the characteristic of spatial data, or link the spatial data with attribute data using common key codes.

2.2.6 GIS capacity (GISTDA, 2004)
Generally, GIS capacity has been divided into three dimensions.

2.2.6.1 Data input; there are several methods for data input such as

1) Painting; painting tool will read map data and translate to number. First data will be raster database. And there is software to translate raster database to vector database.

2) Digitizing table; this instrument will transfer data to computer.

3) Number database can be directly inputted to GIS. Number database can come from satellite or GPS.

2.2.6.2 Database management means storage, retrieval, editing, updating including spatial and attribute database displays.

2.2.6.3 Data manipulation and analysis, there are different commands, functions and methodologies used for GIS computing process. GIS software system is greatly complicated. Each GIS software system has its own methodology and function to solve the complicated problem. GIS competency on analysis function can be explained as follows.
1) Storing and displaying the spatial and attribute data GIS can display picture as point line and area in both vector and raster structure and also display shape and size of objects on the global surface in term of geographical coordinate. Moreover, GIS has the data management system, which related to those pictures.

- GIS can be defined size, shape and color of pictures;
- GIS can be defined thickness, form and color of line to show the difference of things;
- GIS can be defined the geographical location of things;
- GIS can be created shape, size, color and explanation in the monitor or printing documents;
- GIS also can be created color and format of borderline.

GIS also can be measured size, area, diameter, length, and location of any things. GIS can be linked to the outside database. The GIS data management system can be stored both quality and quantitative spatial data for example the forest database may comprise of forest type, tree type, area, tree’s ages.

2) Data retrieval
This GIS function comprises of 3 sub functions, which are query, retrieval and display function. GIS must be able to read the logical data. That means searching and classification of any specific data and display spatial data. This function makes GIS more practical and better than other data management techniques.

3) Transformation and spatial data
Examples of this type of function are adjusting of scale or direction, changing of map outline, error correction of geometry, and map merging.

4) Overlay of spatial data
The overlay of spatial data is the process to obtain the new map by overlay at least two sets of data. The intersection of the data sets will create new border unit and the attribute data will integrate to explain the new emerging border unit. There is a function to delete the similar attribute data out from the system. The mathematics spatial modeling by weight of border factors or line or point also is included.
5) Buffers
Buffer means area or border that was built around points or lines or any borders to prevent the impact form any activities or the conservation zone. For example, 10 miles around the area or 100 meters from the river is the conservation area.

6) Measurement
Measurement is the system’s capacity to count the number of anything, measure the distance, area, and volume. The system also can measure the length, area and volume of each border unit and summation of each separate unit.

7) Database abstraction
This function can use the contour lines from the survey which comprise of location and height (X,Y,Z) including quantity of rain water, air pressure. The function can also use Thiessan or Vorono polygons which known as Prazimal mapping, centroid calculation and reclassification.

8) Terrain analysis; the example of this function are as follows
- Landscape planning, visibility analysis
- Digital elevation model, elevation map, aspect map, three dimensions

2.3 Geographical statistics analysis

2.3.1 Centrograms analysis
Centrograms analysis has been developed for the analysis of any evident in the area by calculation of data reduction in statistics. This technique has been developed since early 20th century in Russia (Taylor, 1997 cited by Rachawong, 1993) by measuring central tendency. Mean or evident scatter in the area is the data’s central. Until 1950, the geographical scientist is interested to apply this technique for problem solving. Especially, Warntz and Neft published the article entitled “Contributions to a Statistical Methodology for Areal Distributions” in the Regional Science Journal. After that, in 1960, they indicated that this technique is very useful for geographical scientists (Rachawong, 1993).

2.3.1.1 Central tendency of point distributions (Lee and Wong, 2001)
In classical statistics, the conventional approach to summarizing a set of values (or numerical observations) is to calculate the measure of central tendency.
The central tendency of a set of values gives some indication of the *average* value as their representative.

The *mean center*, or spatial mean, gives the average location of a set of points. Points may represent water wells, houses, power poles in a residential subdivision, or locations where landslides occurred in a region in the past. As long as a location can be defined, ever with little or no areal extent, it can be represented as a point in a spatial database. Whatever the points in a spatial database represent, each point, \( p_i \), may be defined operationally by a pair of coordinates, \((x_i, y_i)\), for its location in a two-dimensional space.

The coordinate system that defines the location of points can be quite arbitrary. Geographers have devised various map projections and their associated coordinate systems, so the locations of points in space can be referred to by their latitude/longitude, easting/northing, or other forms of coordinates. When working with known coordinate systems, the location of a point is relatively easy to define or even to measure from maps. There are, however, many situations requiring the use of coordinate systems with an arbitrary origin as the reference point. Arbitrary coordinate systems are often created for small local studies or for quick estimation project. In those cases, the coordinate system needs to be carefully structured so that (1) it orients to a proper direction for the project, (2) it situates with a proper origin, and (3) it uses suitable measurement units. For more detailed discussion of these selections, interested readers may refer to the monograph by Monmonier (1993). All these issues have to be taken into account so that the resulting mean center will approximate its most appropriate location.

With a coordinate system defined, the mean center can be found easily by calculating the mean of the \( x \) coordinates (eastings) ans the mean of the \( y \) coordinates (northings). These two mean coordinates define the location of the mean center as

\[
(x_{mc}, y_{mc}) = \left( \frac{\sum_{i=1}^{n} x_i}{n}, \frac{\sum_{i=1}^{n} y_i}{n} \right),
\]

where

\( x_{mc}, y_{mc} \) are coordinates of the mean center,
\( x_i, y_i \) are coordinates of point \( i \), and
\( n \) is the number of points.
2.3.1.2 Dispersion of point distributions (Lee and Wong, 2001)

Similar to using measures such as standard deviations to assist an analyst in understanding a distribution of numeric values, standard distances or standard ellipses have been used to describe how a set of points disperse around a mean center. These are useful tools because they can be used in very intuitive ways. The more dispersed a set of points is around a mean center, the longer the standard distance and the larger the standard ellipse it will have.

1) Standard Distance: SD

*Standard distance* is the spatial analogy of standard deviation in classical statistic. While standard deviation indicates how observations deviate from the mean, standard distance indicates how points in a distribution deviate from the mean center. Standard deviation is expressed in units of observation values, but standard distance is expressed in distance units, which are a function of the coordinate system or projection adopted.

The standard distance of a point distribution can be calculated by using the following equation:

$$SD = \sqrt{\sum_{i=1}^{n} (x_i - x_{mc})^2 + \sum_{i=1}^{n} (y_i - y_{mc})^2},$$

Where \((x_{mc}, y_{mc})\) is the mean center of the point distribution.

2) Standard Deviational Ellipse: SDE

The standard distance circle is a very effective tool to show the spatial spread of a set of point locations. Quite often, however, the set of point locations may come from a particular geographic phenomenon that has a directional bias. For instance, accidents along a section of highway will not always form a circular shape represented by a standard distance circle. Instead, they will appear as a linear pattern dictated by the shape of that section of highway. Similarly, occurrences of algae on the surface of a lake will form patterns that are limited by the shape of the lake. Under these circumstances, the standard distance circle will not be able to reveal the directional bias of the process.
A logical extension of the standard distance circle is the standard deviational ellipse. It can capture the directional bias in a point distribution. There are three components in describing a standard deviational ellipse: the angle of rotation, the deviation along the major axis (the longer one), and the deviation along the minor axis (the shorter one). If the set of points exhibits certain directional bias, then there will be a direction with the maximum spread of the points. Perpendicular to this direction is the direction with the minimum spread of the points. The two axes can be thought of as the $x$ and $y$ axes in the Cartesian coordinate system but rotated to a particular angle corresponding to the geographic orientation of the point distribution. This angle of rotation is the angle between the north and the $y$ axis rotated clockwise.

### 2.3.2 Pattern Analysis: Spatial Autocorrelation (Lee and Wong, 2001)

In detecting spatial patterns of a point distribution, both Quadrat Analysis and Nearest Neighbor Analysis treat all points in the distribution as if they are all the same. These two methods analyze only the location of points: they do not distinguish points by their attributes.

To detect spatial patterns of a point distribution by considering both the locations of the points and their attributes, spatial autocorrelation is used to measure and test how clustered/dispersed points in space with respect to their attribute values. This measure is considered to be more powerful and more useful than the two methods discussed previously in certain way. Different geographic locations rarely have identical characteristics, making it necessary to consider the characteristics of points in addition to their locations. Not only do locations matter; the conditions of these locations or activities happening there are also of great importance.

Spatial autocorrelation of a set of points is concerned with the degree to which points or things happening at these points are similar to other points or phenomena happening there. If significantly positive spatial autocorrelation exists in a point distribution, points with similar characteristics tend to be near each other. Alternatively, if spatial autocorrelation is weak or nonexistent, adjacent points in a distribution trend to have different characteristics. This concept corresponds to what was once called the *first law of geography*: everything is related to everything else, but near things are more related than distant things.
With the spatial autocorrelation coefficient, they can measure
1. The proximity of locations and
2. The similarity of the characteristics of these locations.

For proximity of locations, they calculate the distance between points. For similarity of the characteristics of these locations, they calculate the difference in the attributes of spatially adjacent points.

There are two popular indices for measuring spatial autocorrelation in a point distribution: Geary’s Ratio and Moran’s $I$. Both indices measure spatial autocorrelation for interval or ratio attribute data. The two indices yield different numeric ranges, as shown in Table 2-2.

<table>
<thead>
<tr>
<th>Spatial Patterns</th>
<th>Geary’s C</th>
<th>Moran’s I</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Clustered pattern in which adjacent points show</td>
<td>$0 &lt; C &lt; 1$</td>
<td>$I &gt; E(I)$</td>
</tr>
<tr>
<td>similar characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Random pattern in which points do not show</td>
<td>$C \sim 1$</td>
<td>$I \sim E(I)$</td>
</tr>
<tr>
<td>particular patterns of similarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Dispersed/uniform pattern in which adjacent points</td>
<td>$1 &lt; C &lt; 2$</td>
<td>$I &lt; E(I)$</td>
</tr>
<tr>
<td>show different characteristics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$E(I) = \frac{-1}{(n-1)}$, with $n$ denoting the number of malaria cases 2004 each villages.

2.4 Relevant research

Wall et al. (1985) studied point pattern analyses of accommodation in Toronto. This study draws attention to the significance of large cities as tourist destinations and to the importance of accommodation establishments as a component of the urban fabric. Using accommodation directories as the major source of information, the changing numbers and types of accommodation are described and the spatial distribution of accommodation is analyzed using three methods of point pattern analysis. An increase in the number of establishments has been replaced by a more recent decline. There has also been a decline in the relative importance of motels. The average size of establishments has increased markedly and the very large hotels, which are less constrained spatially than the smaller units, nevertheless are concentrated in the downtown area and the airport environs.
Buttraporn et al. (1986) studied on social factors, patients’ behavior and house’s characteristic with malaria infection in Eastern part of Thailand. The match case control study backward for one year was used in the study. Data collection was conducted from malaria patients who came to cure malaria in malaria clinics in Muang district, Tak province. The study found that malaria infection occurred less in people who lived in this area by 10 years. These people were well educated, high income. Malaria infection occurred more in people who worked in or near the forest and patients who have gone to forest. Most of malaria patients worked in the forest or worked in the area around 2 kilometers from the forest. The house’s location was one of the factors related with malaria. For example houses located in or near the forest, houses located near the mosquito breeding site. Most of patients had one or more following house’s characteristic; incomplete wall, unstable structure; and no bed. The analysis indicated that non patients had better socio-economic status than patients. Poorness leads the patients to work in activities that had high risk for malaria infection.

Fungladda et al. (1987) studied on socio-economic factors, environmental factors and behavior related with malaria patients who came to Phaholponpayuhasena Hospital in Kanchanaburi province. The study was conducted during August to September 1984 by hospital match case-control. The questionnaires were used to collect information from 210 patients and control cases were 210 person.

The report indicated that 90% of patients infected *P. faciparum* while only 10% infected by *P.vivax*. Male patients were 68%, the rest were female patients. Single patients was more than married patients (p=0.00). Age of patients group and control group was significantly difference (p=0.00). 15 years old patients were more than other ages (p=0.024). Control group knew about malaria infection more than another group (p=0.0123). Patients were sleep outside mosquito net. Patients who were working in the forest 14 days before they sick were more than control people (p=0.0002). Logistic regression analysis was used to analyze risk for malaria infection by controlling age, sex, district, education, and duration stay in malaria endemic area. The analysis shown that factors associated with malaria sickness are knowledge on malaria infection (OR=0.54, 95% CI = 0.37-0.79), sleeping outside mosquito net (OR=2.45, 95% CI = 1.02-5.92), working in the forest (OR=7.19, 95% CI = 4.47-
0.79), and staying in the forest 2 weeks before got sick (OR=10.25, 95% CI = 6.28-16.74). The inception for severances of malaria, chemical spray acceptance, taking malaria preventive medicine had no relation with malaria sickness.

Wongchantarapong (1990) studied malaria patients’ behavior and environment in Klaeng District, Rayong province. The study shown that patients’ behaviors associated with malaria sickness were marital status, income, and living area. While environmental factors associated with malaria sickness were house’s characteristic, locations, working place or school, household size, malaria patients in the house, behavior of patients when entering the forest, mosquito coil, using, electric fan using, sleeping in the net, house outside excretion at night, choosing the hospital when they were sick. These factors is relate with malaria infection.

Koram et al. (1995) studied on socio economic factors related with malaria sickness in suburban area of Gambia during infectious season. The study was conducted by case control study in 350 children. The results were that factors associated with malaria sickness were improper house’s characteristic, tightly house and traveling to stay in malaria endemic area. The factor was not associate with malaria sickness was educational level of their parents.

Abeysekera et al. (1996) studied the use of GIS in research and control of malaria. The incidence of malaria and the type of house were used for analysis. For the incidence of malaria, household with 2 persons or less were eliminated for statistical reasons. Another one, the type of house was classified into two according the type of house construction namely the walls and roofs; ‘good’ house and ‘poor’ house. It was shown that the malaria incidence rate of ‘poor’ house was significantly higher (2.5 times) than that of distances between individual houses and water bodies and the edge of the forest. There were no association between the incidence of malaria and the distance from house to the forest edge forest controlling for house type. There was a significant negative correlation between the incidence of malaria and the distance form a house to a water body only in the case of ‘poor’ house. A buffer zone of 200 meters around water bodies was simulated, from which, we eliminated the ‘poor’ houses and relocated them outside the buffer zone. The reduction in the incidence of malaria that this intervention would yield was estimated to be approximately 30%.
Nuachawee et al. (1997) studied an epidemiological and ecological study had been conducted to determine the correlation between various factors contributing to malaria transmission that analysis as follows: a) The relation between percent of forest and malaria incidence, b) The relation between changes in land-use with changes in malaria transmission. GIS is used as the analysis tool to map parameters contributing to malaria transmission by creating overlays of epidemiological, entomological and environmental data on land cover data from different dates. Analysis of environmental factors related to malaria transmission.

Taneewut (1997) studied the factors associated with Malaria Incidence in Tong Pha Phum District, Kanchanaburi Province by case control study. This study was collect data at 9th Tong Pha Phum malaria clinic. This clinic is covering a minimum of 100 people. A total of comparison is 100 people. The result of the research, social and economics factors that are closely related to malaria disease such as 5-14 years old group (OR =13.09, 95% CI = 1.31-37.64), low income group (OR =1.14, 95% CI = 1.89-28.53), unmarried (OR =18.17, 95% CI = 1.01-3.44), none study (OR =10.65, 95% CI = 2.87-42.01). Habitat and environment factors that are closely related to malaria disease such as house same hut (OR =3.06, 95% CI = 1.20-8), house from bamboo (OR =3.21, 95% CI = 1.16-9.06), house’s wall from bamboo (OR =4.26, 95% CI = 1.63-11.35), house’s wall that incomplete (OR =2.69, 95% CI = 1.09-6.79), water bodies far away from house (OR =4.24, 95% CI = 1.84-9.95). Protection behaviors such as sleep without net (OR =4.03, 95% CI = 1.42-11.97), without electric fan (OR = 4.00, 95% CI = 1.01-18.75), without mosquito repellent that stay in the forest (OR =2.67, 95% CI = 1.30-5.49).

Walker (1997) studied the Ethology of Anopheles Gambiae, the vector of malaria. This study will attempt to describe in detail the identification, lifestyle, lifecycle, habits, and behavior of this mosquito both male and female, although it is only the female that will attempt to draw a blood meal from Homo sapien.

Schellenberg et al (1998) studied an analysis of the geographical distribution of severe malaria in children in Kilifi District, Kenya. This study assessed the spatial pattern of hospital admission rates for severe malaria. As expected, admission rates were significantly higher in children with easier access to the hospital. For example,
those living more than 25 km from the hospital had admission rates which were about one-fifth of those for children living with in 5 km of the hospital. Those living more than 2.5 km from nearest road had admission rates that were about half of those for children living within 0.5 km of a road.

Kleinschmidt et al. (2000) studied a spatial statistical approach to malaria mapping. Good maps of malaria risk have long been recognized as an important tool for malaria control. The production of such maps relies on modeling to predict the risk for most of the map, with actual observations of malaria prevalence usually only known at a limited number of specific locations. Estimation is complicated by the fact that there is often local variation of risk that cannot be accounted for by the known covariates and because data points of measured malaria prevalence are not evenly or randomly spread across the area to be mapped. They describe, by way of an example two-stage procedure for producing maps of predicted risk: they use logistic regression modeling to determine approximate risk on a larger scale and they employ geostatistical (‘kriging’) approaches to improve prediction at a local level. Malaria prevalence in children under 10 was modelled using climate, population and topographic variables as potential predictors. After the regression analysis, spatial dependence of the model residuals was investigated. Kriging on the residuals was used to model local variation in malaria risk over and above that which is predicted by the regression model. The method is illustrated by a map showing the improvement of risk prediction brought about by the second stage. The advantages and shortcomings of this approach are discussed in the context of the need for further development of methodology and software.

Reid (2000) studied the implications of climate change on malaria in Karnataka, India. Temperature, precipitation, relative humidity, and wind are the four main climatic factors that affect malaria transmission and upon which the predictions of the effects of climate change on malaria are based. These relationships can be best understood in relation to the malaria life cycle. There are maximum, minimum and optimum temperatures for the development and survival of both the parasite and the vector of malaria, and increases in temperature tend to show increases in feeding and egg laying frequency of the vector. The amount of precipitation affects the amount of
surface water within which the malaria vectors, different member of the *Anopheles* family, can breed. Relative humidity limits vector survival, and strong winds hinder biting by Anopheles mosquitoes and also allow for the distribution of the vector further than its own short flight span. Mugisha and Arinaitwe (2003) studied Sleeping arrangements and mosquito net use among under-fives: results from the Uganda Demographic and Health Survey. The preferences at the household level seem to be different; children use mosquito nets primarily because they happen to share a bed with their parents. A child who shares a bed with the mother is 21 times more likely to use a mosquito net than his/her counterpart.

Menach *et al.* (2005) studied the unexpected importance of mosquito oviposition behaviour for malaria: non-productive larval habitats can be sources for malaria transmission. Biting and host seeking, not oviposition, have been the focus of most previous studies of mosquitoes and malaria transmission. This study presents a mathematical model that incorporates mosquito oviposition behaviour. The model demonstrates that oviposition is one potential factor explaining heterogeneous biting and vector distribution in a landscape with a heterogeneous distribution of larval habitat. Adult female mosquitoes tend to aggregate around places where they oviposit, thereby increasing the risk of malaria, regardless of the suitability of the habitat for larval development. Thus, a water body may be unsuitable for adult mosquito emergence, but simultaneously, be a source for human malaria.

Tawatsin *et al.* (2006) studied Bioactivity of phytochemicals against mosquitoes. This study evaluated and reported repellent effects of essential oils extracted from local plant species of Thailand. The essential oils were extracted from 20 plant species, belonging to 12 families, and the oils were then prepared as 10% solution in absolute ethanol and additives. Two chemical repellents, deet and IR3535, were also prepared as same formulation as the essential oil repellents and tested for repellency as standards. The essential oils were also evaluated for oviposition deterrent effects against *Ae. aegypti* and *Ae. albopictus* under laboratory conditions. The results showed that the night-biting mosquitoes (*An. dirus* and *Cx. quinquefasciatus*) and *Ae. albopictus* were more sensitive to all essential oils (repellency 4.5 -8 hours) than did
*Ae. aegypti* (repellency 0.3 - 2.8 hours), whereas deet and IR3535 provided excellent repellency against all four mosquito species (repellency 6.7 -8 hours).

Saraf *et al.* (n.d.) studied a spatial statistical technique in relating earthquake epicenters with structural features. The position of the epicenters and the associated information of the earthquakes that occurred in an area can help to establish a relationship between the geological structural features and the occurrences of earthquakes. For detecting spatial pattern in point distribution, three techniques are commonly used such as the Quadrat analysis, the nearest neighbor analysis and spatial autocorrelation coefficient. The statistical analysis of this dataset reveals a clustered pattern in which adjacent points show similar characteristics. The structural features mainly thrusts and faults occurring in the area believed to be instrumental in the occurrence of earthquakes.

Srivastava (n.d.) studied mapping malaria that factors concerning a change of environmental. This study used remote sensing technologies combined with GIS can describe local and landscape-level features influencing disease and vector distribution as follows: a) Mapping of disease vector distribution b) To develop GIS based malaria surveillance system. There are a few obvious advantages of this technique i) The technique is good for covering vast areas. It can map distribution at macro and as well as micro level. Through GIS vector distribution in inaccessible and unsurveyed areas can be map. Once the desired scale maps are ready the information can easily be updated and analyzed quickly. The technique is fast, reliable and good to study vast geographic areas to identify regions for specific distribution of vectors for planning cost-effective control strategy to interrupt malaria transmission.
CHAPTER III
MATERIALS AND METHODS

This survey research aimed to study an incidence of endemic malaria at community level with expectation to use for malaria management by the following concept. Surveillance of risk groups, reduction of risk factors, environmental factors to be malaria positive cases were studied. The research use data and information from statistical data analysis about social science and apply geographic information system for analysis and presentation of spatial data in order to obtain data and information enhanced changing behavior of risk groups to be malaria positive cases.

3.1 Study area selection

Study areas were selected by using a purposive sampling. It is follow a rule about a risk areas by Department of Disease Control, Ministry of Public Health reported in 2001 that is ten provinces of Thailand with highest malaria cases including Kanchanaburi, Chanthaburi, Sa-Kaeo, Trat, Prachuap Khiri Khan, Ratchaburi, Phetchaburi, Chon Buri, Prachin Buri, and Chachoengsao province.

The next step is selection one village from these provinces by the consideration of malaria positive cases in that area where province was a perennial transmission area including whole of entomological data and topology. Also all areas were suitable for breeding sites of vector. Ten villages were selected such as Ban Kui Yea, Lin Tin sub-district, Thong Pha Phum district, Kanchanaburi province, Ban Na Bon/Tung Krang, Tubsai sub-district, Pong Nam Rorn district, Chanthaburi province, Ban Kao Chan Dang, Klong Kai Thean sub-district, Klong Had district, Sa-Kaeo province, Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province, Ban Dan Sing Khon, Klong Waan sub-district, Muang district, Prachuap Khiri Khan province, Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province, Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province, Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province, Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin
Buri province, and Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province.

Because of this malaria outbreak research study at community level, it was necessary to use aerial photograph to help data arrangement for spatial analysis. It made some village in the study area was international border sites. It is prohibited areas so the aerial photograph could not be used. Therefore, 3 villages such as Ban Kui Yea, Lin Tin sub-district, Thong Pha Phum district, Kanchanaburi province, Ban Dan Sing Khon, Klong Waan sub-district, Muang district, Prachuap Khiri Khan province, and Ban Kao Chan Dang, Klong Kai Thean sub-district, Klong Had district, Sa Kaeo province could not be conducted. According to case study totally 7 villages were selected, Ban Na Bon/Tung Krang, Tubsai sub-district, Pong Nam Rorn district, Chanthaburi province, Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province, Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province, Ban Rai Phoom, Par Deng Neuar sub-district, Keang Kra Charn district, Phetchaburi province, Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong District, Chon Buri province, Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province, and Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province.

3.2 Target population

The target populations were composed of malaria positive cases in study area in 2004. They were divided as following:

3.2.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province (CT) total 31 cases.

3.2.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province (TR) total 11 cases.

3.2.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province (RA) total 24 cases.

3.2.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province (PE) total 9 cases.

3.2.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province (CH) total 2 cases.
3.2.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province (PJ) total 7 cases.
3.2.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province total (CS) 1 case.

3.3 Data collection

3.3.1 Data of malaria positive cases
The positive cases were obtained according to the report of Investigation and Radical Treatment of Malaria case (EP.3), Fiscal year 2004 from Disease Prevention and Control Office no.5.

3.3.2 Data of a disease protection behavior
A questionnaire concerning about disease protection behavior was used including application a mosquito repellent to exposed skins, the usage of mosquito coil to protect from mosquito bite, the usage of impregnated mosquito net, and using a fan. This questionnaire receives from Project of Spatial analysis of malaria risk to the determination of epidemiological surveillance in an endemic region of Thailand and the effectiveness of a new control strategy, 2004-2005.

3.3.3 Data of the breeding sites of vector about environment
A field survey for recording the environmental factors of vector breeding sites were composed of 8 factors such as air temperature, wind velocity, absolute humidity, sunlight around a breeding sites, water temperature, pH, dissolved oxygen (DO) and density rate of mosquito’s larva that to record by use water bodies is media and search for suitable breeding sites of vector. These environmental factors were recorded by Mini thermo-hygrometer, Mini anemometer, Mini thermo-hygrometer, Light meter, DO meter kit, pH meter kit, DO meter kit respectively. The first data collection was store in March 2004 which was low malaria transmission period. The second data collection in July 2004 and the third data collection in December 2004 were performed according to the high peak of transmission malaria.

3.3.4 Data of geographic information
- Coordinate of houses of malaria positive cases in study area was recorded by GPS. For this spatial research using the coordinate of houses of malaria positive cases
is a representative. Because of human have many activity that to remove all the time, so it is essential to use a houses where almost human live in it.

- Coordinate of water bodies was recorded by using GPS in survey for a representation of the vector breeding sites. The suitable natural water bodies included water flow slowly, shallow stream or a water bodies that human made, shading area, rather a clean water.

- Aerial photograph scale 1:25000 from Ministry of Agriculture and Cooperatives.

- Digital topographic maps scale 1:50,000 sheet 4840III, 4934IV, 5237III, 5335I, 5335III, 5435II, and 5534III from Royal Thai Survey Department.

- Maps of villages showing position of every house that no scale. It was hand made maps from Vector-Borne Disease Control Unit.

### 3.4 Data arrangement

3.4.1 Malaria patient data in each village

Malaria patient data were loaded in to computer program, Microsoft Excel and exported to DBASE IV for relating to schedule point of malaria study case.

3.4.2 Risk behavior data of malaria in each village

Risk behavior data of malaria were collected by computer Microsoft Excel program and exported to DBASE IV for relating to schedule point of malaria study case.

3.4.3 Environment data of vector breeding

The environment database of vector breeding sites were arranged by computer program Microsoft Excel and were exported by DBASE IV for relating to the schedule. And water body position of collected data at the vector breeding sites and case study sites were organized.

3.4.4 Geographic information

- Village position of malaria patients and environmental data collected water bodies were transfer data to computer by using computer program Map Source version 5.4 and converted from DXF file to shapefile by computer program Arcview GIS version 3.2a.
- Aerial photograph used to collect positive case and household position were collected geometrically by reference point from topographic maps to image in Image Geometric Correction function of ERDAS IMAGINE 8.5. Then, re-sampling Aerial Photograph is used to fix point of every village by compare with maps in each village.

3.5 Data preparation for spatial analysis

In this step, to strain a data for decrease error from statistical analysis and bring to analyze follow no.3.6. The principles for straining a data were as followings;

3.5.1 Infectious behavior from another transmission area

From a whole of case study population, malaria patient due to behavior malaria transmission from other sources such as work in forest, travel to malaria risk areas (Koram et al., 1995) were selected and cut out. So they had a balance only population group that infectious disease from only stay at house.

3.5.2 Malaria incidence found in study community

The spatial analysis use data form no.3.5.1 for study the malaria distribution patterns. In addition, a relationship study of a distance between patient houses and breeding sites of vector was considered.

3.6 General data and spatial analysis

For general analysis, package program SPSS/PC+ (Statistical Package for the social science/personal computer plus) was applied. The data analysis by computer program in geographic information system is ArcView GIS version 3.2a and ArcGIS version 8.3 by means of analysis statistic.

3.6.1 Data analysis

3.6.1.1 A frequency of data in malaria personal protection uses a percentage.

3.6.1.2 A middle of data in distance between a house of patient and water bodies and a middle of data in environment of water bodies uses a mean.

3.6.1.3 A dispersion of data in environment of water bodies uses a standard deviation.
3.6.1.4 A distribution of data in environmental factors was checked by Pearson correlation coefficient and a distribution of data in protection behaviors was checked by Chi-Square Test.

3.6.2 Spatial data analysis

3.6.2.1 Central Tendency of Point Distributions (malaria incidence) uses the mean center in order to explain an area value trend to mean center of malaria patient.

3.6.2.2 Dispersion of Point Distributions (malaria incidence) uses the Standard Distance (SD) and Standard Deviational Ellipse (SDE) in order to deviate from center for the explanation of malaria distribution.

3.6.2.3 Pattern Detectors Analysis uses the spatial autocorrelation for what the pattern is: clustered or random or regular under condition in distance between a patient houses and breeding site of vector were.
CHAPTER IV

RESULTS

This spatial analysis was aimed to explore the malaria distribution pattern to study the relations of environmental factors of vector breeding sites and to study the self-protection behaviors from malaria at community level in endemic regions. This spatial analysis could be shown into 3 articles as follows:

1) The location of malaria incidence and spatial distribution pattern of malaria incidence.
2) The relations of environmental factors of vector breeding sites.
3) The relations of self-protection behaviors from malaria.

4.1 The location of malaria incidence and spatial distribution pattern of malaria incidence

4.1.1 Mapping of all households, patient houses, breeding sites of vector and distance between patient houses and breeding sites of vector

The spatial data analysis in order to study the distribution pattern of malaria needed to collect data in term of x and y coordination. Therefore, the data were collected by 2 methods. First method was field survey to gather coordination of patient houses and vector breeding sites. This data had calculated to obtain the average distance between patient houses and vector breeding sites. Then, the distribution pattern of malaria was obtained. The second method was designed to the map and aerial photographs to obtain the satellite coordination of every household in the survey village which was used to establish the surveillance system and to prevent other households in risk area where environmental factors were suitable for malaria outbreak.
Since the study assumed that the study population was the patient in the year 2003. They were infected disease because they lived in the study area. Moreover, it was expected that they were infected disease by vector from only water bodies. To verify this assumption, the pre-interview information of patients at hospital was checked. The information showed that those patients have not infected from other areas. Furthermore, mosquito usually bites and finds their food in the evening, and normally patients were living in their houses in evening so this study used the household location as a patient location. Breeding sites selected for the environmental data collection have to include 3 important characteristics for representation the good breeding site. These characteristics are watershed, light and quite clear water.

4.1.1.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

This village comprised of 417 households with 31 patients and 6 breeding sites of vector. The village located at upper-left corner with 202362 E, 1442899 N and at lower-right corner 206151 E, 1438138 N with area of 18,110,952 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient houses and breeding sites of vector was 32.72 meters. The maximum distance between them was 4,107.28 meters. The minimum average distance between them was 1,659.42 meters. The maximum average distance was 2,506.88 meters. (Table 4-1 and figure 4-2)

**Table 4-1** Distance and average distance of vector breeding sites of CT

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Distance (meters)</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>New Breeding site 01</th>
<th>New Breeding site 02</th>
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Table 4-1 Distance and average distance of vector breeding sites of CT (continue)

<table>
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<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>New Breeding site 01</th>
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<td>768.32</td>
<td>504.15</td>
<td>1807.17</td>
</tr>
</tbody>
</table>

4.1.1.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

This village comprised of 122 households with 11 patients and 5 breeding sites of vector. The village located at upper-left area with 236134 E, 1394400 N and at lower-right 240234 E, 1391980 N with area of 9,953,600 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient houses and breeding sites of vector was 187.73 meters. The maximum distance between them was 3,891.02 meters. The minimum average distance between them was 919.74 meters. The maximum average distance was 2,844.12 meters. (Table 4-2 and figure 4-2)
Table 4-2 Distance and average distance of vector breeding sites of TR

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>New Breeding site 01</th>
<th>New Breeding site 02</th>
<th>Average</th>
</tr>
</thead>
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<td>1571.36</td>
<td>1307.12</td>
</tr>
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<td>1153.69</td>
<td>1966.35</td>
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<td>1507.10</td>
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<td>1745.36</td>
</tr>
<tr>
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<td>3126.75</td>
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<td>1675.46</td>
<td>1405.80</td>
<td>353.07</td>
<td>1303.18</td>
</tr>
</tbody>
</table>

4.1.1.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

This village comprised of 80 households with 24 patients and 3 breeding sites of vector. The village located at upper-left area with 524729 E, 1500337 N and at lower-right 525583 E, 1499597 N with area of 635,128 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient house and breeding sites of vector was 42.93 meters. The maximum distance between them was 1,020.54 meters. The minimum average distance between them was 230.77 meters. The maximum average distance was 771.19 meters. (Table 4-3 and figure 4-2)

Table 4-3 Distance and average distance of vector breeding sites of RA

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>New Breeding site 01</th>
<th>Average</th>
</tr>
</thead>
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</table>
Table 4-3 Distance and average distance of vector breeding sites of RA (continue)

<table>
<thead>
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<th>Patient houses</th>
<th>Breeding site 01 (meters)</th>
<th>Breeding site 02 (meters)</th>
<th>New Breeding site 01 (meters)</th>
<th>Average (meters)</th>
</tr>
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</tr>
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<td>817.89</td>
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</tr>
</tbody>
</table>

4.1.1.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

This village comprised of 92 households with 9 patients and 3 breeding sites of vector. The village located at upper-left area with 554576 E, 1403152 N and at lower-right 558183 E, 1400726 N with area of 8,761,185 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient house and breeding sites of vector was 251.36 meters. The maximum distance between them was 2,294.96 meters. The minimum average distance between them was 641.62 meters. The maximum average distance was 1,798.43 meters. (Table 4-4 and figure 4-2)
Table 4-4 Distance and average distance of vector breeding sites of PE

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>Breeding site 05</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE_P05</td>
<td>2294.96</td>
<td>1072.84</td>
<td>1193.02</td>
<td>1520.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE_P06</td>
<td>1743.27</td>
<td>503.66</td>
<td>681.05</td>
<td>975.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE_P07</td>
<td>1028.03</td>
<td>2270.78</td>
<td>2096.47</td>
<td>1798.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE_P08</td>
<td>366.46</td>
<td>1566.04</td>
<td>1382.99</td>
<td>1105.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE_P09</td>
<td>1556.10</td>
<td>402.68</td>
<td>734.14</td>
<td>897.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.1.1.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH

This village comprised of 106 households with 2 patients and 7 breeding sites of vector. The village located at upper-left area with 782876 E, 1461749 N and at lower-right 789046 E, 1458888 N, with area of 17,715,019 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient house and breeding sites of vector was 51.78 meters. The maximum distance between them was 2,2817.54 meters. The minimum average distance between them was 1,500.47 meters. The maximum average distance was 1,673.27 meters. (Table 4-5 and figure 4-2)

Table 4-5 Distance and average distance of vector breeding sites of CH

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>Breeding site 05</th>
<th>Breeding site 06</th>
<th>New Breeding site 01</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH_P01</td>
<td>649.16</td>
<td>460.30</td>
<td>1283.96</td>
<td>1417.74</td>
<td>2817.54</td>
<td>1714.81</td>
<td>2159.76</td>
<td>1500.47</td>
</tr>
<tr>
<td>CH_P02</td>
<td>51.78</td>
<td>1071.35</td>
<td>1909.29</td>
<td>2044.08</td>
<td>2535.96</td>
<td>2306.15</td>
<td>1794.27</td>
<td>1673.27</td>
</tr>
</tbody>
</table>
4.1.1.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ

This village comprised of 96 households with 7 patients and 5 breeding sites of vector. The village located at upper-left area with 779431 E, 1569446 N and at lower-right 780822 E, 1567758 N with area of 2,361,968 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient house and breeding sites of vector was 148.90 meters. The maximum distance between them was 1,496.41 meters. The minimum average distance between them was 542.39 meters. The maximum average distance was 690.39 meters. (Table 4-6 and figure 4-2)

Table 4-6 Distance and average distance of the vector breeding sites of PJ

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>Breeding site 05</th>
<th>New Breeding site 01</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJ_P01</td>
<td>1172.55</td>
<td>902.89</td>
<td>360.39</td>
<td>291.58</td>
<td>157.26</td>
<td>576.93</td>
</tr>
<tr>
<td>PJ_P02</td>
<td>1227.32</td>
<td>959.50</td>
<td>308.64</td>
<td>283.21</td>
<td>217.49</td>
<td>599.23</td>
</tr>
<tr>
<td>PJ_P03</td>
<td>1283.78</td>
<td>1008.98</td>
<td>410.47</td>
<td>148.90</td>
<td>267.02</td>
<td>623.83</td>
</tr>
<tr>
<td>PJ_P04</td>
<td>743.52</td>
<td>468.51</td>
<td>727.88</td>
<td>643.64</td>
<td>281.46</td>
<td>573.00</td>
</tr>
<tr>
<td>PJ_P05</td>
<td>579.14</td>
<td>306.66</td>
<td>858.93</td>
<td>808.58</td>
<td>442.07</td>
<td>599.08</td>
</tr>
<tr>
<td>PJ_P06</td>
<td>1496.41</td>
<td>1221.51</td>
<td>435.90</td>
<td>164.63</td>
<td>478.25</td>
<td>542.39</td>
</tr>
<tr>
<td>PJ_P07</td>
<td>1047.47</td>
<td>774.48</td>
<td>814.86</td>
<td>442.86</td>
<td>372.27</td>
<td>690.39</td>
</tr>
</tbody>
</table>

4.1.1.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS

This village comprised of 217 households with only one patient and 12 breeding sites of vector. The village located at upper-left area with 796765 E, 1490620 N and at lower-right 799670 E, 1485180 N with area of 15,856,598 square meters. (Table 4-8 and figure 4-1)

The minimum distance between the patient house and the water body was 791.00 meters. The maximum distance between them was 3,557.89 meters. Because, there was only one patient in this village, therefore the maximum and minimum average distance between them can not be calculated. (Table 4-7 and figure 4-2)
Table 4-7 Distance of the vector breeding sites of CS

<table>
<thead>
<tr>
<th>Patient houses</th>
<th>Breeding site 01</th>
<th>Breeding site 02</th>
<th>Breeding site 03</th>
<th>Breeding site 04</th>
<th>Breeding site 05</th>
<th>Breeding site 06</th>
<th>Breeding site 07</th>
<th>Breeding site 08</th>
<th>Breeding site 09</th>
<th>Breeding site 10</th>
<th>Breeding site 11</th>
<th>New Breeding site 01</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS_P01</td>
<td>2111.6</td>
<td>1984.82</td>
<td>1908.31</td>
<td>2533.77</td>
<td>3557.89</td>
<td>3546.98</td>
<td>2072.61</td>
<td>2076.12</td>
<td>1779.01</td>
<td>719.00</td>
<td>804.06</td>
<td>2052.34</td>
</tr>
</tbody>
</table>

Table 4-8 Number and location of all households, number of patient houses, number of vector breeding sites and area of villages

<table>
<thead>
<tr>
<th>Villages</th>
<th>Houses</th>
<th>Patient houses</th>
<th>Breeding sites</th>
<th>UTM Upper Left</th>
<th>UTM Lower Right</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>417</td>
<td>31</td>
<td>6</td>
<td>202362 E,1442899 N</td>
<td>206151 E,1438138 N</td>
<td>18,110,952</td>
</tr>
<tr>
<td>TR1</td>
<td>122</td>
<td>11</td>
<td>5</td>
<td>236134 E,1394400 N</td>
<td>240234 E,1391980 N</td>
<td>9,953,600</td>
</tr>
<tr>
<td>RA</td>
<td>80</td>
<td>24</td>
<td>3</td>
<td>524729 E,1500337 N</td>
<td>525583 E,1499597 N</td>
<td>635,128</td>
</tr>
<tr>
<td>PE</td>
<td>92</td>
<td>9</td>
<td>3</td>
<td>554576 E,1403152 N</td>
<td>558183 E,1400726 N</td>
<td>8,761,185</td>
</tr>
<tr>
<td>CH</td>
<td>106</td>
<td>2</td>
<td>7</td>
<td>782876 E,1461749 N</td>
<td>789046 E,1458888 N</td>
<td>17,715,019</td>
</tr>
<tr>
<td>PJ</td>
<td>96</td>
<td>7</td>
<td>5</td>
<td>779431 E,1569446 N</td>
<td>780822 E,1567758 N</td>
<td>2,361,968</td>
</tr>
<tr>
<td>CS</td>
<td>217</td>
<td>1</td>
<td>12</td>
<td>796765 E,1490620 N</td>
<td>799670 E,1485180 N</td>
<td>15,856,598</td>
</tr>
</tbody>
</table>

Figure 4-1 Number of all households, number of patients and number of vector breeding sites in villages
Figure 4-2 Minimum and maximum average distance: patient houses to breeding sites of vector

Figure 4-3 Location of all households, patient houses, breeding sites of vector and distance between the patient houses and breeding sites of vector
Figure 4-3 Location of all households, patient houses, breeding sites of vector and distance between the patient houses and breeding sites of vector (continue)
Figure 4-3 Location of all households, patient houses, breeding sites of vector and distance between the patient houses and breeding sites of vector (continue)
Figure 4-3 Location of all households, patient houses, breeding sites of vector and distance between the patient houses and breeding sites of vector (continue)
4.1.2 Central tendency of malaria incidence and distance between the mean center to breeding sites of vector

Mean center or spatial mean was used to calculate the central tendency of malaria incidence. These 2 values could explain the average location of malaria incidence point. Then the area of central tendency of malaria incidence was obtained.

4.1.2.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

The X and Y coordinate of mean center of 31 patient houses were calculated. The X coordinate was 203826 E and Y coordinate was 1440847 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was 929.56 meters. The maximum distance between the central tendency and breeding sites of vector was 2,372.95 meters. The average distance between them was 1,689.46 meters. (Table 4-9 and Figure 4-3)

4.1.2.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

The X and Y coordinate of mean center of 11 patient houses were calculated. The X coordinate was 238142 E and Y coordinate was 1393084 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was 851.07 meters. The maximum distance between the central tendency and breeding sites of vector was 2,021.29 meters. The average distance between them was 1,393.75 meters (Table 4-9, Figure 4-3)

4.1.2.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

The X and Y coordinate of mean center of 24 patient houses were calculated. The X coordinate was 525105 E and Y coordinate was 1499999 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was 138.03 meters. The maximum distance between the central tendency and breeding sites of vector was only 526.29 meters. The average distance was 367.39 meters (Table 4-9, Figure 4-3)
4.1.2.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

The X and Y coordinate of mean center of 9 patient houses were calculated. The X coordinate was 556722 E and Y coordinate was 1401811 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was 154.10 meters. The maximum distance between the central tendency and breeding sites of vector was 1,123.90 meters. The average distance between them was 495.97 meters (Table 4-9, Figure 4-3)

4.1.2.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH

The X and Y coordinate of mean center of 2 patient houses were calculated. The X coordinate was 785771 E and Y coordinate was 1460779 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was 336.88 meters. The maximum distance between the central tendency and breeding sites of vector was 2,662.01 meters. The average distance between them was 1579.52 meters (Table 4-9, Figure 4-3)

4.1.2.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ

The X and Y coordinate of mean center of 7 patient houses were calculated. The X coordinate was 779979 E and Y coordinate was 1568395 N as showed in table 4-9 and figure 4-3.

The minimum distance between mean center of patient houses and breeding sites of vector was only 76.83 meters. The maximum distance between the central tendency and breeding sites of vector was 1,069.71 meters. The average distance between them was 535.55 meters (Table 4-9, Figure 4-3)

4.1.2.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS

For Ban Kao Ta Lard Mai, the calculation of the central tendency of malaria incidence could not be done because there was only one patient.
Table 4-9 The mean center of patient houses and distance between the mean center of patient houses and breeding sites of vector

<table>
<thead>
<tr>
<th>Villages</th>
<th>UTM</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X coordinate</td>
<td>Y coordinate</td>
</tr>
<tr>
<td>CT</td>
<td>203826</td>
<td>1440847</td>
</tr>
<tr>
<td>TR</td>
<td>238142</td>
<td>1393084</td>
</tr>
<tr>
<td>RA</td>
<td>525105</td>
<td>1499999</td>
</tr>
<tr>
<td>PE</td>
<td>556722</td>
<td>1401811</td>
</tr>
<tr>
<td>CH</td>
<td>785771</td>
<td>1460779</td>
</tr>
<tr>
<td>PJ</td>
<td>779979</td>
<td>1568395</td>
</tr>
<tr>
<td>CS</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 4-4 Minimum, maximum, and average distance: mean center of patient houses to breeding sites of vector
Figure 4-5 Mean center of patient houses and distance between the mean center of patient houses and breeding sites of vector
Figure 4-5: Mean center of patient houses and distance between the mean center of patient houses and breeding sites of vector (continue)
Figure 4-5 Mean center of patient houses and distance between the mean center of patient houses and breeding sites of vector (continue)
4.1.3 Dispersion of malaria incidence

Standard Distance (SD) and Standard Deviation Ellipse (SDE) were used to explain the dispersion around the mean center of malaria incidence.

4.1.3.1 Standard Distance: SD

1) Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

Standard Distance of the central tendency of malaria incidence was 1,076.93 meters. There were 185 households out of 417 households located within this area. (Table 4-4)

2) Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

Standard Distance of the central tendency of malaria incidence was 1,296.48 meters. There were 98 households out of 122 households located within this area. (Table 4-4)

3) Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

Standard Distance of the central tendency of malaria incidence was 337.13 meters. There were 46 households out of 80 households located within this area. (Table 4-4)

4) Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

Standard Distance of the central tendency of malaria incidence was 1,032.68 meters. There were 69 households out of 92 households located within this area. (Table 4-4)

5) Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH

Standard Distance of the central tendency of malaria incidence was 313.94 meters. There were 8 households out of 106 households located within this area. (Table 4-4)
6) Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ

Standard Distance of the central tendency of malaria incidence was 326.01 meters. There were 33 households out of 96 households located within this area. (Table 4-4)

7) Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS

For this village, Standard Distance could not be obtained because there was no central tendency.

4.1.3.2 Standard Deviation Ellipse: SDE

1) Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

Angle of rotation of the ellipse area was 68.5 degree from north to south. There were 137 households out of 417 households located in the ellipse area. (Figure 4-5)

2) Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

Angle of rotation of the ellipse area was 73.3 degree from east to west. There were 31 households out of 122 households located in the ellipse area. (Figure 4-5)

3) Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

Angle of rotation of the ellipse area was 45.4 degree from northern east to southern west. There were 28 households out of 80 households located in the ellipse area. (Figure 4-5)

4) Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

Angle of rotation of the ellipse area was 33.0 degree from southern east to northern west. There were 45 households out of 92 households located in the ellipse area. (Figure 4-5)
5) Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH
For Ban Kao Cha Ang Bon, SDE could not be calculated because there were only 2 patients.

6) Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ
Angle of rotation of the ellipse area was 25.6 degree from north to south. There were 16 households out of 96 households located in the ellipse area. (Figure 4-5)

7) Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS
For this village, SDE could not be calculated because there was no mean center of patient houses.

<table>
<thead>
<tr>
<th>Villages</th>
<th>Houses</th>
<th>SD from Mean center (meters)</th>
<th>Number of houses in SD (houses)</th>
<th>Angle of rotation (degree)</th>
<th>Number of houses in SDE (houses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>417</td>
<td>1,076.93</td>
<td>185</td>
<td>68.5</td>
<td>137</td>
</tr>
<tr>
<td>TR</td>
<td>122</td>
<td>1,296.48</td>
<td>98</td>
<td>73.3</td>
<td>31</td>
</tr>
<tr>
<td>RA</td>
<td>80</td>
<td>337.13</td>
<td>46</td>
<td>45.4</td>
<td>28</td>
</tr>
<tr>
<td>PE</td>
<td>92</td>
<td>1,032.68</td>
<td>69</td>
<td>33.0</td>
<td>45</td>
</tr>
<tr>
<td>CH</td>
<td>106</td>
<td>313.94</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PJ</td>
<td>96</td>
<td>326.01</td>
<td>33</td>
<td>25.6</td>
<td>16</td>
</tr>
<tr>
<td>CS</td>
<td>217</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 4-6 Standard Distance and Standard Deviation Ellipse
Figure 4-6 Standard Distance and Standard Deviation Ellipse (continue)
Figure 4-6 Standard Distance and Standard Deviation Ellipse (continue)
4.1.4 Pattern detector of malaria incidence

To measure the spatial distribution pattern of malaria incidence by spatial autocorrelation, two indexes; Geary’s Ratio and Moran’s Index were analyzed. If Geary’s Ratio approached to 1, the point distribution pattern was random. If the ratio was greater than 1, the point distribution pattern was regular. If the ratio was less than 1, the point distribution pattern was clustered. If Moran’s Index approached to E(I), the point distribution pattern was random. If the index was less than E(I), the point distribution pattern was regular. If the index was greater than 1, the point distribution pattern was clustered. Where, E(I) = (-1)/(n-1) (Jay Lee, 2001:81). Spatial autocorrelation could analyze both location of points and attribution data. In this study, attribute data was the distance between patient houses and breeding sites of vector as follow:

4.1.4.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

Geary’s Ratio and Moran’s Index of CT were 0.313 and 0.080 respectively (Table 4-11). Therefore, CT had significant clustered spatial distribution of malaria incidence (p-value<0.05).

4.1.4.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

Geary’s Ratio and Moran’s Index of TR were 0.294 and 1.622 respectively (Table 4-11). As a result, TR had significant clustered spatial distribution of malaria incidence (p-value<0.05).

4.1.4.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

Geary’s Ratio and Moran’s Index of RA were 0.002357 and 0.976 respectively (Table 4-11). Then RA had significant clustered spatial distribution of malaria incidence (p-value<0.05).

4.1.4.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

Geary’s Ratio and Moran’s Index of PE were 0.297 and 0.187 respectively (Table 4-11). Therefore, PE had significant clustered spatial distribution of malaria incidence (p-value<0.05).
4.1.4.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri Province: CH

Geary’s Ratio and Moran’s Index of CH were 1 and -1 respectively (Table 4-11). Therefore, CH showed significant random spatial distribution of malaria incidence (p-value<0.05).

4.1.4.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ

Geary’s Ratio and Moran’s Index of PJ were 0.710 and -0.128 respectively (Table 4-11). Therefore, if consider Geary’s Ratio, PJ had significant clustered spatial distribution of malaria incidence (p-value<0.05). However, if consider Moran’s Index, PJ yielded significant random spatial distribution pattern of malaria incidence (p-value>0.05).

4.1.4.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS

Since there was only one patient in CS therefore the average distance between patient houses and breeding sites of vector could not be obtained. As a result, the other index also could not be calculated.

Table 4-11 Geary’s Ratio and Moran’s Index of Spatial autocorrelation

<table>
<thead>
<tr>
<th>Villages</th>
<th>Geary’s Ratio</th>
<th>Moran’s Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index Value</td>
<td>Expected Value</td>
</tr>
<tr>
<td>CT</td>
<td>0.313</td>
<td>1</td>
</tr>
<tr>
<td>TR</td>
<td>0.294</td>
<td>1</td>
</tr>
<tr>
<td>RA</td>
<td>0.002357</td>
<td>1</td>
</tr>
<tr>
<td>PE</td>
<td>0.297</td>
<td>1</td>
</tr>
<tr>
<td>CH</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PJ</td>
<td>0.710</td>
<td>1</td>
</tr>
<tr>
<td>CS</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
4.2 The correlation of environmental factors of vector breeding sites

To analyze the relation of environmental factors of vector breeding sites, this survey were collected in March, July and December of the year 2004. The environmental factors of air temperature (A-temp), wind velocity (V-wind), absolute humidity (Humid), sunlight around breeding sites of vector (LUX), water temperature (W-temp), pH, dissolved oxygen (DO), density rate of mosquito’s larva per 200 dip (D-Larva) were investigated by using the Pearson correlation coefficient. The characteristics of environmental factors of vector breeding sites were shown in Table 4-19.

4.2.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

The overall average values of environmental factors were 32.38 ºC of A-temp, 0.33 m/s of V-wind, 48.64% of Humid, 9,713 LUX, 27.54 ºC of W-temp, 7.73 of pH, 5.04 mg/L of DO and 1.81 of D-Larva.

The correlation of environmental factors of vector breeding sites was shown in Table 4-12. It could be observed that values of A-temp, V-wind, Humid, LUX, W-temp, pH and DO had low correlated with D-Larva. However, pH had correlated with D-Larva more than any factors (r = 0.497). When comparing A-temp and W-temp, it was found that the differences were statistically significant (p-value<0.01).

Table 4-12 The correlation of environmental factors of vector breeding sites at CT

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>-0.302</td>
<td>-0.230</td>
<td>0.540</td>
<td>0.817*</td>
<td>-0.170</td>
<td>0.239</td>
<td>-0.066</td>
</tr>
<tr>
<td>V-wind</td>
<td>-0.302</td>
<td>1</td>
<td>-0.065</td>
<td>-0.338</td>
<td>-0.293</td>
<td>-0.230</td>
<td>-0.201</td>
<td>-0.461</td>
</tr>
<tr>
<td>Humid</td>
<td>-0.230</td>
<td>-0.065</td>
<td>1</td>
<td>-0.090</td>
<td>-0.031</td>
<td>0.175</td>
<td>-0.368</td>
<td>0.019</td>
</tr>
<tr>
<td>LUX</td>
<td>0.540</td>
<td>-0.338</td>
<td>-0.090</td>
<td>1</td>
<td>0.345</td>
<td>-0.145</td>
<td>0.135</td>
<td>0.126</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.817*</td>
<td>-0.293</td>
<td>-0.031</td>
<td>0.345</td>
<td>1</td>
<td>0.169</td>
<td>0.329</td>
<td>0.023</td>
</tr>
<tr>
<td>pH</td>
<td>-0.170</td>
<td>-0.230</td>
<td>0.175</td>
<td>-0.145</td>
<td>0.169</td>
<td>1</td>
<td>0.220</td>
<td>0.497</td>
</tr>
<tr>
<td>DO</td>
<td>0.239</td>
<td>-0.201</td>
<td>-0.368</td>
<td>0.135</td>
<td>0.329</td>
<td>0.220</td>
<td>1</td>
<td>-0.108</td>
</tr>
<tr>
<td>D-Larva</td>
<td>-0.066</td>
<td>-0.461</td>
<td>0.019</td>
<td>0.126</td>
<td>0.023</td>
<td>0.497</td>
<td>-0.108</td>
<td>1</td>
</tr>
</tbody>
</table>

* : Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient
4.2.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

The overall average values of environmental factors were 29.07 °C of A-temp, 0.33 m/s of V-wind, 64.24% of Humid, 9,644 LUX, 26.77°C of W-temp, 7.27 of pH, 5.12 mg/L of DO and 9.42 of D-Larva.

The correlation of environmental factors of vector breeding sites was shown in Table 4-13. The values of A-temp, V-wind, Humid, LUX, W-temp, pH and DO had very low correlated with D-Larva. However, W-temp had correlated with D-Larva more than other factors (r = 0.317). It could be observed that W-temp had correlated with A-temp (p-value<0.01), and LUX (p-value<0.01) while LUX had correlated with A-temp (p-value<0.001), and Humid (p-value<0.05).

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>0.377</td>
<td>0.140</td>
<td>0.749**</td>
<td>0.870**</td>
<td>0.171</td>
<td>0.267</td>
<td>0.167</td>
</tr>
<tr>
<td>V-wind</td>
<td>0.377</td>
<td>1</td>
<td>0.097</td>
<td>0.342</td>
<td>0.301</td>
<td>-0.533</td>
<td>0.305</td>
<td>-0.197</td>
</tr>
<tr>
<td>Humid</td>
<td>0.140</td>
<td>0.097</td>
<td>1</td>
<td>0.640*</td>
<td>0.189</td>
<td>-0.508</td>
<td>0.212</td>
<td>-0.181</td>
</tr>
<tr>
<td>LUX</td>
<td>0.749**</td>
<td>0.342</td>
<td>0.640*</td>
<td>1</td>
<td>0.796**</td>
<td>0.059</td>
<td>0.366</td>
<td>-0.008</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.870**</td>
<td>0.301</td>
<td>0.189</td>
<td>0.796**</td>
<td>1</td>
<td>0.286</td>
<td>0.418</td>
<td>0.317</td>
</tr>
<tr>
<td>pH</td>
<td>0.171</td>
<td>-0.533</td>
<td>-0.508</td>
<td>0.059</td>
<td>0.286</td>
<td>1</td>
<td>0.089</td>
<td>0.281</td>
</tr>
<tr>
<td>DO</td>
<td>0.267</td>
<td>0.305</td>
<td>0.212</td>
<td>0.366</td>
<td>0.418</td>
<td>0.089</td>
<td>1</td>
<td>0.202</td>
</tr>
<tr>
<td>D-Larva</td>
<td>0.167</td>
<td>-0.197</td>
<td>-0.181</td>
<td>-0.008</td>
<td>0.317</td>
<td>0.281</td>
<td>0.202</td>
<td>1</td>
</tr>
</tbody>
</table>

*: Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient
**: Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient

4.2.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province: RA

The overall average values of environmental factors were 32.26 °C of A-temp, 0.27 m/s of V-wind, 48.84% of Humid, 14,894 LUX, 26.85°C of W-temp, 7.35 of pH, 6.44 mg/L of DO and 5.75 of D-Larva.

The correlation of environmental factors of vector breeding sites was shown in Table 4-14. The values of A-temp, V-wind, Humid, LUX, W-temp, pH and DO had low correlated with D-Larva. However, A-temp had correlated with D-Larva more than other factors (r = 0.684). When comparing V-wind and pH, it was found that the differences were statistically significant (p-value<0.05).
Table 4-14 The correlation of environmental factors of vector breeding sites at RA

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>-0.436</td>
<td>0.140</td>
<td>-0.300</td>
<td>0.330</td>
<td>-0.500</td>
<td>0.254</td>
<td>0.684</td>
</tr>
<tr>
<td>V-wind</td>
<td>-0.436</td>
<td>1</td>
<td>0.551</td>
<td>0.079</td>
<td>-0.020</td>
<td>0.710*</td>
<td>-0.243</td>
<td>-0.335</td>
</tr>
<tr>
<td>Humid</td>
<td>0.140</td>
<td>0.551</td>
<td>1</td>
<td>0.072</td>
<td>0.420</td>
<td>0.200</td>
<td>0.100</td>
<td>-0.064</td>
</tr>
<tr>
<td>LUX</td>
<td>-0.300</td>
<td>0.079</td>
<td>0.072</td>
<td>1</td>
<td>0.196</td>
<td>0.013</td>
<td>-0.239</td>
<td>-0.477</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.330</td>
<td>-0.020</td>
<td>0.420</td>
<td>0.196</td>
<td>1</td>
<td>-0.209</td>
<td>0.476</td>
<td>-0.394</td>
</tr>
<tr>
<td>pH</td>
<td>-0.500</td>
<td>0.710*</td>
<td>0.200</td>
<td>0.013</td>
<td>-0.209</td>
<td>1</td>
<td>0.175</td>
<td>-0.132</td>
</tr>
<tr>
<td>DO</td>
<td>0.254</td>
<td>-0.243</td>
<td>0.212</td>
<td>-0.239</td>
<td>0.476</td>
<td>0.175</td>
<td>1</td>
<td>0.008</td>
</tr>
<tr>
<td>D-Larva</td>
<td>0.684</td>
<td>-0.335</td>
<td>-0.064</td>
<td>-0.477</td>
<td>-0.394</td>
<td>-0.132</td>
<td>0.008</td>
<td>1</td>
</tr>
</tbody>
</table>
* : Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient

4.2.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

The overall average values of environmental factors were 32.99 °C of A-temp, 0.63 m/s of V-wind, 51.93% of Humid, 11,885 LUX, 29.36°C of W-temp, 7.80 of pH, 4.90 mg/L of DO and 38.50 of D-Larva.

The correlation of environmental factors of vector breeding sites was shown in Table 4-15. The values of V-wind and D-Larva showed the negatively high significant correlation with coefficient value of -0.712 at p-value<0.05 but other factors had low correlated with D-Larva. It could be observed that A-temp had correlated with W-temp (p-value<0.01), and pH (p-value<0.05).

Table 4-15 The correlation of environmental factors of vector breeding sites at PE

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>0.190</td>
<td>-0.088</td>
<td>-0.458</td>
<td>0.893**</td>
<td>-0.727*</td>
<td>-0.232</td>
<td>-0.413</td>
</tr>
<tr>
<td>V-wind</td>
<td>0.190</td>
<td>1</td>
<td>0.428</td>
<td>0.032</td>
<td>0.429</td>
<td>0.081</td>
<td>0.079</td>
<td>-0.712*</td>
</tr>
<tr>
<td>Humid</td>
<td>-0.088</td>
<td>0.428</td>
<td>1</td>
<td>-0.229</td>
<td>0.256</td>
<td>0.060</td>
<td>0.324</td>
<td>0.069</td>
</tr>
<tr>
<td>LUX</td>
<td>-0.458</td>
<td>0.032</td>
<td>-0.229</td>
<td>1</td>
<td>-0.506</td>
<td>0.743*</td>
<td>0.021</td>
<td>-0.385</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.893**</td>
<td>0.429</td>
<td>0.256</td>
<td>-0.506</td>
<td>1</td>
<td>-0.552</td>
<td>-0.140</td>
<td>-0.407</td>
</tr>
<tr>
<td>pH</td>
<td>-0.727*</td>
<td>0.081</td>
<td>0.060</td>
<td>0.743*</td>
<td>-0.552</td>
<td>1</td>
<td>0.366</td>
<td>0.035</td>
</tr>
<tr>
<td>DO</td>
<td>-0.232</td>
<td>0.079</td>
<td>0.324</td>
<td>0.021</td>
<td>-0.140</td>
<td>0.366</td>
<td>1</td>
<td>0.319</td>
</tr>
<tr>
<td>D-Larva</td>
<td>-0.413</td>
<td>-0.712*</td>
<td>0.069</td>
<td>-0.385</td>
<td>-0.407</td>
<td>0.035</td>
<td>0.319</td>
<td>1</td>
</tr>
</tbody>
</table>
* : Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient
**: Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient
4.2.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH

The overall average values of environmental factors were 30.83°C of A-temp, 0.34 m/s of V-wind, 55.21% of Humid, 8,477 LUX, 28.35°C of W-temp, 7.41 of pH, 4.43 mg/L of DO and 9.81 of D-Larva.

The correlation of environmental factors of vector breeding sites was shown in Table 4-16. The values of A-temp, V-wind, Humid, LUX, W-temp and pH had low correlated with D-Larva. However, DO had correlated with D-Larva (p-value<0.05). It could be observed that A-temp had correlated with W-temp (p-value<0.01) while A-temp had correlated with pH (p-value<0.05) and V-wind (p-value<0.05).

Table 4-16 The correlation of environmental factors of vector breeding sites at CH

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>-0.520*</td>
<td>0.051</td>
<td>0.034</td>
<td>0.926**</td>
<td>-0.600*</td>
<td>0.400</td>
<td>0.402</td>
</tr>
<tr>
<td>V-wind</td>
<td>-0.520*</td>
<td>1</td>
<td>-0.215</td>
<td>-0.053</td>
<td>-0.423</td>
<td>0.514</td>
<td>0.091</td>
<td>0.011</td>
</tr>
<tr>
<td>Humid</td>
<td>0.051</td>
<td>-0.215</td>
<td>1</td>
<td>-0.401</td>
<td>0.152</td>
<td>-0.585*</td>
<td>-0.629*</td>
<td>-0.356</td>
</tr>
<tr>
<td>LUX</td>
<td>0.034</td>
<td>-0.053</td>
<td>-0.401</td>
<td>1</td>
<td>0.010</td>
<td>0.153</td>
<td>-0.011</td>
<td>0.065</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.926**</td>
<td>-0.423</td>
<td>0.152</td>
<td>0.010</td>
<td>1</td>
<td>-0.591*</td>
<td>0.391</td>
<td>0.419</td>
</tr>
<tr>
<td>pH</td>
<td>-0.600*</td>
<td>0.514</td>
<td>-0.585*</td>
<td>0.153</td>
<td>-0.591*</td>
<td>1</td>
<td>0.241</td>
<td>0.135</td>
</tr>
<tr>
<td>DO</td>
<td>0.400</td>
<td>0.091</td>
<td>-0.629*</td>
<td>-0.011</td>
<td>0.391</td>
<td>0.241</td>
<td>1</td>
<td>0.693*</td>
</tr>
<tr>
<td>D-Larva</td>
<td>0.402</td>
<td>0.011</td>
<td>-0.356</td>
<td>0.065</td>
<td>0.419</td>
<td>0.135</td>
<td>0.693*</td>
<td>1</td>
</tr>
</tbody>
</table>

*: Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient
**: Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient

4.2.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachinburi province: PJ

The overall average values of environmental factors were 30.44°C of A-temp, 0.14 m/s of V-wind, 62.09% of Humid, 8,272 LUX, 28.49°C of W-temp, 7.04 of pH, 3.99 mg/L of DO and 5.43 of D-Larva.

The correlation of environmental factors of water bodies was shown in Table 4-17. The values of A-temp, V-wind, Humid, LUX, W-temp, pH and DO had very low correlated with D-Larva. However, pH had correlated with D-Larva more than other factors (p-value<0.05). It could be observed that A-temp had correlated with LUX (p-value<0.01), and W-temp (p-value<0.01). Also W-temp had correlated with LUX (p-value<0.01)
### Table 4-17 The correlation of environmental factors of vector breeding sites at PJ

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>0.310</td>
<td>-0.030</td>
<td>0.777**</td>
<td>0.747**</td>
<td>0.083</td>
<td>0.143</td>
<td>-0.256</td>
</tr>
<tr>
<td>V-wind</td>
<td>0.310</td>
<td>1</td>
<td>0.049</td>
<td>0.155</td>
<td>0.483</td>
<td>0.008</td>
<td>-0.190</td>
<td>-0.496</td>
</tr>
<tr>
<td>Humid</td>
<td>-0.030</td>
<td>0.049</td>
<td>1</td>
<td>0.051</td>
<td>0.149</td>
<td>-0.678**</td>
<td>-0.614*</td>
<td>-0.473</td>
</tr>
<tr>
<td>LUX</td>
<td>0.777**</td>
<td>0.155</td>
<td>0.051</td>
<td>1</td>
<td>0.793**</td>
<td>0.030</td>
<td>0.303</td>
<td>0.069</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.747**</td>
<td>0.483</td>
<td>0.149</td>
<td>0.793**</td>
<td>1</td>
<td>0.047</td>
<td>0.056</td>
<td>-0.216</td>
</tr>
<tr>
<td>pH</td>
<td>0.083</td>
<td>0.008</td>
<td>-0.678**</td>
<td>0.030</td>
<td>0.047</td>
<td>1</td>
<td>0.145</td>
<td>0.552*</td>
</tr>
<tr>
<td>DO</td>
<td>0.143</td>
<td>-0.190</td>
<td>-0.614*</td>
<td>0.303</td>
<td>0.056</td>
<td>0.145</td>
<td>1</td>
<td>0.430</td>
</tr>
<tr>
<td>D-Larva</td>
<td>-0.256</td>
<td>-0.496</td>
<td>-0.473</td>
<td>0.069</td>
<td>-0.216</td>
<td>0.552*</td>
<td>0.430</td>
<td>1</td>
</tr>
</tbody>
</table>

* : Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient  
**: Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient

4.2.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoensao province: CS

The overall average values of environmental factors were 34.04 °C of A-temp, 0.42 m/s of V-wind, 45.55% of Humid, 18,523 LUX, 30.35 °C of W-temp, 8.36 of pH, 3.57 mg/L of DO and 7.71 of D-Larva.

The correlation of environmental factors of water bodies was shown in Table 4-18. The values of A-temp, V-wind, Humid, LUX, W-temp, pH and DO had very low correlated with D-Larva. However, V-wind had correlated with D-Larva more than other factors (r = 0.300). It could be observed that W-temp had correlated with A-temp (p-value<0.01), and Humid (p-value<0.01) while Humid had correlated with V-wind (p-value<0.05). Also LUX had correlated with A-temp (p-value<0.05).

### Table 4-18 The correlation of environmental factors of vector breeding sites at CS

<table>
<thead>
<tr>
<th>Factors</th>
<th>A-temp</th>
<th>V-wind</th>
<th>Humid</th>
<th>LUX</th>
<th>W-temp</th>
<th>pH</th>
<th>DO</th>
<th>D-Larva</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-temp</td>
<td>1</td>
<td>0.093</td>
<td>0.038</td>
<td>0.473*</td>
<td>0.572**</td>
<td>0.233</td>
<td>-0.101</td>
<td>0.017</td>
</tr>
<tr>
<td>V-wind</td>
<td>0.093</td>
<td>1</td>
<td>-0.464*</td>
<td>0.418</td>
<td>-0.166</td>
<td>0.231</td>
<td>-0.230</td>
<td>0.300</td>
</tr>
<tr>
<td>Humid</td>
<td>0.038</td>
<td>-0.464*</td>
<td>1</td>
<td>-0.315</td>
<td>0.545**</td>
<td>0.008</td>
<td>0.000</td>
<td>-0.046</td>
</tr>
<tr>
<td>LUX</td>
<td>0.473*</td>
<td>0.418</td>
<td>-0.315</td>
<td>1</td>
<td>0.141</td>
<td>0.141</td>
<td>-0.448</td>
<td>0.010</td>
</tr>
<tr>
<td>W-temp</td>
<td>0.572**</td>
<td>-0.166</td>
<td>0.545**</td>
<td>0.411</td>
<td>1</td>
<td>0.250</td>
<td>-0.062</td>
<td>-0.006</td>
</tr>
<tr>
<td>pH</td>
<td>0.233</td>
<td>0.231</td>
<td>0.008</td>
<td>0.141</td>
<td>0.250</td>
<td>1</td>
<td>0.069</td>
<td>0.129</td>
</tr>
<tr>
<td>DO</td>
<td>-0.101</td>
<td>-0.230</td>
<td>0.000</td>
<td>-0.448</td>
<td>-0.062</td>
<td>0.069</td>
<td>1</td>
<td>0.022</td>
</tr>
<tr>
<td>D-Larva</td>
<td>0.017</td>
<td>0.300</td>
<td>-0.046</td>
<td>0.010</td>
<td>-0.006</td>
<td>0.129</td>
<td>0.022</td>
<td>1</td>
</tr>
</tbody>
</table>

* : Significant different at p-value < 0.05 (2-tailed), Pearson correlation coefficient  
**: Significant different at p-value < 0.01 (2-tailed), Pearson correlation coefficient
The environmental factors recorded by villages (Table 4-19), mean average of CS had been presented the highest than other study sites. There were higher presented of mean values of factors such; A-temp, LUX, W-temp, and pH than others which were 34.04 18,523 30.35 and 8.36 respectively. While TR found that the highest Humid condition of 64.24, but the A-temp and W-temp found lowest at 29.07 and 26.77 degree celcius, respectively. RA had been shown the highest of sunlight of 14894 LUX and V-wind was lower than of PJ where the less of 0.14 was found. Nevertheless, PE where V-wind was 0.63 and highest D-Larva detection at about 38.50 larva/200 dips, followed by CH that found 9.81 larva/200 dips. The study site at CH, presented of sunlight which was more soft of 8477 LUX than other sites, while CT showed Humid equal to 48.64 and this area was presented the lower density of mosquito’s larva that was equal to 1.81 larva/200 dips.

Table 4-19 Mean and Standard deviation of environmental factors of vector breeding sites

<table>
<thead>
<tr>
<th>Villages</th>
<th>A-temp (°c)</th>
<th>V-wind (m/s)</th>
<th>Humid (%)</th>
<th>LUX</th>
<th>W-temp (°c)</th>
<th>pH</th>
<th>DO (mg/L)</th>
<th>D-Larva (larva/200 dips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>32.28 ± 3.43</td>
<td>0.33 ± 0.19</td>
<td>48.64 ± 5.46</td>
<td>9,713</td>
<td>27.54 ± 4.14</td>
<td>7.73 ± 0.38</td>
<td>5.04 ± 1.92</td>
<td>1.81 ± 3.21</td>
</tr>
<tr>
<td>TR</td>
<td>29.07 ± 3.79</td>
<td>0.33 ± 0.43</td>
<td>64.24 ± 9.52</td>
<td>9,644</td>
<td>26.77 ± 3.08</td>
<td>7.27 ± 0.35</td>
<td>5.12 ± 2.03</td>
<td>9.42 ± 20.90</td>
</tr>
<tr>
<td>RA</td>
<td>32.36 ± 3.33</td>
<td>0.27 ± 0.13</td>
<td>48.84 ± 20.06</td>
<td>14,894</td>
<td>26.85 ± 2.52</td>
<td>7.35 ± 0.38</td>
<td>6.44 ± 0.89</td>
<td>5.75 ± 7.94</td>
</tr>
<tr>
<td>PE</td>
<td>32.99 ± 3.58</td>
<td>0.63 ± 0.53</td>
<td>51.93 ± 13.98</td>
<td>11,885</td>
<td>29.36 ± 3.17</td>
<td>7.80 ± 0.28</td>
<td>4.90 ± 1.90</td>
<td>38.50 ± 35.64</td>
</tr>
<tr>
<td>CH</td>
<td>30.83 ± 2.41</td>
<td>0.34 ± 0.33</td>
<td>55.21 ± 13.37</td>
<td>8,477</td>
<td>28.35 ± 3.08</td>
<td>7.41 ± 0.23</td>
<td>4.43 ± 1.13</td>
<td>9.81 ± 25.46</td>
</tr>
<tr>
<td>PJ</td>
<td>30.44 ± 2.59</td>
<td>0.14 ± 12.32</td>
<td>62.09 ± 0.09707</td>
<td>8,272</td>
<td>28.49 ± 2.13</td>
<td>7.04 ± 0.55</td>
<td>3.99 ± 1.63</td>
<td>5.43 ± 8.31</td>
</tr>
<tr>
<td>CS</td>
<td>34.04 ± 2.49</td>
<td>0.42 ± 11.31</td>
<td>45.55 ± 10,504.87</td>
<td>18,523</td>
<td>30.35 ± 3.02</td>
<td>8.36 ± 0.72</td>
<td>3.57 ± 1.84</td>
<td>7.71 ± 14.92</td>
</tr>
</tbody>
</table>
4.3 The relationship of malaria protection behaviors

The relationship of malaria protection behaviors indicated that there were other factors affecting malaria not only the distance factor and the environmental factors. The main 4 malaria protection behaviors were application of mosquito repellent to exposed skin, usage of mosquito coil to protect from mosquito bites, usage of impregnated mosquito net, and using an electric fan. The following was the study results.

4.3.1 Ban Na Bon/Tung Krang, Tub Sai sub-district, Pong Nam Rorn district, Chanthaburi province: CT

The study population about malaria protection behaviors had 77 persons. There had 47 persons using an electric fan (63.5%) and 39 persons used a mosquito coil (52.7%). The others application of mosquito repellent on their skin and used impregnated mosquito net accounted for 13.57% and 10.8% respectively. There were 30 patients or 40.5% from 74 cases. Most of the patients (90%) used an electric fan. The persons who were not sick by malaria usage an electric fan 45.5% and used a mosquito coil account for 59.1%. While patient’s group used a mosquito coil about 43.3%. The application of mosquito repellent for patients and non-patients was not much different accounted for 13.3% and 13.6% accordingly. It was noticed that there were no patients who used impregnated mosquito net.

The test for independent of variable between malaria protection behaviors and malaria infection indicated that usage of mosquito repellent and mosquito coil to protect from mosquito bites were not related to the cause of malaria infection. But usage of impregnated mosquito net and usage an electric fan were related to malaria infection, it was found that the differences were statistically significant at p-value < 0.05; ($\chi^2 = 0.016, 14.418, df = 1$) as showed in Table 4-20.

4.3.2 Ban Mern Darn, Bor Ploy sub-district, Bor Rai district, Trat province: TR

The study population about malaria protection behaviors had 31 persons. Almost all of these persons used impregnated mosquito net had 26 persons or 83.9%. Only 9 persons used an electric fan or accounted for 29%. Usage of mosquito repellent and usage of mosquito coil to protect from mosquito bites accounted for 19.4% and 16.1% respectively. There were 15 patients or 48.4% from total. 73.3% of the study population used impregnated mosquito net.
The test for independent of variable between malaria protection behaviors and malaria infection indicated that usage of mosquito repellent and mosquito coil to protect from mosquito bites were related to the cause of malaria infection, it was found that the different were statistically significant at p-value < 0.05; ($\chi^2 = 6.975, 5.589$, df = 1). Usage of impregnated mosquito net and used an electric fan were not related to the cause of malaria infection. (Table 4-20).

4.3.3 Ban Pha Pok Kao, Suan-Puang sub-district, Suan-Puang district, Ratchaburi province; RA

The study population about malaria protection behaviors had 48 persons. Most of study populations used impregnated mosquito net had 44 persons or 93.6%. There were 14 persons who used mosquito coil that accounted for 29.8%. Only 4 persons or 8.5% used an electric fan and nobody used mosquito repellent. Among the population, 48.9% were patients (23 patients). The malaria prevention behaviors of patients were similar to the non-patients group, 91.3% of patients used mosquito net whereas this behavior accounted for 95.8% for non-patients group. The usage of mosquito coil of patient group and non-patient group were 39.1% and 20.8% respectively. The usage of an electric fan for this 2 groups accounted for 8.7% and 8.3% respectively.

The independent test between cause factors and the usage of mosquito repellent could not be tested because of nobody used this method. However, the statistical analysis indicated that the other behaviors also not associated with malaria infection (Table 4-20).

4.3.4 Ban Rai Phum, Par Deng Neuar sub-district, Kang Kra Charn district, Phetchaburi province: PE

The survey result of PE was quite different from the others. Because, all 18 cases had the same prevention behaviors accounted for 100% which were usage of mosquito repellent, usage of mosquito coil and usage of impregnated mosquito net. But nobody used an electric fan as prevention behaviors. The survey result showed that there were the same number of patients and non-patients for PE. As a result of this survey, there was no data variation so the independent test could not be analyzed.
4.3.5 Ban Kao Cha Ang Bon, Ploung Thong sub-district, Bor Thong district, Chon Buri province: CH

In CH, there were 38 persons whom were considered as the survey population. Almost all of these persons used impregnated mosquito net (35 persons, 92.1%). Only 12 persons used an electric fan accounted for 31.6%. Usage of mosquito repellent and usage of mosquito coil to protect from mosquito bites accounted for 10.5% and 2.6% respectively. There were 2 patients in CH. Both of them used only impregnated mosquito net. For non-patients, they used an electric fan, mosquito coil and mosquito repellent accounted for 33.3%, 11.1% and 2.8% respectively.

The independent test showed that usage of mosquito repellent, mosquito coil and an electric fan were not related with the cause of malaria infection (Table 4-20).

4.3.6 Ban Tra Kor Neuar, Bu Fai sub-district, Pra Chan Ta Karm district, Prachin Buri province: PJ

There were 27 persons whom were considered as the survey population. All of them used impregnated mosquito net. 17 persons used an electric fan (63%). Usage of mosquito repellent and usage of mosquito coil accounted for 29.6% and 14.8% respectively. Among the population, there were 7 patients or 25.9% of the population. All of the patients used impregnated mosquito net as same as non-patients. The usage of an electric fan of patients and non-patients were 57.1% and 65% respectively. It was notice that patients group using mosquito coil accounted for 42.9% whereas non-patients group using mosquito coil accounted for 25%. However, the usage of mosquito repellent of both groups was not much different (14.3% and 15% respectively).

The test for independent between factors and malaria prevention behavior indicated that usage of mosquito repellent, mosquito coil and an electric fan were not related to the cause of malaria infection. Since nobody of the population used the impregnated mosquito net so the independent test of this behavior could not be obtained (Table 4-20).
4.3.7 Ban Kao Ta Lard Mai, Tha Ta Keab sub-district, Tha Ta Keab district, Chachoengsao province: CS

The survey population for the malaria prevention behavior of CS was 36 persons. 21 persons used impregnated mosquito net (60%). There were 19 persons using an electric fan (54.3%). Only 4 persons used mosquito coil (11.4%). Nobody used mosquito repellent. There was only one patient of the population (2.9% of 35 persons). All of patients used mosquito net while non-patients used impregnated mosquito net 61.8%. The usage of an electric fan and mosquito coil to protect mosquito bites of non-patients were 52.9% and 11.8% respectively. But no one in patients group had these behaviors.

The independent test between factors and malaria prevention behavior showed that usage of mosquito coil, impregnated mosquito net and an electric fan were not related with the cause of malaria infection. Since nobody of the population used the mosquito repellent so the independent test of this behavior could not be obtained (Table 4-20).

Table 4-20 The results of independent test of malaria protection behaviors

<table>
<thead>
<tr>
<th>Villages</th>
<th>Mosquito repellent</th>
<th>Behaviors</th>
<th>Mosquito Coil</th>
<th>Impregnated mosquito net</th>
<th>Electric fan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\chi^2$</td>
<td>p-value</td>
<td>$\chi^2$</td>
<td>p-value</td>
<td>$\chi^2$</td>
</tr>
<tr>
<td></td>
<td>(2-sided)</td>
<td></td>
<td>(2-sided)</td>
<td>(2-sided)</td>
<td>(2-sided)</td>
</tr>
<tr>
<td>CT</td>
<td>&lt;0.001</td>
<td>0.986</td>
<td>1.576</td>
<td>0.209</td>
<td>6.016</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.014*</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td>14.816</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>TR</td>
<td>6.975</td>
<td>0.008*</td>
<td>5.589</td>
<td>0.018*</td>
<td>2.386</td>
</tr>
<tr>
<td></td>
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<td>0.122</td>
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<td>0.079</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.779</td>
</tr>
<tr>
<td>RA</td>
<td>-</td>
<td>-</td>
<td>1.613</td>
<td>0.204</td>
<td>1.091</td>
</tr>
<tr>
<td></td>
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<td>0.296</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>PE</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>CH</td>
<td>0.057</td>
<td>0.811</td>
<td>0.248</td>
<td>0.618</td>
<td>0.181</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.671</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.324</td>
</tr>
<tr>
<td>PJ</td>
<td>0.002</td>
<td>0.963</td>
<td>0.793</td>
<td>0.373</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.711</td>
</tr>
<tr>
<td>CS</td>
<td>-</td>
<td>-</td>
<td>0.129</td>
<td>0.720</td>
<td>1.440</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.230</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.337</td>
</tr>
</tbody>
</table>

* : Significant different at p-value < 0.05 (2-tailed)
- : No case or all cases were detected for above behavior
CHAPTER V
DISCUSSIONS

From the study resulted in chapter IV, the spatial analysis to indicate the malaria pattern, the relationship of environmental factors of vector breeding sites and the relationship of prevention behavior within the epidemic community were shown as following.

5.1 Characteristic locations of malaria incidence and spatial pattern of malaria incidence

GIS was a tool able to analyze and display spatial data. GIS could also possess high efficiency in managing the variety size of objects. As a result, GIS was applied for many research (Lee and Wong, 2001 and Saraf et al., n.d.). Thus GIS was applied in this public health and environmental study.

5.1.1 Coordination of all households, patient houses, breeding sites of vector and distance between patient houses to breeding sites of vector

From figure 4-2 in chapter IV, it showed that there were difference in spatial patterns of household’s locations and patient households. Breeding sites of vector aspect had also different spatial patterns because of difference in geographical locations and demand of water storage. Mosquito life cycle need water bodies as a breeding site, so the researcher emphasized on water bodies survey and data collection. The distance between patient household and breeding sites of vector was a cause of patient whom sick by malaria. The patients suspected to be sick from other areas were excluded from this study.

Based on the results in 4.1.1, in seven villages, the maximum average distance from patient houses to breeding sites was three kilometers. This result was consistent with the study of Lek-Uthai (1999), which stated that malaria mosquito vector lives within 2-3 kilometers from its breeding site. Abeysekera et al. (1996) used GIS to
analyze and control malaria. There were two factors; malaria incidence and type of house which “rich” houses had brick walls and tiled roofs and “poor” houses had mud walls and cadjan roofs in the study. It was indicated that distance from a “poor” houses to a water body significantly relationship to malaria incidence. By moving people who lived in “poor” houses to the place 200 meters far from the buffer zone, it can be decreased malaria incidence by 30%. Buttraporn et al. (1986) studied the relationship between social factors, behaviors and household characteristics with malaria incident in eastern part of Thailand. The results indicated that most of patients work in a forest or two kilometers from a forest. Menach et al. (2005) studied on the unexpected behavior of carrier mosquitoes’ laying. The results showed un-proper management of water bodies could be an origin of malaria infection. Adult mosquitoes may highly dispersion between villages and can fly up to five kilometers far but mostly they could fly within 1 kilometer from the village. Walker (1997) studied the behaviors of Anopheles gambiae. He found that the mosquitoes lived and died nearby their breeding water bodies as same as the other mosquitoes species. Male mosquitoes could fly around the breeding water bodies and near the flower considered as their feeding sites. And male mosquitoes may not ever fly beyond a kilometer.

5.1.2 Mean center of patient houses and distance between mean center of patient houses to breeding sites of vector

Figure 4-3 (chapter IV), showed that mean center of malaria incidence of the villages located a part of middle the villages. It was known that the household located near the mean center had higher risk of malaria infection than those located far from the mean center.

The calculation results, which obtained the distance between, mean center and water bodies in 4.1.1 showed that all surveyed village had average distance from mean center and water bodies, not exceed two kilometers. The result was in line with studies mentioned in 5.1.1.
5.1.3 Measuring the dispersion of malaria incidence’s location

Standard Distance (SD) and Standard Deviational Ellipse (SDE) were used to measure the dispersion of malaria incidence’s location. Standard Distance Circle was the efficient tool which able to shown the spatial pattern of point locations by calculating point’s average distance. If point locations occur by particular geographic phenomenon, directional bias will also be created. However, Standard Distance Circle could not be shown the directional bias (Lee and Wong, 2001). For this study, a patient house was a representative of patients that was considered as particular geographic phenomenon. As a result, directional bias occurred. Therefore, SDE was more efficient than Standard Distance Circle for measuring the dispersion of malaria incidence’s location.

In figure 4-4 (chapter IV), the spatial pattern of malaria in the year 2003 was displayed. Certainly, Standard Distance Circle of each village was different. SD value of TR, RA, CT, PE and PJ were 1,296.48, 1076.93, 1032.68, 337.13, 326.01 meters respectively. SD of CH and CS could not be known due to the fact that there were two patients in CH and there was only one patient in CS. Area of CT was biggest whereas area of RA was smallest (Table 4-8). Thus, the size of area was not the factor which determined the dispersion of malaria. When comparing the SD and SDE of each village from Table 4-10 and figure 4-4, it was found that the center of malaria located in the same position. It was noted that number of households in Standard Distance Circle was more than number of households in SDE. The explanation of this fact was that the dispersion of malaria incidence was the particular geographical phenomena, which create directional bias. SDE was efficient tool to measure the dispersion of malaria incidence’s location because it was able to capture directional bias. Thus, the SDE showed the dispersion of malaria incidence in the same direction of household’s location. It was consistent with the study of Saraf et al. (n.d.) on the relationship of earthquake epicenters and geographical characteristics using spatial statistic. This study also referred to Lee and Wong (2001)’s methodology- calculating SD and SDE of earthquake epicenters data set.
Consequently, SDE can be use as an efficient tool to monitor the malaria incidence because this tool can capture directional bias as already mentioned. Households locate in the ellipse area have higher risk to infect malaria than households locate outside ellipse area. In conclusion, the risk area was clearly determined. This technique also reduced the cost of field survey.

5.1.4 Spatial pattern of malaria incidence

From table 4-12 (chapter IV), it showed that five out of seven villages were CT, TR, RA, PE, and PJ. These five villages had clustered spatial pattern of malaria incidence, which means that most of households located far from the breeding sites at the same distance. It was noted that only TR had significant clustered spatial pattern (p-value< 0.05). As mention earlier, since number of patients in CH and CS were two patients and one patient respectively, thus the spatial pattern of the villages could not be obtained.

Investigating the spatial pattern of malaria incidence was similar to the study of Saraf (n.d.) using spatial statistic technique to find the relationship of earthquake epicenters and geographical structure. The study found that it was the clustered earthquake epicenter. Points in the same area also had the same geographical structure. Geographical structure-thrusts and faults created earthquake at the studied area. Wall, Dudycha and Hutchinson (1985) using point’s pattern analysis for resident planning in Toronto. They discovered that number of building was increased because hotels were built to replace motels. It indicated that buildings were significantly increased whereas area units were the same. Most of buildings located in the business area and airport.

In addition, the study found that the water bodies far from patient house 2-3 kilometers was one of factors increasing risk of malaria infection. From this knowledge, the prevention of malaria infection could be manage through the improvement of household characteristics such as plugging holes of the house, put a mosquito net at the door and window. The result was in line with the study of Thaneewut (1997) on factors related with malaria incidence in Tong Pa Phum district, Kanchanaburi province. She stated that resident factor and environmental factor such as a cottage (OR = 3.06, 95% CI= 1.20-8), bamboo house (OR = 3.21, 95% CI= 1.16-9.06), house with bamboo wall (OR = 4.26, 95% CI= 1.63-11.35), house with less than 4 size wall (OR = 2.69, 95% CI= 1.09-6.79) and house nearby water bodies (OR =
3.06, 95% CI= 1.20-8). Moving the house nearby the water bodies to the safe area also reduced the malaria incidence. The study by Abeysekera et al. (1996) using GIS to find out measures to prevent malaria incidence of rich house (brick walls and tiled roofs) and poor house (mud walls and cadjan roofs). The study indicated that the distance from poor house significantly related with malaria incidence. Moving poor house to the area which far beyond buffer zone 200 meters, reduced malaria incidence by 30%.

5.2 The relationship of environmental factors of vector breeding sites

From the analysis by GIS, the results indicated that spatial pattern of malaria relate with distance from patient house and breeding sites of vector. This result was consistent with finding of Menach et al. (2005) on the mosquito breeding behavior. They stated that water bodies, which were not suitable for breeding, can also the origin of malaria.

According to table 4-19, average values of environmental factors of all seven villages were as follows. Air temperature was 32-34.04 °C. Wind velocity was 0.14-0.42 m/s. Absolute humidity was 45.55-64.24%. Sunlight around breeding sites of vector was 8,272-18,523 LUX. Water temperature was 26.77-30.35 °C. pH was 7.04-8.36. Dissolved oxygen (DO) was 1.81 and density rate of mosquito’s larva was 38.50 unit/200 dips. PE’s environmental factors and that of CH significantly related with quantity of mosquito’s larva (p-value<0.05). In PE, wind velocity had negative relation with larva density, which meant that the more velocity was the less larva density was. It was due to the fact that, wind disturbs mosquito’s breeding. In CH, quantity of DO has positive relation with larva density. The water bodies that high DO was the clean water body, which was suitable for breeding. In PJ, pH increase, it could be found increase of density rate of mosquito’s larva. These result were consistent with finding of Reid (2000) on the relationship between the climate’s change and malaria incidence. The study stated that temperature, rainfall, humidity and wind velocity associated with malaria infection. Temperature, 25-27 °C was suitable for mosquito vector. Temperature at 40 °C harmed mosquito and infection. Rainfall associated with malaria infection because rainfall also had effected on humidity and temperature resulting in breeding of mosquito vector. Humidity had no relation with...
infection but humidity had relation with mosquito vector. It was believed that humidity less than 60% will shorten mosquito’s life cycle whereas, wind velocity had both negative and positive impacts to malaria incidence. Strong wind velocity reduced mosquito’s biting and mosquito’s breeding. But strong wind velocity also supported mosquito’s flying to longer distance. This will change mosquito’s spatial pattern. The study of Walker (1997) on the behavior of *Anopheles gambiae* stated that clean water body with enough light was the suitable breeding site for the mosquito. Temperature around the water body at 38.1 °C harmed mosquitoes.

Since, the suitable breeding site was the clean water body with enough sunlight, the malaria control measures could be formulated from this result. The recommended malaria prevention and control measures were putting fish in water bodies to eat mosquito’s larva and changing physical characteristics of water bodies to protect mosquito breeding.

### 5.3 The correlation of malaria prevention behaviors

The malaria prevention behaviors of people are needed to investigate in order to formulate intervention to increase the awareness of people living in high-risk area. Malaria prevention behaviors in the study were applying mosquito repellent, mosquito coil, impregnated mosquito net and an electric fan. The mentioned behaviors were easy for people to apply in order to prevent themselves from malaria infection. If people were aware and prevent themselves although they lived in high-risk area, the malaria infection will not occur. Contradictory, if people ignored to prevent themselves, malaria infection will increase. In line with Report of a WTO Study Group: Malaria Vector Control and Personal Protection (2006) mentioned that protection measures to directly control adult mosquito using impregnated mosquito net was preferable and effective than measured to control mosquito’s larva by identification of vector breeding sites and ecology of mosquito vector.

Table 4-20 indicated that all four malaria prevention behaviors in each village differently associated with malaria infection. In TR, using mosquito coil of malaria patient had significantly associated with malaria infection (p-value<0.05) and especially, applying mosquito repellent of malaria patient had significantly associated with malaria infection (p-value = 0.008). The result was consistent with Report of a
WTO Study Group: Malaria Vector Control and Personal Protection (2006) stated that mosquito repellent was widely used by tourist in developed and developing countries to protect from mosquito biting. It was widely used because it was comfortable. Tawatsin et al. (2006) studied on bioactivity of phytochemicals to prevent mosquito vector’s biting. They found that extraction from 3 kind of plants- *Psidium guajava*, *Curcuma longa* and *Boesenbergia rotunda* can prevent 100% of mosquito biting during 9 hours in the night. In CT, using impregnated mosquito net had significantly associated with malaria infection (p-value<0.05) and especially, using an electric fan of malaria patient had significantly associated with malaria infection (p-value<0.001).

In line with the article of National Institutes of Health, U.S. Department of Health and Human Services (2007) studied on the relation of understanding malaria and free of outbreak disease. They stated that mosquito net impregnated with pyrenthroid was able to prevent mosquito biting. It affected on the decrease of malaria and certainly it was consistent with finding of Fungladda et al. (1987) on the relationship of socio-economic factor, environmental factor and behavior with malaria infection of malaria patients who treated malaria at Pahonponpayahasena hospital, Kanchanaburi province. They found that patient sleeping outside mosquito net more than control group (p=0.0003) and not sleeping inside the mosquito net was related with malaria infection (OR=2.45, 95% CI = 1.02-5.92). Mugisha and Arinaitwe (2003) studied on sleeping management and using mosquito net of less than 5 years old children in Uganda. They found that children had used mosquito net because they had slept with their parent. Children slept in mosquito net more than a couple 21 times. In conclusion, these behaviors associated with malaria infection. It was consistent with findings of Wongchantarapong (1990) on behavior and environmental factors of malaria patients in Krang district, Rayong province. She stated that behavior when entering forest, using mosquito coil, using an electric fan, sleeping in mosquito net, the evacuation outside houses during the night, choosing hospital when they were sick, had associated with malaria sickness. Taneewut (1997) studied factors related with malaria sickness in Tong Pha Phum district, Kanchanaburi province. The investigation on self behavior prevention yielded that; sleeping outside mosquito net (OR= 4.03, 95% CI = 1.42-11.97) not using an electric fan (OR= 4.00, 95% CI = 1.01-18.75) not using mosquito repellent when entering forest (OR= 2.67, 95% CI = 1.30-5.49).
Based on the results, self-behavior prevention from malaria associated with malaria infection. Therefore, the researcher recommends the prevention strategy and how to reduce risk of malaria infection as follows. Households in SDE should perform the prevention behavior to avoid mosquito biting such as impregnated mosquito net, mosquito repellent or public health officials should provide the knowledge on how to prevent for malaria infection in community.
CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The analysis of spatial data for the study of spatial pattern of malaria by determining coordinate of all household, patient house, and water bodies that were a breeding site of mosquito vector were surveyed seven villages under the main headings of i) distance between patient house and breeding sites of vector. Mosquito life cycle needed to breeding in water bodies. When mosquito hatch from egg until become adult mosquito they will live and feed in breeding sites. Only the females feed on blood, which is what is occurring when they are biting. Females evidently gain little nourishment from blood meals but need them in order to develop eggs. For this reason, female mosquito is capable of flying within 2-3 kilometers from breeding water bodies. The study found that maximum average distance between patient house and breeding sites of vector was 3 kilometers. ii) Measuring central tendency of point distribution of malaria incidence using mean center in order to explain an area value trend to mean center of malaria patient. Households located nearby mean center of malaria incidence have higher risk to malaria infection than those located far away. The study also found that mean center of malaria incidence of CT and CH was more than 200 meters. Mean centers of malaria incidence of TR, RA, PE and PJ were near the center of villages which were not far beyond 200 meters. This implies that malaria dispersion over these four villages. The maximum average distance from mean center of six villages to breeding sites of vector were not exceed 2,000 meters or 2 kilometers except CS which has only one patient so the mean center could not be obtained. iii) Study the dispersion of malaria incidence point by SD and SDE because Standard Distance Circle is an efficient tool to display spatial pattern of point locations by calculating average distance of any points. The study proved that area size could not
determined malaria dispersion. The study employed patient household as a representative of patients, which was considered as particular geographic phenomenon. This geographic phenomenon creates directional bias. Thus, SDE is efficient in measuring the dispersion of malaria incidence’s location because SDE can capture directional bias of malaria incidence. SDE shows the dispersion of malaria incidence in the same direction of household’s location. Number of households located in Standard Distance Circle is more than those in SDE. SDE can be determined as risk area of malaria. Households in SDE had higher risk to infect malaria than those located outside SDE.

iv) Investigation of spatial pattern of malaria incidence by spatial autocorrelation using Geary’s Ratio and Moran’s Index. This methodology can measure both locations of points and attributes. The results indicated that five villages had clustered spatial pattern of malaria incidence, which means that households in the same location were far by same distance from breeding site. It also stated that most of households far from breeding 2-3 kilometers. This was the factors influence the malaria infection of patients. It was noted that only TR has significant clustered spatial pattern at p-value<0.05. Since number of patients in CH and CS were two and one respectively, thus the spatial pattern of these villages could not be obtained.

Studying on the correlation of environment factors of vector breeding sites, field surveys were conducted 3 times in March, July and December 2003 in order to investigate what are the environmental factors which make water bodies suitable for mosquito breeding sites. Thus, the malaria control measures can be designed to make water bodies unsuitable for mosquito breeding sites. The eight environmental factors were air temperature (A-temp), wind velocity (V-wind), Absolute humidity (Humid), sunlight around breeding sites of vector (LUX), water temperature (W-temp), pH and density rate of mosquito’s larva (larva/200 dips). The overall results indicated that the environmental factors of vector breeding sites in PE, and CH had significantly associated with density rate of mosquito’s larva (p-value<0.05). In PE, the study found that the more velocity was the less density rate of mosquito’s larva, was. This is due to the fact that wind disturbs mosquito’s breeding. In CH, quantity of DO had positive relation with larva density. The reason supported this result was depend on the breeding sites of vector containing high of DO. Therefore, the vector breeding sites is clean, which is suitable for mosquito’s breeding.
The malaria prevention behaviors of people are also important to investigate because it is cost effectiveness. The four malaria prevention behaviors studied were applying mosquito repellent, mosquito coil, impregnated mosquito net and an electric fan. If people are aware and prevent themselves although they live in high-risk area, the malaria infection will not occur. Contradictory, if people ignore to prevent themselves, malaria infection will increase. The study results indicated that applying mosquito repellent and using mosquito coil in TR had significantly associated with malaria incidence (p-value<0.05). Using impregnated mosquito net and an electric fan of CT to prevent mosquito’s biting had significantly associated with malaria infection (p-value <0.05).

6.2 Recommendations

6.2.1 Recommendations from the study
- Using GIS technique in the study found that SDE can be use as an efficient tool to determined malaria control area. Households locate in the ellipse have higher risk to infect malaria than households locate outside ellipse. In conclusion, the risk area should be clearly determined and thus reduce the cost of field survey.

- The study found that studied villages have clustered malaria incidence spatial pattern and the breeding sites of vector far from patient houses 2-3 kilometers is one of the factors increasing risk of malaria infection. Therefore, the prevention of malaria infection could be able to manage through the improvement of household characteristics such as plugging holes of the house, put a mosquito net at the door and window. Moving the house nearby the water bodies to the safe area also reduce the malaria incidence. But in practice, this prevention measure is quite difficult and costly. The high-level policy decision should consider by comparing to other prevention measures.

- The breeding sites of vector are the origin of mosquito. Thus the survey on density population of mosquito’s larva in water bodies should be done continuously. Moreover, releasing mosquito’s larva eating fish in the breeding sites of vector or adding environmentally friendly substance that destroy eggs or mosquito’s larva in the breeding sites of vector.
- The activities or work plan to promote awareness of people living in risk area to prevent themselves from malaria should be formulated.

6.2.2 Recommendations for further study

- At community level, the coordination of all household should be recorded to ensure the accuracy of data. The map is created can be use in long term.

- The survey of both permanent and temporary water bodies in the village should be investigated and the further study should be developed for searching an originate of water source that will be useful for proper strategic planning to stop the suitable for mosquito breeding sites such as check dam, that will increase the water stream, which it is not appropriated to be the vector breeding place.

- The mapping sources will be useful for being further applications to the study of risk zoning buffer.

- The survey on self-prevention behavior from malaria covering the village should be done.

- The environmental factors data collection was presented the different of characteristics and malaria situation according to the presence of the related factors of those malaria infected cases. During the seasonal change, the characteristics of mosquito breeding places will be also changed. As the results of this study was trend to be shown the different values of both environmental characteristics by regional of endemic areas. So the cross-sectional survey method had shown the relationships of malaria cases and the distance between the mosquito breeding place and patient household. The time series of cross-sectional surveys should be more observed.
REFERENCES


# BIOGRAPHY

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