LARVAL HABITATS AND DISTRIBUTION PATTERNS OF *AEDES AEGYPTI* (LINNAEUS) AND *AEDES ALBOPICTUS* (SKUSE), IN THAILAND

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Abstract. This study was conducted to survey larval breeding habitats and to obtain larval abundance during the dry period covering all 5 geographical zones of Thailand. Our results indicated *Aedes aegypti* is prevalent all over the country, whereas *Aedes albopictus* is more restricted to the remote area of the south. Water storage containers, especially water jars, served as a main larval breeding habitats of *Ae. aegypti,* whereas broken cans and plastic containers are considered primary breeding sites for *Ae. alpopictus* during the dry period. In addition, *Aedes* larval indices, container index (CI), house index (HI), and Breteau index (BI) were measured. CI and HI values from the central part were significantly higher than those from other areas ($p<0.01$). BI values of all collection sites were greater than 50 (a maximum BI value accepted by the Ministry of Public Health, Thailand). In brief, *Ae. aegypti* and *Ae. albopictus* populations heavily infested many towns and residential areas of the country. Drought could not limit the density of *Aedes* mosquitos in Thailand. Systematic vector control and vector surveillance programs by public health organizations, if practical, should be continuously conducted to reduce or prevent dengue risk.

INTRODUCTION

Dengue hemorrhagic fever (DHF) represents one of the most important arthropod-borne viral diseases in the world and commonly occurs throughout Asia. An outbreak started in the Philippines in 1953, subsequently in Thailand with 150,000 to 200,000 reported cases (CDC, Ministry of Public Health, Thailand, 1978). During the last 2 decades, dengue outbreaks in Thailand have occurred periodically. The rate of spread of dengue virus in Thailand has comparatively increased and disease transmission remains prevalent all over the country. In addition, there has been a significant increase in the human population, demographic movement of the people and accommodation-based tourism facilities. These changes can have a great impact on the densities of *Aedes* mosquitos, by creating more larval breeding habitats for dengue mosquitos.

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Only 2 species of *Aedes* mosquitos, *Ae. aegypti* (Linnaeus) and *Ae. albopictus* (Skuse) are known to be important dengue virus vectors in Thailand (Gould *et al*, 1968; Russell *et al*, 1969). *Aedes aegypti* is more prevalent around human dwellings and is a principal vector in urban zones *ie* Bangkok, whereas *Ae. albopictus* serves as an important vector in the rural and undeveloped areas (Halstead, 1966; Scanlon, 1966; Pant *et al*, 1973; WHO, 1986; Bhamarapravati, 1990; Thavara *et al*, 2001). *Aedes aegypti* prefers the clean water found in many types of domestic containers inside or near human dwellings, whereas *Ae. albopictus* is more likely to be found in natural containers or outdoor man-made habitats containing a greater amount of organic debris (Rattanarithikul and Panthusiri, 1994). The latter species is much more prevalent in the rural and remote areas of southern Thailand than another parts of the country. Recent observation suggested that *Ae. alpopictus* is now invading many residential habitats in urban zones. Although different, the preferred breeding habitats of these 2 species slightly overlap (Gould *et al*, 1970; Thavara *et al*, 2001). This survey was conducted to report the diversity of larval breeding habitats and distribution of *Ae. aegypti* and *Ae. albopictus* in five different regions of Thailand, and to provide updated background information on the biology and ecology of these 2 species that could facilitate the *Aedes* control program in Thailand.

MATERIALS AND METHODS

Study sites

In this study, surveys of larval breeding places and larval abundance were conducted covering all five geographical regions of Thailand during the dry season, in 2002. Collection sites included the areas in the north, east, northeast, south and center of Thailand, as described below (Fig 1).

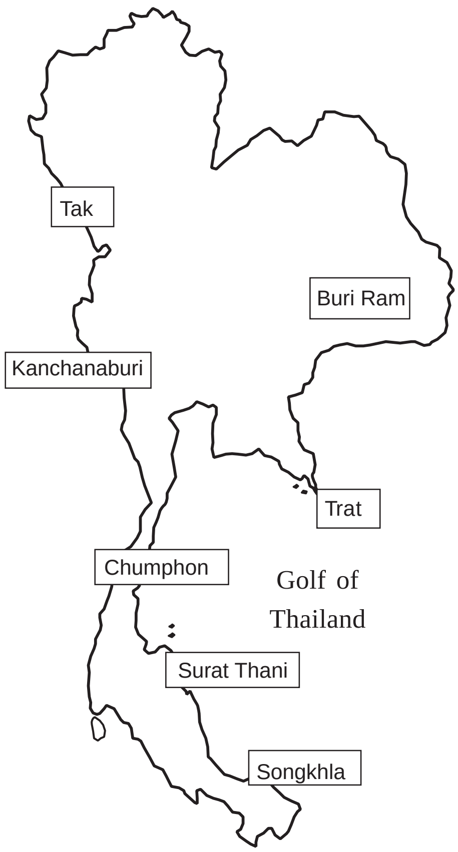

Fig 1–Map of *Aedes* collection sites in Thailand.

1. North: Tak Province was selected as representative of the north. This area is about 600 km north of Bangkok and easily accessible by car. A survey was carried out in a rural residential area of Mae Sot district, in the west of Tak Province, one of the dengue hyperendemic areas. Approximately 50 houses were randomly sampled and larval breeding habitats were identified.

2. East: collection sites were selected in both town and rural residential areas of Trat Province, a hyperendemic area for dengue. The town residential area collection was conducted in Mueang Trat district, Trat Province, whereas the rural residential collection area was Chang Island, Ko Chang district. The island is approximately 25 km from the mainland. Approximately 50 houses were randomly chosen for the presence or absence of mosquito larvae.

3. Center: a survey was carried out in the town residential area of Mueang district of Kanchanaburi Province, central Thailand. All water containers in 30 houses were randomly checked for the presence or absence of *Aedes* larvae.

4. South: three provinces along the Gulf of Thailand were selected: Chumphon, Surat Thani and Songkhla Provinces. At Chumphon, investigation was made exclusively in rural residential area of Sai Ree Sand Beach, Mueang district, whereas both town and remote residential areas of Songkhla Province were surveyed for larval breeding places and larval abundance. In Surat Thani Province, 2 different geographical collections, mainland and island, were selected. The mainland survey was done at the Donsak Harbor, a rural residential area as described in a recent publication (Chareonviriyaphap and Lerdthusnee, 2002). On the island, the collection was done in a rural residential area of Samui Island.

5. Northeast: a survey of *Aedes* mosquitos was done in the rural residential area of Mueang district, Buri Rum Province, an endemic area for dengue hemorrhagic fever. Approximately 50 houses were surveyed for the presence or absence of *Aedes* mosquitos.

Entomological studies

For each collection site, approximately 50 houses were sampled and all larval breeding habitats were surveyed by two entomological teams (two persons per team). Larval survey techniques were used to obtain the house index (HI), container index (CI), and Breteau index (BI) (Service, 1976).

Surveys were conducted by searching for containers containing water and recording their types and site locations. Larval habitats were first identified as "indoor or outdoor". Indoor larval habitats were examined for all accessible water containers inside the house. At least 30 specimens, if feasible, for each container were collected for further species identification. Outdoor larval habitats were also surveyed in all natural and artificial containers including all trash near and around dwellings (less than 10 m from the selected house). Mosquito larvae were collected and processed in the same manner as the indoor mosquitos.

All live larvae and pupae were brought back to the insectary at the Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand. Each population (larval container) was maintained separately in a plastic tray. For the purpose of identification, pupae were separated and kept in a small vial containing clean water. Adults were identified using the Conventional Key for *Aedes* species (Darsie, 1986; Rattanarithikul and Panthusiri, 1994).

Data analysis

The mean number of mosquitos from indoors and outdoors in different locations was compared using two-tail analysis of variance (ANOVA) using the SAS software program. The accepted level for all significances was determined at 99% (p-value <0.01).

RESULTS

In this investigation, we collected 4,666 *Aedes* mosquitos from 5 different geographical areas of Thailand during the dry season. A similar number of houses (approximately 50 houses) from 5 different regions was surveyed for the presence or absence of *Aedes* larvae, except from the south. In the south, 70 houses in 3 provinces, Chum Phon, Surat Thani, and Songkhla, along the Gulf of Thailand, were sampled. Among all collections, 3,995 (85.6%) belonged to *Ae. aegypti* and 671 (14.4%) were *Ae. albopictus*. Roughly 40% of *Aedes* larvae were collected from the south, whereas 17.12%, 16.35%, 16.78% and 10.26% were obtained from the north, east, northeast and central regions, respectively (Table 1). *Aedes aegypti* mosquitos are widely distributed throughout the country, whereas *Ae. albopictus* is more likely the prominent species in the south (Table 1).

Indoor and outdoor collections of *Ae. aegypti* and *Ae. albopictus* were compared (Table 2). In general, both *Ae. aegypti* and *Ae. albopictus* larvae were found more abundantly outdoors than indoors, except for those *Ae. aegypti* specimens from the south. There were almost seven times greater *Ae. aegypti* larvae collected outside than inside dwellings in the central area. In the south, *Ae. aegypti* larvae collected indoors (66.3%) were significantly more numerous than those collected from outdoors (33.7%) ($p<0.01$). The reason for this is discussed later. In contrast, *Ae. albopictus* larvae from the south were found to be significantly more abundant outdoors than indoors ($p<0.01$). No *Ae. albopictus* larva was collected

Table 1
Number (%) of *Aedes aegypti* and *Aedes albopictus* collected from 5 different regions of Thailand.

Collection site	No. houses	*Aedes aegypti*		*Aedes albopictus*		Total
		Number	%	Number	%	
North	27/52	666	83.45	132	16.54	798
South	53/68	1,319	71.56	524	28.43	1,843
East	46/52	749	98.16	14	1.84	763
Northeast	32/50	783	100	0	0	783
Center	48/50	478	99.8	1	0.2	479
Total	206/272	3,995		671		4,666

Table 2
Percent of indoor and outdoor collections of *Aedes aegypti* and *Aedes albopictus* from different regions of Thailand.

Mosquito species	Sites	Indoor (%)	Outdoor (%)	Indoor : Outdoor ratio
Aedes aegypti	North	353 (53.0)	313 (47.0)	1.12 : 1.0
	South	875 (66.3)	444 (33.7)	1.97 : 1.0
	East	375 (50.0)	374 (50.0)	1.0 : 1.0
	Northeast	265 (33.8)	518 (66.2)	1.0 : 1.95
	Center	63 (13.1)	415 (86.8)	1.0 : 6.58
Aedes albopictus	North	6 (4.5)	126 (95.5)	1.0 : 21
	South	15 (2.8)	509 (97.2)	1.0 : 33
	East	0 (0)	14 (100)	0 : 14.0
	Northeast	0	0	-
	Center	0	1 (100)	-

Table 3
Inspection of larval breeding habitats and number of *Aedes aegypti* and *Aedes albopictus* by region.

		Aedes aegypti					*Aedes albopictus*				
Habitats	Container	N	S	E	N/E	C	N	S	E	N/E	C
Water storages	Water jar	434	484	248	608	394	76	53	0	0	1
	Cement tank	79	715	70	171	63	2	19	0	0	0
	Plastic tank	13	50	225	0	15	12	38	0	0	0
	Flower vase	14	7	9	0	0	0	20	1	0	0
	Animal feeder	26	1	0	4	0	28	57	0	0	0
	Ant trap	0	0	0	0	0	0	0	0	0	0
Trash	Glass	10	0	0	0	0	0	0	0	0	0
	Plastic bottle	0	38	0	0	6	0	28	0	0	0
	Can	50	0	0	0	0	0	100	0	0	0
	Coconut husk	0	16	3	0	0	0	35	10	0	0
	Tire	49	0	5	0	0	14	108	0	0	0
Sinks		8	189	0	0	0	0	3	0	0	0
Total		666	1,319	749	783	478	132	524	14	0	1

N: North, S: South, E: East, W: West, C: Center, and N/E: Northeast.

in the northeast and the species was rare in the central region (Table 2).

To identify the potential breeding habitats of *Aedes* mosquitos, all accessible water containers, both natural and artificial, were inspected in and around houses. Larval breeding habitats of *Aedes* mosquitos are shown in Table 3. They can be categorized as water storage, trash and unused household. Our results indicated that water storage, especially water jars, served as primary breeding habitats for *Aedes* mosquitos. Cement and plastic tanks also served as preferred breeding habitats, especially for *Ae. aegypti* larvae (Table 3). In contrast, trash containers and unused household are considered minor breeding sites for *Ae. aegypti* in this study. It has been noted that trash, especially broken cans around dwellings, served as major larval breeding habitats for *Ae. albopictus* from in south. Water storage was also a potential breeding site for *Ae. albopictus* in the north and south (Table 3).

Larval indices, BI, CI, and HI for *Aedes* mosquitos from all 5 different regions during the dry season were assessed (Table 4). From the total of 272 houses, 206 were infested with *Aedes* mosquitos. Houses infested with *Aedes* larvae can be expressed as HI. In this study, HI varied from 52 to 96. The highest HI was obtained from the central region (HI=96), whereas the smallest HI was from the north (HI=52). Larval prevalence is determined by the BI and the values ranged from 99 to 190. The highest BI value was found in the north (190) and an almost similar number was found in the northeast (186). The lowest BI was obtained in the central region (99). In addition, water containers that are infested by *Aedes* larvae can be expressed by the CI. CI varied from 22 to 78. The lowest CI was from the north (22) whereas the highest CI was from the northeast (78).

DISCUSSION

Since acceptable dengue vaccine for mass use is unavailable, efforts to prevent dengue hemorrhagic fever rely mainly on anti-vector programs that require the continuous participation of people in the community. It is known that *Ae. aegypti* and *Ae. albopictus* serve as dengue vectors in Thailand. *Aedes aegypti* was introduced to countries in the Southeast Asian region a long time ago, possibly via rubber tires, whereas *Ae. albopictus* is native to this region. Larvae of these two species were found in clear and clean water in all types of artificial and natural containers (Rattanarithikul and Panthusiri, 1994). Although these two species have great epidemiological importance, there have been few published studies focusing on larval ecological habitats and the distribution of *Ae. aegypti* and *Ae. albopictus* in Thailand. Sampling was conducted to survey various types of larval breeding places and larval distribution of *Aedes* mosquitos, as well as *Aedes* larval indices during the dry season, to facilitate the current vector control program in the country.

Table 4
Larval indices of *Aedes* mosquitos from different geographical areas of Thailand during the dry season (January 2002-April 2002).

Location	HI	CI	BI
North	52	22	190
South	78	23	140
East	88	50	101
Northeast	64	41	186
Center	96	78	99

HI: Percentage of houses positive for *Aedes* larvae; CI: Percentage of containers positive for *Aedes* larvae; BI: Number of containers positive for *Aedes* larvae per 100 houses.

In this study, we found dense populations of *Ae. aegypti* and *Ae. albopictus* in many parts of the country during the dry period, indicating that drought could not interrupt *Aedes* abundance. Shortage of water supply during the dry season can increase the number of storage containers in the community and therefore created more larval breeding habitats (Swaddiwudhipong *et al*, 1992). Our study indicated that *Ae. aegypti* preferred to breed primarily in water storage containers, especially water jars, as well as other man-made artificial and natural containers, throughout the country. *Aedes albopictus* prefers to breed in various kinds of trash.

Generally, there are 2 different seasons, wet and dry, in Thailand. The wet season commonly runs from June to November, and the dry season from November to May. The peak dengue outbreak in Thailand generally occurs during the rainy period (July-September) when the mosquito population begins to expand. A previous study suggested that natural breeding habitats such as coconut leaves and husks and coconut floral spathes served as the main breeding sites of *Ae. albopictus* from the south during the rainy period (Thavara *et al*, 2001). No such natural breeding habitats were observed as potential breeding sites of *Aedes* mosquitos during the dry season in this study. It has been noted that, for survival purposes, *Aedes* mosquitos tend to breed more in artificial man-made containers, *ie*, broken bottles and plastic cans, in the dry season. In the south, a variety of native fruits, such as durian, mango, papaya, rambutan and longgon are more common and represent major commercial and export crops. Watering these crops is frequently required during drought. This activity could accidentally store water in unused containers, such as garbage cans, that serve as potential breeding sites for *Aedes* mosquitos. This agrees with our study, since all kinds of trash containing water served as the main larval breeding habitats for *Ae. albopictus*, followed by water storage containers. A similar study in Guatemala observed that discarded tires and broken bottles were the major breeding sites for *Ae. albopictus* (Ogata and Samayoa, 1996). However, in the wet season, coconut shells and other plant axils serve as the main breeding places for this species, as suggested by Thavara *et al* (2001).

Although larval source reduction is a newly supportive technique, temephos, an organophosphate, is regularly used in containers to control *Ae. aegypti* larvae (CDC, Ministry of Public Health, Thailand). Ultra low volume (ULV) applications of either fenitrothion, malathion or deltamethrin are also used during the peak period for adult *Aedes* populations, especially during the rainy season (Chareonviriyaphap *et al*, 1999). In addition, small scale use of *Bacillus thuringiensis* subsp *israelensis (Bti)*, a safe and commonly used biopesticide, has been conducted for the control of *Aedes* mosquito larvae in indoor containers (Lerdthusnee and Chareonviriyaphap, 1999). This study suggested that *Bti* dramatically suppressed populations of *Aedes* larvae. Although effective, *Bti* formulations are short lived and high cost is incurred in mass production.

Our results also show that both species of *Aedes* seem to breed outside, rather than inside, dwellings except for *Ae. aegypti* in the south. *Aedes albopictus* in this study is a good example of an outside breeding founder. Larvae of *Ae. albopictus* were found in significantly greater numbers in outdoor breeding habitats than indoor ($p<0.01$). The government of Thailand launched an effective *Aedes* control campaign in 2000. The main objective was to reduce larval breeding sources of *Aedes* mosquitos using an Integrated Vector Management (IVM) program in and around houses. In this program Potential breeding habitats must be discarded or destroyed if found. It has been observed that larval breeding sources inside houses are dramatically reduced, whereas outdoor habitats remain ignored. This could be the only reason that *Aedes* larvae have adapted their breeding places to outside houses, for survival purposes. In addition, we also found that the habitats of *Ae. aegypti* and *Ae. albopictus* have approximately 20% overlap, mainly in the south (data not shown). This coexistence was greater than those reported by Gould *et al* (1970) and Thavara *et al* (2001).

In this study, all three *Aedes* larval indices were obtained (BI, CI and HI). All indices were significantly higher than those accepted by the Ministry of Public Health ($p<0.01$). The national BI target for the Vector Control Program of the Ministry of Public Health is less than 50. In our study, BI values were quite high, ranging from 99 to 190. CI and HI were also high for all collection sites. These indices indicated heavy infestation of *Aedes* larvae in the local communities. Rapid and rigorous control strategies should be implemented to prevent or reduce future dengue outbreaks that may occur in the community. In this regard, the Ministry Public Health's National Control Program should take appropriate steps and launch further effective and quick vector control measures immediately. Health education, training in vector control and educational training technology should be considered as a supplementary program to prevent an unexpected outbreak. Vector surveillance should be conducted continuously for evaluation of the progress of the national control program and for further planning.

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