GEO-DATABASE USE TO PROMOTE DENGUE INFECTION PREVENTION AND CONTROL

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Abstract. Dengue infection (DI) is a major health problem in Thailand and is especially prevalent in Ubon Ratchathani Province. The objectives of the project were: 1) to develop a geo-database system for DI prevention and control, 2) to perform an *Aedes aegypti* larval vector survey for DI prevention and control in Ubon Ratchathani Province, 3) to study the behavior and perceptions regarding DI prevention among the target population in Ubon Ratchathani Province. Ten villages with high incidences of DI over a 3 year period from 2005 to 2007 were selected. The survey was divided into 2 periods, pre-outbreak period (February-April 2008) and outbreak period (June-August 2008). The data were collected in April and June 2008. The households in each village were purposively sampled. Water containers inside and outside of the houses were surveyed using the World Health Organization's house index (HI), container index (CI), and Breteau index (BI). The location of each household was recorded using the global positioning system (GPS). Data regarding people's perceptions and behaviors concerning DI prevention were collected during interviews of 383 families in Mach 2008. A database for DI was developed using ArcView® version 9.2. The results showed during the pre-outbreak period, Non Jig, Non Sawang, and Huai Teeneu villages had the highest risk level (BI ≥ 50). During the outbreak period, Non Jig and Huai Teeneu village had the highest risk level (BI ≥ 50). Results regarding DI perceptions showed the target population had high levels of DI perceptions. DI preventive behavior was found in 50.9%.

Key words: Geo-database, dengue infection, larval vector survey, prevention, control

INTRODUCTION

Dengue Infection (DI) is an acute febrile disease found usually in tropical regions, spreads by mosquitoes, similar to malaria (Teng, 1997). It is caused by one of four virus serotypes of the genus *Flavivirus*. Epidemics can occur due to multiple serotypes of this virus (hyperendimicity). Persons with DI may have high fever, hemorrhagic phenomena, a low number of platelets in the blood and an increase in the concentration of red blood cells (Fakeeh and Zaki, 2001). DHF is a serious public health problem in Thailand and many other tropical countries around the

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world. No treatment or vaccine is currently available. Control of the vector responsible for transmission is the only method to control DI (Thavara, 2004).

The main vector for the disease among humans is the "Tiger" mosquito, *Aedes aegypti*, and sometimes *Aedes albopictus*. Female mosquitoes lay eggs in containers, such as jars, cans, and used tires, and are responsible for biting humans. Their flight range is less than a kilometer, contributing to the limited local spread of the disease. Vector control strategies are mainly based on mosquito population control by eliminating potential breeding sites (Gubler, 1989). Normally, DI control can be predicted by using dengue vector indices, such as house index (HI), container index (CI), and Breteau index (BI) (Singhasivanon, 2003). Dengue virus transmission depends upon various environmental factors, one being the relationship between temperature and atmospheric humidity that strongly influences vector survival duration and the efficiency of virus transmission (Kuno, 1993; Hlang *et al*, 1998). Additionally, distances between houses also have epidemiological significance, especially in densely-packed housing areas. Patterns of housing have a significant influence on a dengue outbreak, since the interconnection of houses may lead to more efficient transmission of the virus and increased exposure to infection (Alpana and Andrianasolo, 2001).

Remote sensing and Geographic Information System (GIS) technologies have previously been used in public health to help health authorities with surveillance and mitigation strategies. The use of remotely sensed data (satellite images and aerial photographs) in epidemiological studies has become more frequent during the last decade. They provides information about the environment. Remote sensing offers a huge potential for the study of diseases related to environmental conditions (Cline, 1970; Curran *et al*, 2000; Hay and Tatem, 2005). The application of remote sensing to health studies has seen an increase in monitoring, surveillance and risk mapping, particularly for vector-borne diseases. Most studies use remote sensing data to explore the environmental factors that might be associated with disease-vector habitats and human transmission risk.

Using remote sensing imagery, information regarding sea and land is more easily identified at different spatial scales. Advancements in remote sensing technology currently offers high resolution satellite imagery. SPOT 5 (2.5 m), IKONOS (1m) and Quick Bird (0.6 m) satellite data are able to provide detailed ground data. GIS technologies are able to integrate, analyze and display spatial and temporal data from various sources in one central location. Advanced GIS analysis and modeling techniques currently allow researchers to predict risk areas for dengue outbreaks.

GIS technologies have the capability to integrate many types of data and to analyze spatial and temporal data to produce new models. From the public health perspective, GIS is essentially used to determine the health situation of an area, generating and analyzing diseases hypotheses, identify high risk disease affected areas, prioritize areas for mitigation and surveillance programs, monitor the incidence and visualize and analysis or map that information in a more interactive manner for better understanding. Through the use of GIS technology, the Ministry of Public Health, Thailand has the capability to create efficient programs for dengue prevention and surveillance programs. Recent

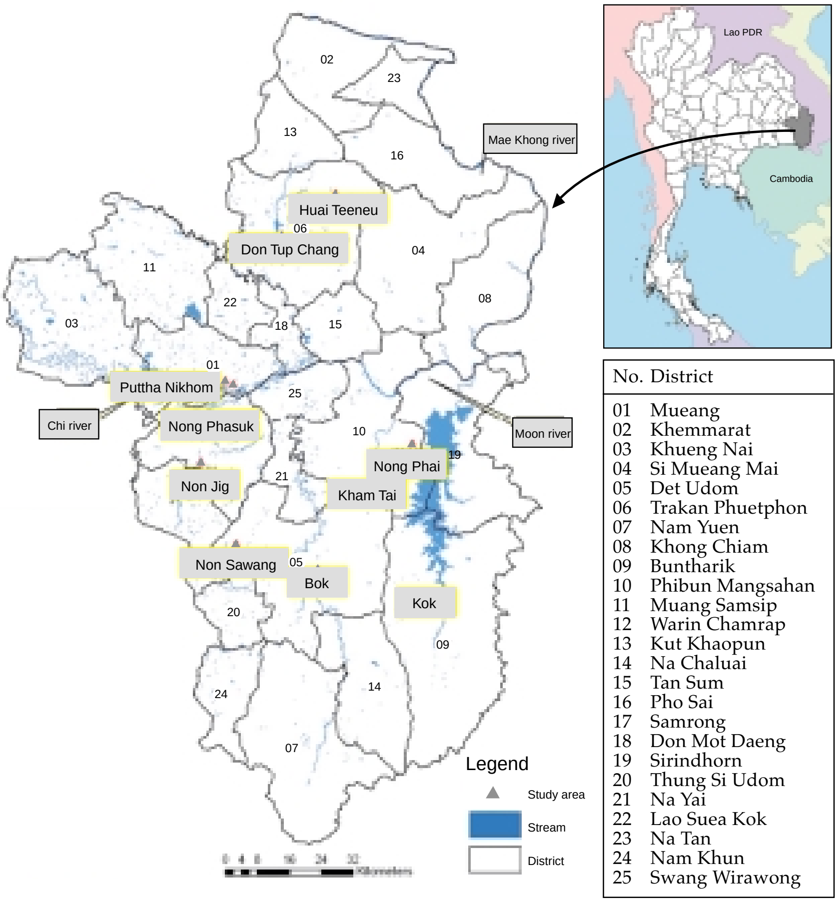


Fig 1–Study areas.

studies have demonstrated the use of GIS satellite imagery, digitized land-use maps and global positioning data promises improvements in predicting changes in habitats of mosquito vectors as they affect disease transmission (Hayes *et al*, 1985; Pope *et al*, 1992; Linthicum *et al*, 1987, 1994; Chaikoolvatana *et al*, 2008; Wongbutdee *et al*, 2009).

The researchers surveyed the larvae of DI vectors and applied the GIS to analyze the risk for DI in specific areas by predicting breeding areas, making decisions regarding support systems, and managing DI surveillance and control via a geo-database system.

MATERIAL AND METHODS

Study areas

The study areas were ten villages in Ubon Ratchathani Province in northeastern Thailand. This province is 625 km from Bangkok, has an area of 15,410 km^2, a population of approximately 1,600,000 people, and shares borders with Cambodia and Lao PDR. The province has a number of major rivers, including the Moon, Chi and Mae Khong. The city of Ubon Ratchathani is known to have one of the country's highest incidences of DHF, cases being reported at rates of 37.27 cases per 100,000 population in 2006 and 50.83 cases

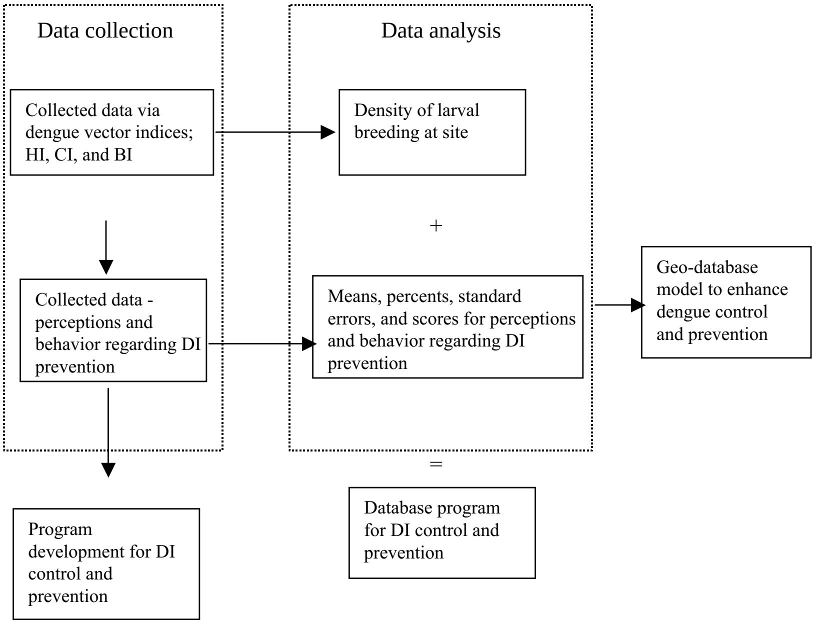


Fig 2–Framework for data collection.

per 100,000 population in 2007 (Department of Public Health, 2006, 2007). The ten selected villages had high incidences of DI during the 3 year period of 2005 to 2007. The villages were Puttha Nikhom, Nong Pasuk, Kok, Non Jig, Kham Tai, Nong Pai, Huai Teeneu, Don Tup Chang, Bok and Non Sawang (Fig 1).

Data collection (Fig 2)

Larval vector surveys. The ten villages contained 1,700 households and the study areas were purposively surveyed. The data was collected from February to August 2008. All survey data were collected following the World Health Organization (WHO) standard guideline, the Visual Larval Survey (Goh, 1993), to indicate the density of mosquitoes. The survey tools used were three dengue vector indices for mosquito density levels: house index (HI), container index (CI), Breteau index (BI). All indoor, outdoor natural and outdoor artificial water containers at each household were inspected to determine the presence of *Aedes aegypti* mosquitoes.

Data surveys were divided into two periods, a pre-outbreak period (February to April 2007 during the dry season) and an outbreak period (June to August 2007 during the rainy season). The precise location of each individual household in each village was geographically mapped via a "Global Positioning System" (GPS).

DI perceptions and DI preventive behavior

Three hundred eighty-three volunteers from 10 villages were purposively sampled for the study (Daniel, 1987).

Data collection was carried out from February to August 2008. A larval vector survey was conducted by inspection of each household and a family member of each household was interviewed and completed a questionnaire. This structured questionnaire was composed of three sections: 1) general information consisting of

9 items; 2) perceptions regarding DI consisting of 15 items; and DI preventive behavior consisting of 15 items.

The responses to the section about perceptions regarding DI scored either one (1) or zero (0) for each questionnaire item. If a participant agreed with the questionnaire item, the response received one (1) point. If the participant disagreed, a zero (0) was awarded. The maximum score possible for the perceptions regarding DI was 15 points. This was classified as follows: a score between 11 and 15 was considered a high level of perception, a score between 6 and 10 was considered an average level of perception and a score of 0 and 5 was considered a low level of perception.

Participants were requested to rate each questionnaire item under DI preventive behaviors from "always" to "never" (5 - 1) with 5 = always, 4 = often, 3 = sometimes, 2 = a few times, and 1 = never. The maximum score possible was 75 points. The results were classified as follows: 51 to 75 was very good behavior, 26 - 50 was good behavior and 0 - 25 was fair preventive behavior.

The reliability test of questionnaire items was evaluated. An average reliability was analyzed via the Cronbach alpha coefficient ($\alpha = 0.64$). Changes were made based on comments from dengue surveillance and control staff, tropical medicine and public health department staff, and public health staff prior to further study.

Statistical analysis

All results were analyzed statistically. HI was defined as the percentage of houses positive for larvae. CI was defined as the percentage of water-filled containers positive for larvae. BI was defined as the number of positive containers per 100 houses (Luemoh *et al*, 2003; Thavara, 2004). The risk of DI transmission in each area was categorized into different levels: a BI value ≥ 50 was defined as high risk for DI transmission, a BI value between 6 and 49 was defined as a moderate risk for DI transmission and a BI value ≤ 5 was defined as a low risk for DI transmission.

DI perceptions and DI preventive behavior were analyzed via descriptive statistics including percentages, means (χ), and standard deviation (SD). The relationship between DI perceptions and DI preventive behavior was analyzed via Pearson's product-moment correlation Coefficient.

Geo-database

The GIS database for DI prevention and control was developed by connecting data from the GPS (remote sensing) larval survey and the perceptions about DI and DI preventive behavior. The graphical relationship between spatial and attributed data was created using primary data (for example, field, address) in each table and using the ArcView 9.2® program. This program has graphically functional tools to search, add, save, edit, and represent data. The conceptual model shows process by which the geo-database model enhances DI control and prevention (Fig 3).

RESULTS

Total population in each village

The population data was updated via a retrospective survey carried out between 2005 and 2007 (Table 1)

Population density and mortality rate

The population density maps for crowded conditions were analyzed for each district in Ubon Ratchathani Province. The densities were classified by different shades (Fig 4).

Larval vector surveys

The results show during the pre-out-

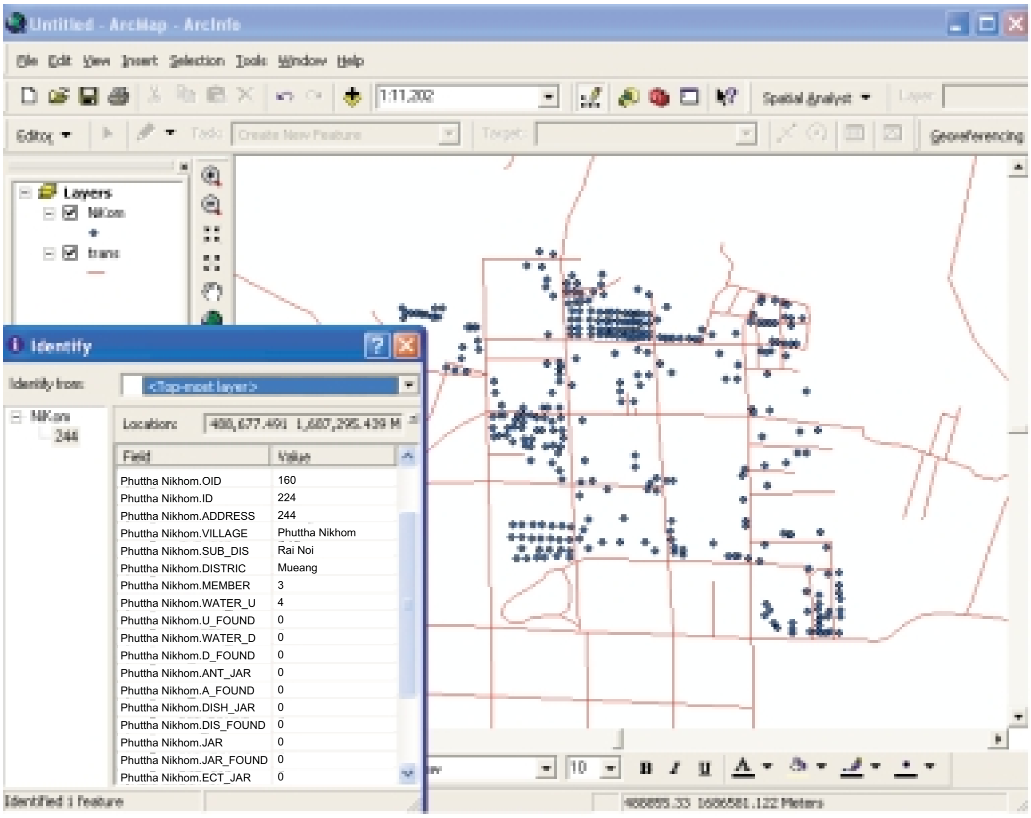
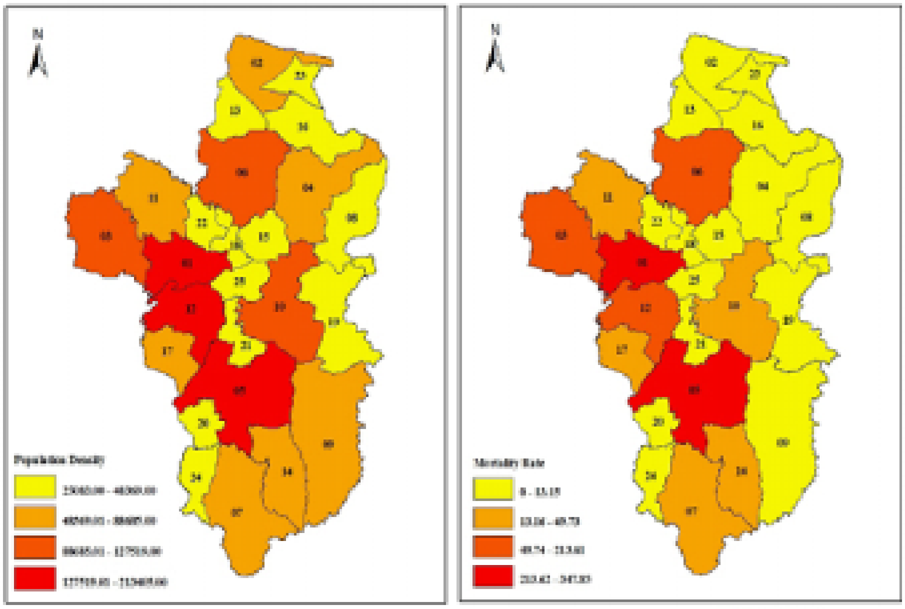


Fig 3–Geo-database model.



No.	District
01	Mueang
02	Khemmarat
03	Khueng Nai
04	Si Mueang Mai
05	Det Udom
06	Trakan Phuetphon
07	Nam Yuen
08	Khong Chiam
09	Buntharik
10	Phibun Mangsahan
11	Muang Samsip
12	Warin Chamrap
13	Kut Khaopun
14	Na Chaluai
15	Tan Sum
16	Pho Sai
17	Samrong
18	Don Mot Daeng
19	Sirindhorn
20	Thung Si Udom
21	Na Yai
22	Lao Suea Kok
23	Na Tan
24	Nam Khun
25	Swang Wirawong

Fig 4–Population density and mortality rate.

Table 1
Total population in each village.

District(s)	Sub-district(s)	Village name	Total population	House (s)	2005	2006	2007
Mueang	Rai Noi	Puttha Nikhom	1,038	444	4	5	1
	Kut Rat	Kok	1,362	357	2	7	1
Warin Chamrap	San Sook	Nong Phasuk	1,018	412	1	1	2
	Khu Mueang	Non Jig	943	200	1	2	2
Phibun Mangsahan	Ban Kham	Kham Tai	864	202	3	3	1
	Don Jik	Nong Phai	936	247	0	5	0
Trakan Phuet Phon	Tum Kae	Huai Teeneu	618	134	2	2	1
	Khu Loo	Don Tup Chang	1,411	418	1	5	2
Det Udom	Krang	Bok	625	137	0	5	0
	Na Krasang	Non Sawang	768	155	0	0	5

break period, Non Jig village was the area with the highest number of households with larvae (approximately 64 households, 19.34%), followed by Huai Teeneu village (42 households, 12.69%), and Non Sawang village (38 households, 11.48%). For the outbreak period, the highest numbers of households with larvae was Non Jig village (53,15.59%), followed by Nong Phasuk village (52, 15.29%), and Kok village (51, 15.00%) (Table 2).

Dengue vector indices (HI, CI and BI) for each village during the pre-outbreak and outbreak periods are shown in Table 2 and Figs 5 and 6. During the pre-outbreak period, HI values were lowest in Nong Phasuk (5.26) and highest in Non Jig (42.67). During the outbreak period, the HI values was lowest in Bok (0.00) and highest in Non Jig (36.30). CI values during the pre-outbreak period were lowest in Bok (4.22) and highest in Non Sawang (14.52). During the outbreak period the CI was lowest in Bok (0.00) and highest in Huai Teeneu (10.20). BI values in the pre-outbreak period were lowest in Nong Phasuk (6.02) and highest in Non Jig (76.00). During the outbreak period BI values were lowest in Bok (0.00) and highest in Huai Teeneu (53.45).

The National Institute for Communicable Diseases (2001) defined high risk for DI transmission when the BI value is > 50 and a low risk for transmission when the BI value is < 5. Non Jig, Non Sawang, and Huai Teeneu villages had a higher risk for DI transmission during the pre-outbreak period. During the outbreak period, Huai Teeneu and Non Jig villages had higher risk for DI transmission (Table 3).

Vector indicies (HI, CI, BI) tended to decrease from pre-outbreak to outbreak periods. However, Kham Tai, Kok, and Nong Phasuk villages had an increase in vector indicies over time.

Housing density map for vector-disease spread (10 villages)

Fig 7 to 16 show the buffer zones for dengue mosquitoes from residential house(s) found with dengue vectors. The buffer zone can be divided into two distances: 30 and 60 meters. Vector mosquitoes can easily fly 30 to 60 meters between breeding sites and house(s) nearby. We may expect to see transmission of DI in these areas, if vector indices are high in these areas.

Table 2
The total number of houses surveyed and houses found with dengue larvae.

Village	Pre-outbreak period		Outbreak period	
	Houses surveyed (%)	Houses found with larvae (%)	Houses surveyed (%)	Houses found with larvae (%)
Kham Tai	117 (7.3)	28 (8.5)	118 (7.4)	26 (7.6)
Kok	167 (10.5)	35 (10.6)	169 (10.6)	51 (15.0)
Non Jig	150 (9.4)	64 (19.3)	146 (9.1)	53 (15.6)
Non Sawang	93 (5.8)	38 (11.5)	95 (6.0)	32 (9.4)
Bok	121 (7.6)	17 (5.1)	116 (7.3)	0.00
Puttha Nikhom	264 (16.5)	37 (11.2)	267 (16.7)	38 (11.2)
Nong Phasuk	266 (16.7)	14 (4.2)	269 (16.9)	52 (15.3)
Nong Pai	78 (4.9)	22 (6.6)	74 (4.6)	22 (6.5)
Huai Teeneu	117 (7.3)	42 (12.7)	116 (7.3)	35 (10.3)
Don Tup Chang	224 (14.0)	34 (10.3)	225 (14.1)	31 (9.1)
Total	1,597	331	1,595	340

Table 3
Dengue vector indices (HI, CI, and BI).

Village name	Pre-outbreak period			Outbreak period		
	HI	CI	BI	HI	CI	BI
Kham Tai	23.93	6.55	29.91	22.03	7.71	35.59
Kok	20.96	10.86	40.12	30.18	10.62	48.52
Non Jig	42.67	14.09	76.00	36.30	9.22	52.74
Non Sawang	40.86	14.52	75.27	33.68	8.73	46.32
Bok	14.05	4.22	18.18	0.00	0.00	0.00
Puttha Nikhom	14.02	7.26	25.00	14.23	5.76	19.85
Nong Phasuk	5.26	1.54	6.02	19.33	6.70	26.02
Nong Pai	28.21	11.95	52.56	29.73	8.02	37.84
Huai Teeneu	35.90	13.97	70.94	30.17	10.20	53.45
Don Tup Chang	15.18	9.10	34.82	13.78	4.37	19.56

HI= house index; CI= container index; BI= Breteau index.

Perceptions regarding DI

Most subjects felt that DI was a contagious disease transmitted by *Aedes aegypti* (97.9%). They also believed a mosquito breeding habitat survey helped to prevent DI transmission (97.9%) and water containers such as jars and tires, were common mosquito breeding habitats (97.40%). However, there was still some 41.3% of subjects disagreed with the statement that "only female mosquitoes can transmit DI to humans" and 68.9% believed that DI is not deadly to humans" (Table 4).

Conversion of these perception responses into a total score for DI indicating preference levels shows most subjects had

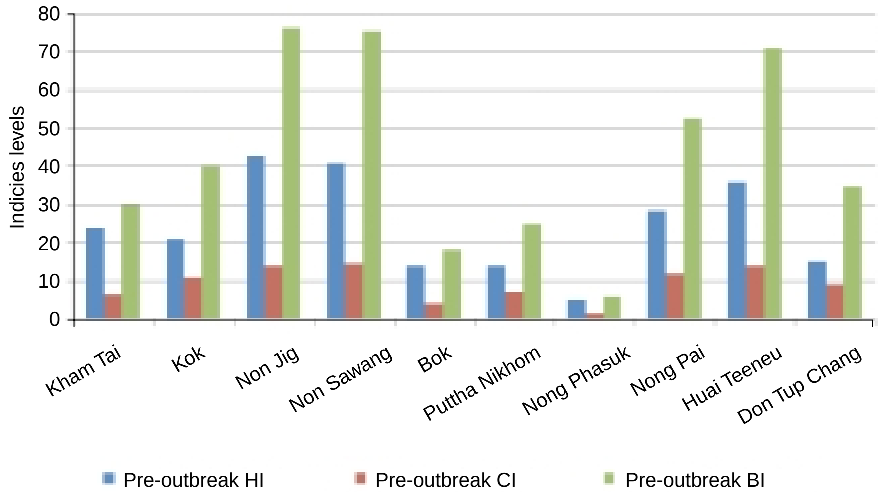


Fig 5–Pre-outbreak dengue vector indices.

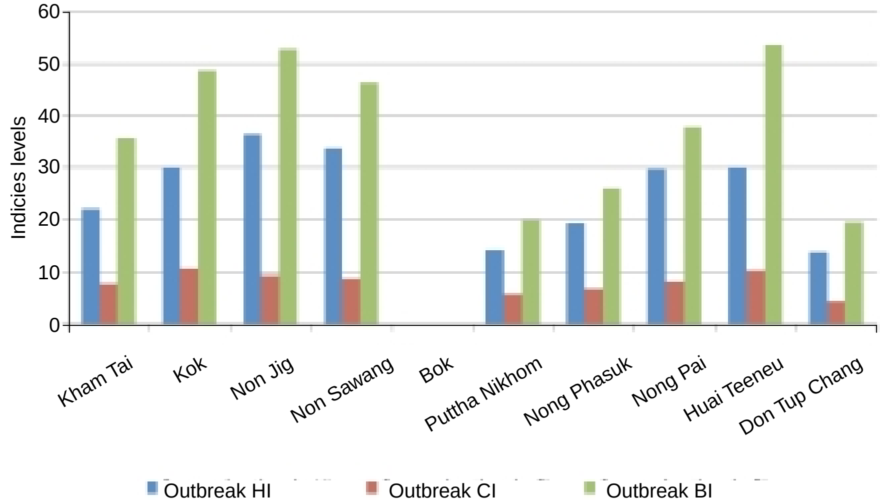


Fig 6–Outbreak dengue vector indices.

a high DI perception level (91.10%; $\bar{\chi}$ = 13.00) showing a basic knowledge of DI (Table 5).

DI preventive behavior

Most subjects had correct preventive behavior with a few deficiencies. For example, participants normally slept without a mosquito net during the daytime (61.9%). Few used insect repellant inside the house (29.8%) and few changed the water in vases or dishes (27.9%). Few attended DI knowledge lectures (30.8%). Few changed the water in containers if mosquito larvae were found (46.5%) (Table 6).

Most participants (50.9%) had good DI preventive behavior (Table 7). There was a positive significant association between DI perceptions and preventive behavior among subjects ($p<0.001$)

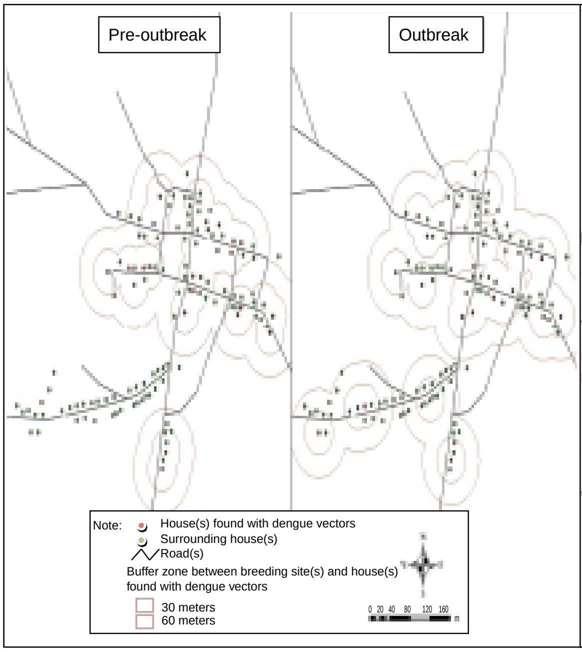


Fig 7–Kham Tai Village.

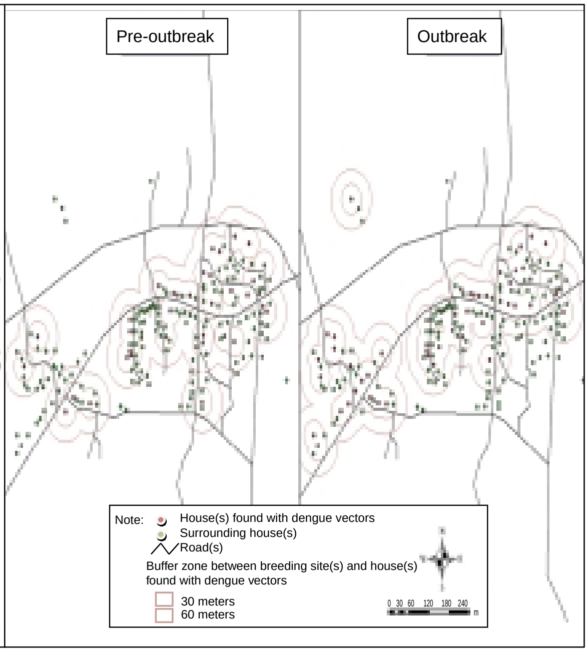


Fig 8–Kok Village.

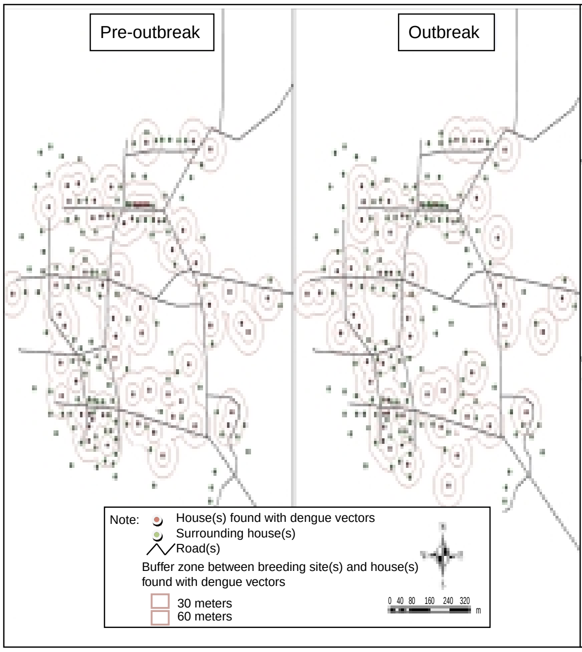


Fig 9–Non Jig Village.

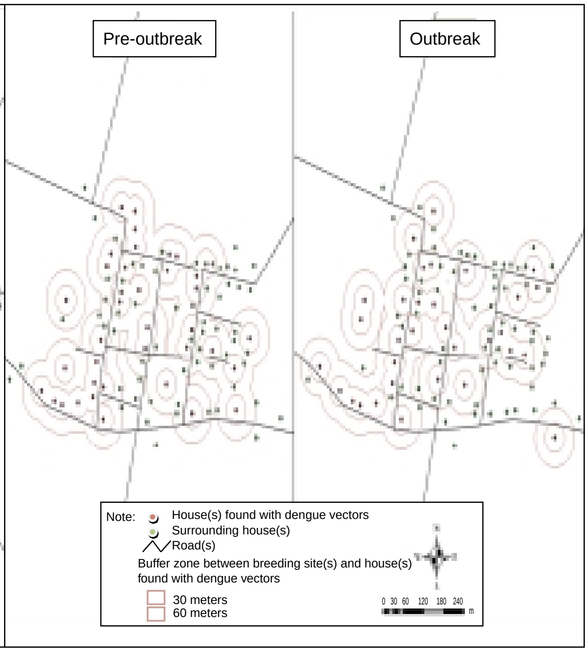


Fig 10–Non Sawang Village.

Fig 11–Puttha Nikhom Village.

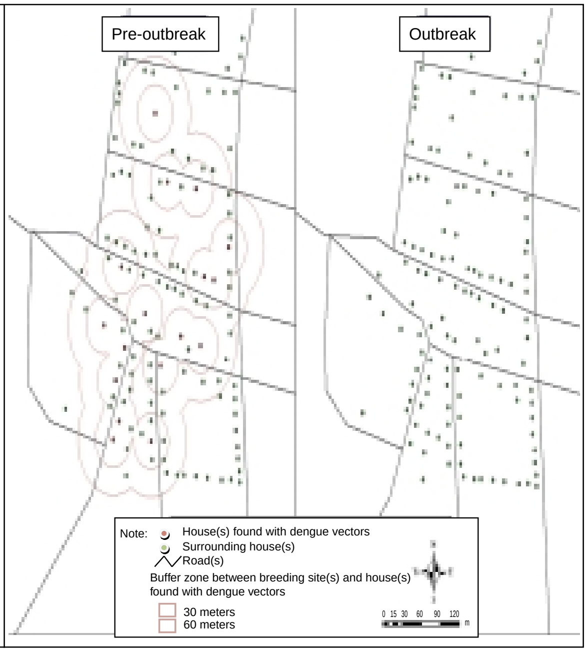


Fig 12–Bok Village.

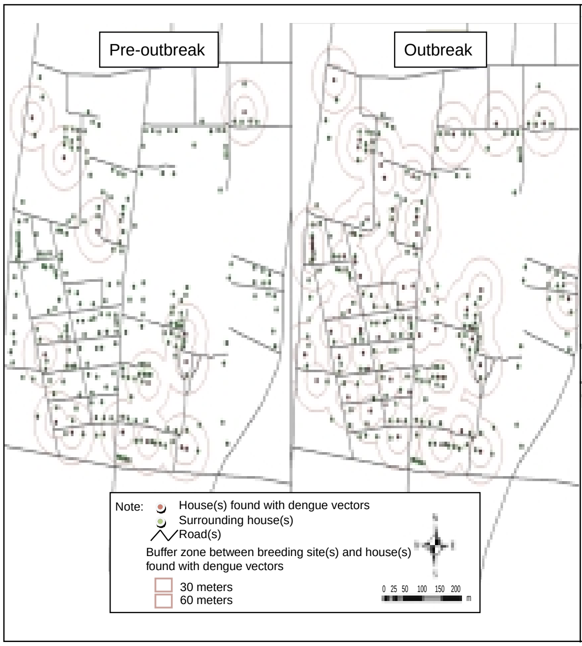


Fig 13–Nong Phasuk Village.

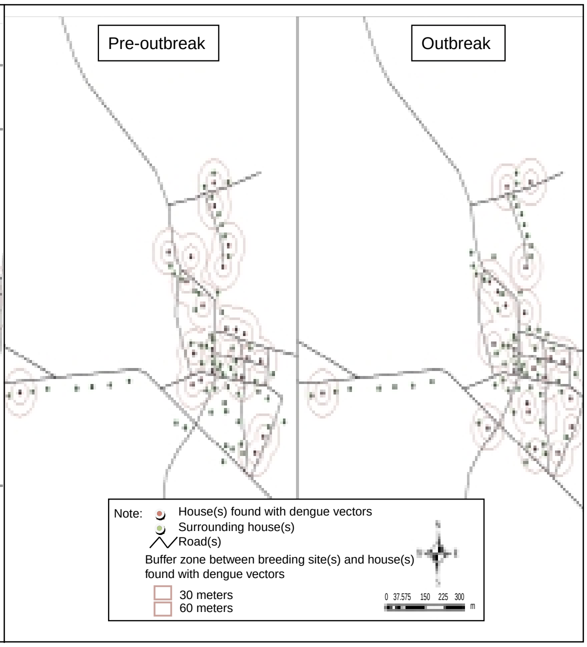


Fig 14–Nong Phai Village.

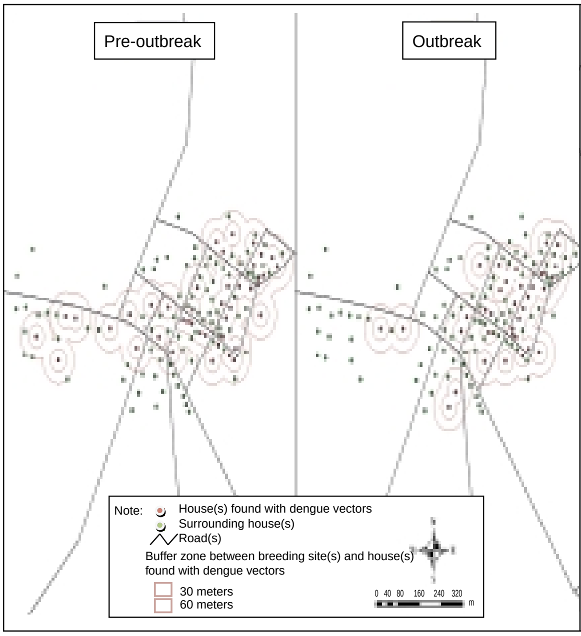


Fig 15–Huai Teeneu Village.

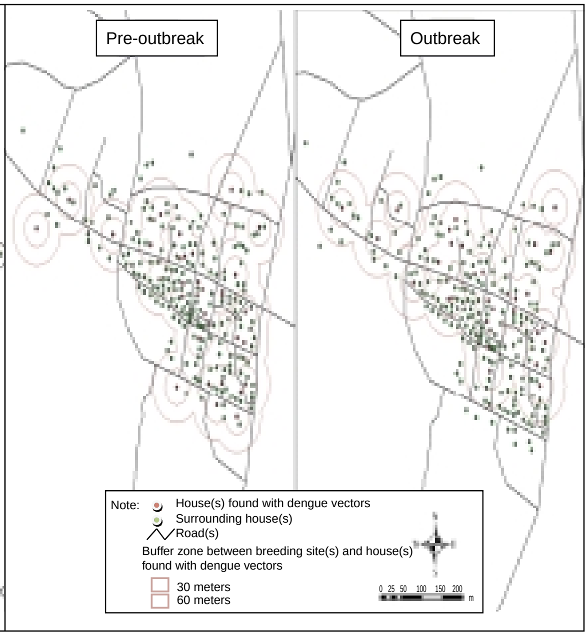


Fig 16–Don Tup Chang Village.

DISCUSSION

In the past, one limitation affecting studies of *Aedes aegypti* and DI was the data were kept as paper records limiting their manipulation and comparison with maps, photos, satellite images and other databases. As a result, subjective estimations, partial descriptions, and/or poorly defined terms were used to describe dengue vector indices and breeding sites, preventing current and future researchers from eliciting a clear picture of the site environment and conditions. Results presented at conferences and in journal articles did not provide easy access to the original, unfiltered data for current and future researchers and, as such, the geographical information, sampling data and results of these studies were not easily accessible to public health officials to help them assess the risk of, plan for, and/or respond to a dengue outbreak (Sanchez *et al*, 2006).

With the advent of the geo-database system, easy and timely access is available to original surveillance fieldwork data and, through cross links, to geographical, and spatial data. The geo-database system integrates data from any source, whether from remote sensing, aerial photographs, survey data or published records (Srivastava *et al*, 2003).

The results of the dengue vector indices survey showed some villages had a higher risk for DI transmission during the pre-outbreak period than during the outbreak period. This may indicate the most appropriate time for public health officers to implement DI prevention programs to eliminate larvae, including pyrethroid space fogging, and use of 1% temephos (abate) sand granules. The results show a decrease in vector indecies during outbreak compared to the pre-oubreak period, except for Kham Tai, Kok, and Nong Phasuk (Table 2, Fig 5,6). A possible rea-

Table 4
Volunteers' perceptions regarding dengue infection (*n*=383).

Perceptions regarding dengue infection (DI)	Agree, *n* (%)	Disagree, *n* (%)
1. DI is a contagious disease and a common house mosquito is the carrier.	375 (97.9)	8 (2.1)
2. Only adults can get DI.	36 (9.4)	347 (90.6)
3. DI is normally spread during the rainy season.	338 (88.3)	45 (11.7)
4. *Aedes aegypti* bite humans during the daytime.	299 (78.1)	84 (21.9)
5. *Aedes aegypti* normally lay their eggs in clear, clean water.	325 (84.9)	58 (15.1)
6. *Aedes aegypti* hang on the wall in dark places.	340 (88.8)	43 (11.2)
7. Only female mosquitoes can transmit DI to humans.	225 (58.7)	158 (41.3)
8. Dishes are often *Aedes aegypti* breeding habitats.	345 (90.1)	38 (9.9)
9. Pouring out and or changing water in containers can eliminate the larvae.	369 (96.3)	14 (3.7)
10. Flooding is a common cause of DI transmission.	373 (97.4)	10 (2.6)
11. Using 1% temephos (abate) sand granules in containers can eliminate *Aedes aegypti* larvae.	363 (94.8)	20 (5.2)
12. DI is deadly to humans.	264 (68.9)	119 (31.1)
13. Once a patient is infected with DI, he/she can possibly be infected again.	307 (80.2)	76 (19.8)
14. The symptoms of DI are feeling uneasy, vomiting and poor appetite.	329 (85.9)	54 (14.1)
15. A mosquito breeding site survey every week is good for DI prevention.	375 (97.9)	8 (2.1)

Table 5
Perception level(s) of dengue infection (*n*=383).

DI perception level	Score	Number	Percent
High level	(11 - 15)	349	91.1
Middle level	(6 - 10)	32	8.4
Low level	(0 - 5)	2	0.5
	$\bar{\chi}$ = 13.00		
	SD = 1.79		
Total		383	100.0

son for this could be the current national surveillance and control program was already well-implemented in those risk areas. The villagers probably followed the instructions of the village headmen. Failure to minimize the vector indices in some villages may have been due to poor sanitation, being a large community, poor education and have poor access to public health services. People in these high risk areas were instructed to eliminate water containers and use mosquito nets and

Table 6
DI Preventive Behaviors (n =383).

DI preventive behavior	Always	Often	Sometimes	Seldom	Never
1. Do you sleep without a mosquito net during the daytime?	58 (15.10)	24 (6.30)	37 (9.7)	27 (7.0)	237 (61.9)
2. Do you get rid of garbage inside your house?	150 (39.2)	125 (32.6)	71 (18.5)	20 (5.2)	17 (4.4)
3. Do you change or pour out water in containers every week?	167 (43.6)	31 (34.2)	62 (16.2)	15 (3.9)	8 (2.1)
4. Do you usually close container lids completely?	145 (37.9)	89 (23.2)	77 (20.1)	26 (6.8)	46 (12.0)
5. Do you like to sit in dark places?	24 (6.3)	28 (7.3)	80 (20.9)	94 (24.5)	157 (41.0)
6. Do you put 1% temephos (abate) sand granules in water containers?	158 (41.3)	134 (35.0)	49 (12.8)	26 (6.8)	16 (4.2)
7. Do you survey for mosquito larva every week?	127 (33.2)	123 (32.1)	79 (20.6)	32 (8.4)	22 (5.7)
8. Do you wear long sleaves and long pants when you are in dark places to protect yourself?	75 (19.6)	53 (13.8)	101 (26.4)	77 (20.1)	7 (20.1)
9. Do you use insect repellent inside the house?	58 (15.1)	73 (19.1)	94 (24.5)	44 (11.5)	14 (29.8)
10. Do you often change water in vases and dishes?	106 (27.7)	89 (23.2)	59 (15.4)	22 (5.7)	107 (27.9)
11. Do you encounter garbage from floods daily?	149 (38.9)	138 (36.0)	65 (17.0)	22 (5.7)	9 (2.3)
12. Do you attend DI training courses at least twice a month?	37 (9.7)	82 (21.4)	96 (25.1)	50 (13.1)	118 (30.8)
13. Do you change water in containers if mosquito larvae are found?	178 (46.5)	131 (34.2)	49 (12.8)	18 (4.7)	7 (1.8)
14. When you see a mosquito, do you hit it immediately?	260 (67.9)	84 (21.9)	23 (6.0)	9 (2.3)	7 (1.8)
15. Do you stay on a farm, in a garden or in the forest?	52 (13.6)	31 (8.1)	62 (16.2)	47 (12.3)	191 (49.9)

other forms of protection. The dengue vector indices in Bok, Non Sawang, and Non Jig villages dropped during the outbreak period compared to the pre-outbreak period (Table 3). A previous study indicated in crowded areas, many people living within the short flight range of the vector and its breeding source may be exposed to transmission even if the HI is low. Therefore, a higher population density and interconnection of houses may lead to more efficient transmission of the virus and thus increase exposure to infection (Morlan and Hayes, 1958; Reiter, 2007).

Most subjects had a knowledge of DI, including how dengue virus is transmitted, *Aedes aegypti* breeding habitats, and DI prevention. Regarding the item "changing water in containers can eliminate mosquito larvae" (Table 4), a previous study (Bhandari, 2008), found changing water and emptying water storage containers once or twice a week greatly reduced the risk for DI. Since water is essential during the first 8 days in the life of mosquitoes, changing the water less frequently than every 8 days can result in an increase in adult mosquitoes and risk for dengue virus transmission. Regarding the item "*Aedes aegypti* normally lay their eggs in

Table 7
DI Preventive behavior (n= 383).

DI preventive behavior	Range of scores	Number	Percent
Very good	(51 - 75)	195	50.9
Good	(26 - 50)	187	48.8
Fair	(0 - 25)	1	0.3
	$\bar{\chi}$ = 50.30		
	SD = 8.14		
Total		383	100.0

clear, clean water," usally *Aedes aegypti* eggs are laid on the damp walls of artificial or natural containers and are able to resist desiccation for several weeks to several months; the eggs then hatch and develop into mosquitoes (WHO, 1997).

The results show DI preventive behavior was satisfactory. Participants realized the importance of reduction in DI transmission as well as the avoidance of mosquito bites. They knew the presence of waste, such as cans, car parts, bottles, and used tires, around the household created potential breeding habitats and the dumping of solid waste over long periods of time, greater than 15-20 days, supports the breeding of *Aedes aegypti* and increases transmission of disease (Katyal, 1996).

The results showed a positive significant relationship between DI perceptions and preventive behavior among subjects (p<0.001). However, there was still a lack of knowledge regarding DI preventive behavior, such as not using mosquito nets when sleeping and the infrequent use of insect repellant. A previous study found the use of nets, screening of houses, creating smoke with neem leaves, spraying insecticides, and closing doors and windows were common methods of protection against mosquitoes (Chareonsook *et al*, 1999). These methods reduced the number of mosquitoes and/or provided protection against bites, thus lessening the risk of DI transmission. The study also showed protection against mosquito bites reduced the incidence of DI. Most subjects had high levels of DI perceptions regarding changing of the water in containers, however only 46.5% of volunteers changed the water in containers when mosquito larvae were found (Table 6). This may also be related to a lack of DI knowledge about prevention (Table 6).

In summary. The development of a geo-database for monitoring DI was productive. The graphical data related to spatial and attributed data was created using primary data, such as addresses, with the program ArcView 9.2®. Dengue vector indices were collected and interpreted for incidence of DI transmission. Such technology has been found to be essential in supporting decision-making regarding DI prevention and control activities. The assessment of DI perceptions and preventive behavior was useful. Further evaluation of the effectiveness of the use of a geo-database in DI prevention and control is necessary to utilize this technology in routine public health work.

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REFERENCES

Alpana B, Andrianasolo H. Application of GIS modeling of dengue risk based on socio-cultural data: case of Jalor, Rajasthan, India. Singapore: 22nd Asian Conference on Remote Sensing, 2001.

Bhandari KP, Raju PLN, Sokhi BS. Application of GIS modeling for dengue fever prone area based on socio-cultural and environmental factors- a case study of Delhi city zone. *Int Arch Photogram, Remote Sens Spat Info Sci* 2008; 37(B8): 165-70.

Chaikoolvatana A, Singhasivanon P, Haddawy P. The Development of a geographic information system (GIS) for dengue vector and hemorrhagic fever surveillance in northeastern of Thailand. *Dengue Bull* 2008; 31: 75-82.

Chareonsook O, Foy HM, Teeraratkul A, Silarug N. Changing epidemiology of dengue hemorrhagic fever in Thailand. *Epidemiol Infect* 1999; 122: 161-6.

Curran PJ, Atkison PM, Foody GM, Milton EJ. Linking remote sensing, land cover and disease. In: Hay SI, Randolph SE Rogers DJ eds. Remote sensing and geographical information systems in epidemiology. *Adv Parasitol* 2000; 47: 37-80.

Cline BL. New eyes for epidemiologists: aerial photography and other remote sensing techniques. *Am J Epidemiol* 1970; 92: 85-9.

Daniel WW. Biostatistics: a foundation for analysis in the health sciences. 4th ed. New York: Wiley & Sons, 1987.

Department of Public Health, Ministry of Public Health, Thailand. An annual report of dengue hemorrhagic fever, Ubon Ratchathani: 2006. [Cited 2009 Nov 17]. Available from: URL: http://www.phoubon.in.th/meeting/epid.pdf

Department of Public Health, Ministry of Public Health, Thailand. An annual report of dengue hemorrhagic fever, Ubon Ratchathani: 2007. [Cited 2009 Nov 17]. Available from: URL: http://www.phoubon.in.th/meeting/epid.pdf

Fakeeh M, Zaki A. Virologic and serologic surveillance for dengue fever in Jeddah, Saudi Arabia, 1994-1999. *Am J Trop Med Hyg* 2001; 59: 764-67.

Gubler DJ. Surveillance for dengue and dengue hemorrhagic fever. *Bull PAHO* 1989; 23: 397-404.

Goh KT. Dengue is emerging infectious disease in Singapore. In: Dengue in Singapore. Singapore: Institute of Environmental Epidemiology, Ministry of the Environment. *Tech Monogr Ser* 1993; 2: 33-40.

Hayes RO, Maxwell EL, Mitchell CJ, Woodzick TL. Detection, identification and classification of mosquito larval habitats using remote sensing scanners in earth-orbiting satellites. *Bull WHO* 1985, 63: 361-74.

Hay SI, Tatem AJ. Remote sensing of malaria in urban areas: two scales, two problems [Letter]. *Am J Trop Med Hyg* 2005; 72: 655-7.

Hlang MT, Khin MA, Soe T. The effect of temperature and humidity on dengue virus propagation in *Aedes aegypti* mosquitoes. *Southeast Asian J Trop Med Pablic Health* 1998; 29: 280-4.

Katyal R, Singh K, Kumar K. Seasonal variations in *Aedes* aegypti population in Delhi, India. *WHO/SEARO Dengue Bull* 1996; 20: 78-81.

Kuno G. Review of the factors modulating dengue transmission. *Epidemiol Rev* 1995; 17: 321-35.

Linthicum KJ, Bailey CL, Davies FG, Tucker CJ. Detection of Rift Valley fever viral activity in Kenya by satellite remote sensing imagery. *Science* 1987; 235: 1656-9.

Linthicum KJ, Bailey CL, Tucker CJ, *et al*. Observations with NOAA and SPOT satellites on the effect of man-made alterations in the ecology of the Senegal River basin in Mauritania on Rift Valley fever virus transmission. *Sistema Terra* 1994; 3: 44-7.

Luemoh A, McNeil D, Kumimg M. Water consumption and distribution of dengue larvae in Pattani villges. *Songkla Med J* 2003; 21: 209-16.

Morlan HB, Hayes RO. Urban dispersal and activity of *Aedes aegypti. Mosq News* 1958; 19: 137-44.

Pope KO, Sheffner EJ, Linthicum KJ, *et al*. Identification of central Kenyan Rift Valley fever virus vector habitats with Landsat TM and evaluation of their flooding status with airborne imaging radar. *Remote Sens Environ* 1992; 40: 185-96.

Reiter M. Geophysical studies relating to the geothermal source of the Valles Caldera, north-central New Mexico. 58th NMGS Fall Field Conference 2007: 78-80.

Sanchez RM, hayden M, Janes C, Anderson G. A web-based multimedia spatial information system to document *Aedes aegypti* breeding sites and dengue fever risk along the US-Mexico border. *Health Place* 2006; 12: 715-27.

Singhasivanon P, Sithiprasasna R, Linthicum KJ, Luti GJ, Jones W. Use of GIS-based spatial modeling approach to characterize the spatial patterns of malaria mosquito vector breeding habitats in northern, Thailand. *Southeast Asian J Trop Med Pablic Health* 2003; 34: 517-28.

Srivastava A, Nagpal BN, Saxena R, *et al*. GIS based malaria information management system for urban malaria scheme in India. *Compu Methods Programs Biomed* 2003; 71: 63-75.

Teng TB. Control of dengue fever/dengue haemorrhagic fever in Singapore. *Dengue Bull* 1997; 21: 15-23.

Thavara U. Biological ecology and control of mosquito in Thailand: *Ae. aegypti* causes dengue hemorrhagic fever. Bangkok: National Institute of Health, Department of Medical Science, Ministry of Public Health, Thailand, 2004: 21-36.

Thavara U, Tawatsin A, Chansang C, *et al*. Larval occurrence, oviposition behavior and biting activity of potential mosquito vectors of dengue on Samui Island, Thailand. *J Vector Ecol* 2001; 26: 172-80.

Wongbutdee J, Saengnill W, Chaikoolvatana A. *Aedes aegypti* larval survey vector and analysis risk area for dengue hemorrhagic fever. *Int J Geoinform* 2009; 5: 35-9.

World Health Organization (WHO). Dengue haemorrhagic fever: diagnosis, treatment, prevention and control. Geneva: WHO, 1997.