

INVESTIGATIONS ON THE DENSITY AND BREEDING HABITATS OF *Aedes* MOSQUITOES IN DENGUE EPIDEMIC AREAS IN TAIWAN

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*Immediately following the discovery of dengue epidemics in southern Taiwan from December 1987 to October 1991, investigations on the vector mosquitoes and their ecology, especially related to the epidemiology of dengue, were undertaken in nine localities in Taiwan in which a number of indigenous dengue cases were found. Results indicated that the density of *Aedes aegypti* was markedly higher than that of *Ae. albopictus* in the nine areas under investigation in southern Taiwan. During an epidemic which occurred in November 1989 in the Sanmin district of Kaohsiung city, no *Ae. albopictus* were found. The data obtained from the present study suggests that *Ae. aegypti* was involved in the transmission of dengue fever in Taiwan. Another finding in the same district in October 1991 revealed that *Ae. aegypti* with a low density figure of two (house index of 5%, container index of 3%, and Breteau index of 6) could still maintain the transmission of dengue in its endemic area. This is the threshold density of *Ae. aegypti* in relation to dengue transmission in Taiwan. However, transmission of the virus is enhanced by a dense human population.*

*Surveys made in the nine localities with dengue epidemics reveal that *Ae. aegypti* breeds primarily in flower vases and buckets, while *Ae. albopictus* breeds mainly in discarded automobile tires and earthenware jars. The percentage of breeding sites used by both *Aedes* species was 32.3% in ornamental containers, 30.0% in discarded containers, 24.6% in water storage containers, 10.4% in refrigerator receptacles and 2.7% in flooded basements. More breeding sites of *Ae. aegypti* and *Ae. albopictus* occur in outdoor containers than in indoor ones. (Chin J Public Health (Taipei): 1995; 14(3): 228-236)*

Key words: dengue fever, *Aedes aegypti*, *Aedes albopictus*

INTRODUCTION

Dengue fever is caused by an infection by the dengue virus. In Taiwan, dengue-like illness was first reported in 1870 [1]. From 1915 to 1942, dengue fever was an islandwide epi-

demic and about 80% of the population were infected [2,3]. Dengue fever was not reported in Taiwan for roughly forty years. In 1981, there was an outbreak of dengue fever in Liuchiu, Pingtung, an offshore islet of south Taiwan. Eighty percent of the island's 15,791 inhabitants were infected. Another outbreak

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occurred in the Fall, 1987 in the southern part of Taiwan. The accumulative number of reported cases reached 1,387 at the end of 1987 [5]. Of these cases, 62% were reported in the Sanmin district of Kaohsiung city, and the largest outbreak took place in 1988 [6]. The number of reported cases was 10,420. Four types of virus were isolated from all of the reported cases, however most were dengue virus type 1 [7,8].

In Taiwan, only two species of *Aedes* (*Ae. aegypti* and *Ae. albopictus*) are considered to be threatening, because of their close association with humans in the urban areas [9]. Extensive larval surveys of *Ae. aegypti* and *Ae. albopictus* in Taiwan were carried out in 1988 to 1990 to reveal larval distribution and density. Results reveal that *Ae. albopictus* is the dominant and most widely distributed species on the island below 1,500m elevation. *Ae. aegypti* occurs mainly along the western coastal belt between the south of Patai and the north of Hengchen, below 1,000m, in the south of Taiwan [10]. By the number of dengue fever cases reported in 1988, dengue can apparently occur throughout the year in southern Taiwan, increasing greatly in July and reaching its peak in October. The number of dengue cases correlates significantly with seasonal fluctuation of population and regional density of *Ae. aegypti* [10].

The precise population density of *Ae. aegypti* in relation to dengue transmission has not been determined in Taiwan or in many other countries. The World Health Organization [11] has adopted a system of world-wide surveillance for vectors. The density figures corresponding to the larval indices of *Ae. aegypti* are used to indicate the epidemiological significance not only for yellow fever but also for dengue. However, the density figures in relation to the dengue transmission may vary in different countries. Investigating dengue transmission in Taiwan, therefore, becomes necessary. The most feasible methods for dengue vector control in Taiwan can be found only by identifying the vector species and their breeding habitats for vector control. The objectives of this investigation is to study the ecology of the two mosquitoes in the areas of the

nine outbreaks of dengue, as well as to evaluate their respective roles in the epidemiology of dengue fever.

MATERIALS AND METHODS

Survey teams:

Survey team consisted of 3 to 5 inspectors. All inspectors had previous experience in mosquito biology and surveillance.

Study area:

Twelve localities were selected for the project: Tungan and Pingtung districts, Pingtung; Tahien, Wanfu and Wantzu villages, Sanmin districts, Kaohsiung city; Linyuan and Fengshan districts, Kaohsiung county; and Hsuanchis district, Tainan county. They are all located in the southern part of Taiwan. These areas had a number of dengue cases recorded and were known to have *Ae. aegypti* and *Ae. albopictus* infestations. Yungching district, Changhua county, located in central Taiwan. Yunggho and Chunggho districts, Taipei county, located in the northern Taiwan were known to have only *Ae. albopictus*. However, at least one or two confirmed indigenous cases of dengue had been reported in each area.

Specimen collection and handling:

Immediately following the discovery of dengue cases from November 1987 to July 1992, a minimum of 50 residential premises were inspected in each selected area. Larval collecting equipment consisted of a large soup ladle, white enamel pan, tea strainer, kitchen baster and a small pipette. Prior to leaving each site, team members carefully cleaned and inspected all equipment to ensure that specimens were not transferred to the other sites. Water-holding containers at or near ground level in each premise were inspected. All of the larvae came from each breeding habitat, except for those from the large ones, e.g., jars, drums, rubber tires and flooded basements, were collected in bottles with the aid of pipettes and ladles. In the case of large containers, as many larvae as possible were collected in one or more samples of water. Each bottle was labeled with the collection area and the type and

location of the habitat. Larvae were killed by 70% alcohol in labeled vials. Whenever possible, pupae were held for adult emergence in holding cages and then processed as adults. Larvae were taken to the laboratory for identification and counting.

Larval indices:

Larval density figures of WHO corresponding to various larval indices [11] are as follows:

1. House index = percentage of examined houses, including examination of surrounding compound, that had larvae of *Aedes* in at least some containers.
2. Container index = percentage of examined water-holding containers that contained larvae of *Aedes*.
3. Breteau index = total number of containers with larvae of *Aedes* per 100 houses.
4. Density figure = an arbitrary scale of 1-9 which allows the different indices to be compared and correlated (Table 1).

Definitions:

For the purposes of this study, the following terms are defined:

Housing unit: The entire area of a house that bears one house number. A block of flats, thus, has as many housing units as house numbers.

Indoor: Any part of a house that is under a roof.

Outdoor: That part of a house that is not under a roof but is within the confines of

a housing unit, e.g., a garden or a compound outside a house.

RESULTS

Critical density of *Aedes* in relation to dengue transmission in Taiwan

From 1987 to 1991 following the outbreak of dengue fever, a survey of the distribution and density of *Aedes* around the patients' houses in epidemic areas was conducted. An investigation regarding the ecology of *Ae. aegypti* and *Ae. albopictus* and their relation to the epidemiology of dengue fever was also undertaken. The surveyed areas were Pingtung and Tungkan districts, Pingtung county; Linyuan and Fengshan districts, Kaohsiung county; Tahjen, Wanfu and Wantzu villages, Sanmin district, Kaohsiung city; and Hsuanchis district, Tainan county. Table 2 shows the indices of the two *Aedes* species in eight of the dengue fever epidemic areas. The house index, container index, and Breteau index for *Ae. aegypti* ranged from 17% to 38%, 14% to 38%, and 23% to 78%; for *Ae. albopictus* 0% to 18%, 0% to 14%, 0% to 34% respectively. Results show that, in the eight dengue fever epidemic areas, the densities of *Ae. aegypti* were all higher than those of *Ae. albopictus*. When the first epidemic occurred at the end of November 1989, *Ae. albopictus* was not found in Sanmin district of Kaohsiung city where the seven confirmed indigenous cases occurred. This observation indicated that *Ae. aegypti* was the sole vector of dengue fever in the Sammin

Table 1. *Aedes* larval density figures of WHO corresponding to various larval indices

Density figure	House index	Container index	Breteau index
1	1-3	1-2	1-4
2	4-7	3-5	5-9
3	8-17	6-9	10-19
4	18-28	10-14	20-34
5	29-37	15-20	35-49
6	38-49	21-27	50-74
7	50-59	28-31	75-99
8	60-76	32-40	100-199
9	77	41	200

Table 2. Larval indices of *Aedes aegypti* and *Aedes albopictus* in the dengue epidemic areas in southern Taiwan, 1987 ~ 1991

Locality	Month/Year	No. houses exam.	No. containers exam.	House index %		Container index %		Breteau index	
				aeg. (a)	alb. (b)	aeg.	alb.	aeg.	alb.
Tungkan, Pingtung	12/1987	50	92	32 (5)(c)	18 (4)	25 (6)	12 (4)	46 (5)	22 (4)
Sanmin, Kaohsiung (Tahien village)	12/1987	50	81	22 (4)	4 (2)	20 (5)	2 (1)	32 (4)	4 (1)
Linyuan, Kaohsiung	05/1988	50	120	38 (6)	12 (3)	33 (8)	14 (4)	78 (7)	34 (4)
Fengshan, Kaohsiung	06/1988	50	60	28 (4)	4 (2)	38 (8)	5 (2)	46 (5)	6 (2)
Pingtung, Pingtung	06/1988	50	94	24 (4)	4 (2)	16 (5)	2 (1)	30 (4)	4 (1)
Hsuanchia, Tainan	06/1988	50	92	32 (5)	12 (3)	26 (6)	9 (3)	48 (5)	16 (3)
Sanmin, Kaohsiung (Wanfu village)	12/1989	60	103	17 (3)	0 (0)	14 (4)	0 (0)	23 (4)	0 (0)
Sanmin, Kaohsiung (Wantzu village)	07/1991	50	72	24 (4)	10 (3)	25 (6)	11 (4)	36 (5)	16 (3)

(a) aeg. = *Aedes aegypti*(b) alb. = *Aedes albopictus*

(c) Number within brackets denotes density figure.

district. At the same time, a survey of 103 artificial water containers in the localities where dengue occurred revealed that the house index of *Ae. aegypti* was 17%, container index 14%, and Breteau index 23. These were the lowest *Ae. aegypti* threshold densities associated with the outbreak of dengue fever in Taiwan, at the time.

The population density was also high in epidemic areas. The population density in epidemic areas ranged from 365 to 10,992 persons per square km. From 1987 to 1991, surveillance of dengue outbreak localities verified that dengue primarily occurred in the urban and coastal belt where *Ae. aegypti* was the dominant species.

Another survey was carried out in December 1991 when an endemic outbreak occurred in Palon village, Sanmin district, Kaohsiung city. During that time, six confirmed indigenous cases were found. Again the predominant

species was *Ae. aegypti*. This time, the house index was 5%, the container index was 3% and Breteau index was 6. Another species with lower density was *Ae. albopictus*. In this case, the house index was 1%, container index 1% and the Breteau index 1. The number of *Ae. aegypti* larvae exceeded that of *Ae. albopictus* (Table 3). This suggests that the *Ae. aegypti* larval index was still sufficiently high to maintain transmission of the disease at an endemic level, even with a Breteau index of only 6. This is the lowest *Ae. aegypti* threshold density of dengue fever in endemic areas in Taiwan. This result was comparable to previous work which mentioned that an *Ae. aegypti* Breteau index of 5 was the threshold for dengue and urban yellow fever transmission [11]. Therefore, keeping *Ae. aegypti* density below that index in Taiwan is necessary to prevent dengue transmission.

A survey was carried out during 1991

Table 3. Threshold density of *Aedes* mosquitoes in the dengue endemic area in Palon village, Sanmin district, Kaohsiung city (October, 1991)

No. houses exam.	No. containers exam.	House index %			Container index %			Breteau index			Ratio of larvae aeg. : alb.
		aeg. (a)	alb. (b)	Both species	aeg.	alb.	Both species	aeg.	alb.	Both species	
161	319	5 (2)(c)	1 (1)	6 (2)	3 (2)	1 (1)	3 (2)	6 (2)	1 (1)	6 (2)	2.6 : 1

(a) aeg. = *Aedes aegypti*(b) alb. = *Aedes albopictus*

(c) Number within brackets denotes density figure.

when dengue occurred in Yungching district, Changhua county, in the absence of *Ae. aegypti*. In 1988 and 1992, similar studies in Chungho and Yungho districts, Taipei county found no *Ae. aegypti*, while *Ae. albopictus* was prevalent. Table 4 shows that the *Ae. albopictus* house index ranged from 38% to 40%, the container index was 25% to 35%, and the Breteau index was 50-64. In these areas, only one or two indigenous dengue cases were reported and no secondary transmission existed. To date there seems to be no definite correlation between *Ae. albopictus* density figures and the outbreak of dengue fever. So it is very difficult to explain the occurrence of these cases on the basis of epidemiology, and this data suggests that *Ae. albopictus* did not play a prominent role in the transmission of dengue in the past five years.

Breeding sites of *Aedes* mosquitoes in epidemic areas:

From the surveillance of *Aedes* breeding sites in 571 houses and 1033 water containers in nine dengue epidemic outbreak areas in southern Taiwan, a total of 181 *Ae. aegypti* breeding containers and 53 *Ae. albopictus* breeding containers were found. Table 5 lists the types of breeding containers in which either *Ae. aegypti* or *Ae. albopictus*, or both, were found. The breeding containers have been classified into 9 categories. Those results show that the breeding habitats of *Ae. aegypti* and *Ae. albopictus* are different. *Ae. aegypti* breeds mainly in flower vases and plates (36%) and buckets (16.0%), followed by cans and bottles (8.8%), tanks (8.8%), earthenware jars (6.6%), refrigerator receptacles (6.1%), tires (5.0%), flooded basements (3.3%), others (9.4%), while *Ae. albopictus* appeared to prefer breeding in tires (33.9%) and earthenware jars (15.1%), followed by flower vases and plates (13.2%), buckets (11.3%), cans and bottles (5.7%), tanks (3.8%), flooded basements

Table 4. The relation between *Aedes albopictus* density and dengue cases in Taiwan

Locality	Month/year	No. houses exam.	No. containers exam.	House index %	Container index %	Breteau index	Indigenous confirmed case
Yungho, Taipei	10/1988	50	93	38 (6)(a)	31 (7)	58 (6)	2
Yungching, Changhua	09/1991	50	102	40 (6)	25 (6)	50 (6)	1
Chungho, Taipei	06/1992	50	92	38 (6)	35 (8)	64 (6)	1

(a) Number within brackets denotes density figure.

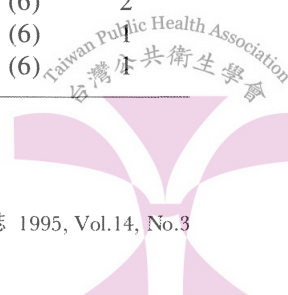


Table 5. Comparison of breeding habitats of *Aedes aegypti* and *Aedes albopictus* in the dengue epidemic areas in Taiwan, 1987-1991 (a)

Breeding habitat	No. positive containers (%)			No. containers with mixed breeding
	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Both species	
Tanks	16 (8.8)	2 (3.8)	17 (7.7)	1
Earthenware jars	12 (6.6)	8 (15.1)	16 (7.3)	4
Buckets	29 (16.0)	6 (11.3)	33 (15.0)	2
Cans and bottles	16 (8.8)	3 (5.7)	19 (8.6)	0
Tires	9 (5.0)	18 (33.9)	24 (10.9)	3
Flower vases and plates	65 (36.0)	7 (13.2)	71 (32.3)	1
Refrigerator receptacles	11 (6.1)	0 (0)	11 (5.0)	0
Flooded basements	6 (3.3)	2 (3.8)	6 (2.7)	2
Others	17 (9.4)	7 (13.2)	23 (10.5)	1
Total	181	53	220	14

(a) 571 houses and 1033 water containers were surveyed in nine epidemic areas during 1987~1991.

(3.8%), refrigerator receptacles (0%), others (13.2%). Both *Aedes* species breeding sites were found in flower vases and plates, followed by buckets, tires, cans and bottles, tanks, earthenware jars, refrigerator receptacles, and flooded basements. Of both species, mixed breeding was found in 6.3% of water containers surveyed, mainly in large outdoor containers, e.g. tanks, earthenware jars, buckets, tires and flooded basements. As classified by different types of containers, the percentage of breeding sites of the two *Aedes* species was 32.3 for ornamental containers, 30.0 for discarded containers, 24.6 for water storage containers, 10.4 for receptacles and 2.7 for flooded basements. Around the houses in four dengue fever epidemic areas in Sanmin district, Kaohsiung city, a high density of *Ae. aegypti* adult mosquitoes and larval in flooded basements was discovered. This result suggests that flooded basements were the major reason for the outbreak of epidemic dengue fever.

Distribution of breeding sites indoors and outdoors:

Table 6 shows that more artificial water containers and more breeding containers for both *Aedes* were found outdoors. It also reveals

that there were more *Ae. aegypti* than *Ae. albopictus* breeding sites, both indoors and outdoors. Of all *Ae. aegypti* breeding containers, 62% were found outdoors. The most common breeding containers found outdoors were earthenware jars, buckets, cans and bottles, tires. On the other hand, tanks, refrigerator receptacles and flooded basements were the most common indoor breeding containers. Similarly, 87% of the *Ae. albopictus* breeding containers were located outdoors, and most categories of breeding containers were located outdoors rather than indoors. Thus, the results suggest *Ae. albopictus* is an outdoor species. The positive rate of *Ae. aegypti* was higher outdoors (18.6%) than indoors (16.0%); in addition, *Ae. albopictus* was also higher outdoors (5.6%) than indoors (3.4%).

DISCUSSION

Dengue fever in Taiwan is a disease commonly found in urban inhabitants, with a concentration of cases occurring in areas of high population density. Mosquito surveys reveal that these areas also had high population densities of *Ae. aegypti*. The results of mosquito surveys, which were carried out from Decem-

Table 6. Distribution of indoor and outdoor breeding containers of *Aedes* Mosquitoes, 1987~1991 (a)

Breeding containers	No. positive containers of <i>Ae. aegypti</i>		No. positive containers of <i>Ae. albopictus</i>	
	Indoor	Outdoor	Indoor	Outdoor
Tanks	13	3	1	1
Earthenware jars	1	11	0	8
Buckets	3	26	1	5
Cans and bottles	1	15	0	3
Tires	0	9	0	18
Flower vases and plates	32	33	3	4
Refrigerator receptacles	11	0	0	0
Flooded basements	5	1	1	1
Others	2	15	1	6
Total	68	113	7	46
(%)	(38)	(62)	(13)	(87)

(a) 571 houses and 1033 water containers were surveyed in nine epidemic areas.

(b) Occurred in Sanmin district, Kaohsiung city.

ber 1987 to October 1991, suggest that *Ae. aegypti* was the sole vector of the disease. The data obtained in the present study suggest that *Ae. aegypti* is involved in the transmission of dengue fever in Taiwan. This species is common in the urban area in southern of Taiwan, and its distribution is consistent with the distribution of the dengue fever cases, which had an urban and suburban distribution. These demonstrate that the numbers of dengue cases which correlate significantly with seasonal population fluctuations and regional density of *Ae. aegypti* [10].

During the 1987 to 1991 mosquito surveys, it was that *Ae. albopictus* was common in both urban and rural areas [10]. This study has confirmed that *Ae. albopictus* is an exophilic species. Based on studies in the past five years, tentative conclusions may be drawn that the Taiwan strain of *Ae. albopictus* does not play a prominent role in the transmission of dengue in Taiwan, when its density figure is below eight. *Ae. albopictus* has been shown to be an efficient vector in the experimental transmission of classical dengue in mainland China and has been considered to be an important

vector of endemic dengue in South East Asia [12,13]. Therefore, when larval density figure is above 8, *Ae. albopictus* is still a potential vector in Taiwan.

The rationale behind most disease control programs based on mosquito control is to reduce the mosquito densities to a point which is below the threshold where epidemic transmission can occur. As mentioned in the WHO system, those places with a density figure of 1 (Breteau index below 5) are considered to be unlikely places for the disease to be transmitted. This study found that Breteau index of 6 or more was still sufficiently high to maintain transmission of the disease at an epidemic level. Therefore, to preventing future outbreaks necessitates keeping the Breteau index below 6 at all times in epidemic areas with high *Ae. aegypti* breeding. This observation indicates that a sustainable program of source reduction should be maintained in order to prevent any possibility of renewal of transmission.

At present, if any area in Taiwan is found to have a Breteau index of 50 or higher, it will be immediately sprayed with pesticide to kill the *Ae. aegypti* adults; and if Breteau index is

5 or more, it will be cleaned of breeding habitats. This strategy is found to be effective in achieving year round control of the vectors [6].

Surveys made in the 9 localities with dengue epidemics, showed that the breeding sites were of different types from those observed in the past. The present survey shows that *Ae. aegypti* breeds primarily in flower vases and plates, and *Ae. albopictus* breeds mainly in discarded automobile tires. The differences in *Aedes* breeding sites, as revealed by the present and past surveys, are due to changes of types of breeding places because of urbanization and industrialization. Thus, the most common breeding sites of *Ae. aegypti* and *Ae. albopictus* in Taiwan are closely associated with the habits of the people. Control of these mosquitoes depends largely on a change in such habits, either through source reduction or public health education.

Measures for the control of these two species can be effective only if information on their breeding habitats is made available. It is sufficient to reduce the *Ae. aegypti* population to below the disease transmission level by removal of only the most common breeding habitats. For the purpose of eradication, however, destroying also the minor breeding habitats would be necessary so that reinfestation from these sources is not possible.

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台灣登革熱流行區斑蚊密度及孳生場所調查

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1987年至1991年於登革熱開始發生之地區，立即在病患住家周圍展開斑蚊分布及密度調查，探討埃及斑蚊和白線斑蚊生態及其與登革熱流行之關係。結果顯示，九個登革熱流行地區埃及斑蚊密度皆高於白線斑蚊；其中在1989年12月高雄市三民區灣復里未發現有白線斑蚊；證明登革熱之發生埃及斑蚊為主要傳播媒介。在1991年10月調查三民區寶龍里埃及斑蚊密度住宅指數5%、容器指數3%、布氏指數6(二級)，此為台灣地區登革熱發生流行後，被擴散蔓延而成為地方性登革熱發生地區，埃及斑蚊最低臨界密度。依不同流行地區登革熱發生病例證實，埃及斑蚊傳播登革熱臨界密度也受人口密度影響。1987至1991年登革熱爆發地點主要發生在埃及斑蚊為優勢種之都市及沿海地區。截至目前止，仍無有力證據證明台灣地區之白

線斑蚊與登革熱流行有直接關係。由台灣南部九個登革熱發生流行區斑蚊孳生場所調查顯示，埃及斑蚊和白線斑蚊孳生環境不同，埃及斑蚊孳生場所主要為花器、水桶，白線斑蚊以輪胎及甕為主。就兩種斑蚊孳生場所用途分類，裝飾容器最高32.3%、廢棄容器30.0%、儲水容器24.6%、冰箱之水盤10.4%、積水地下室2.7%。由此顯示，都市化及工商業化結果，導致登革熱病媒孳生容器種類、材質及其屋內外分布改變，而使埃及斑蚊和白線斑蚊分布及密度異於往昔，同時使埃及斑蚊與人類關係更密切，而導致登革熱之發生。在高雄市三民區三個流行地區住戶周圍皆發現有積水地下室孳生大量埃及斑蚊成、幼蟲，顯示積水地下室在高雄市是發生流行登革熱主要原因。(中華衛誌 1995；14(3)：228-236)

關鍵詞：登革熱、埃及斑蚊、白線斑蚊

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