DENGUE AND ITS VECTORS IN THAILAND: CALCULATED TRANSMISSION RISK FROM TOTAL PUPAL COUNTS OF Aedes aegypti AND ASSOCIATION OF WING-LENGTH MEASUREMENTS WITH ASPECTS OF THE LARVAL HABITAT

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Abstract. Working in a village dengue focus in Chachoengsao Province, Thailand, aedine mosquito larvae and pupae were counted in all containers of 10 houses per month. The wings of female Aedes aegypti (L.) emerging from pupae were measured. Number of pupae and size of emerging females increased in containers with qualities that favored availability of larval food sources (e.g., uncovered containers). The small size of most mosquitoes compared with those raised in the laboratory indicated that the larval population as a whole was under nutritional stress. Applying the number of pupae per house and measurement of air and water temperature with an existing model, the risk of dengue transmission was greatest in May and June. The estimated number of female Aedes aegypti per house was well above the threshold for increasing transmission in all months but December through February. A phased approach to sampling immature aedine mosquitoes in Thailand is proposed, which would consist of routine surveillance of larval index and occasional total counts with measurement of wing size. Such a system would combine the benefits of the simple application of larval surveillance with the valuable data gathered from pupal counts and wing measurements.

INTRODUCTION

Dengue vector control programs often rely heavily on managing larval populations of the mosquito vector, either by eliminating container habitats or by using insecticides. Perhaps the ultimate example was the eradication of Aedes aegypti (L.) from Brazil during the 1930s following a highly organized program of surveillance and larval control. A variety of larval control programs with more modest goals have resulted in reduction of dengue transmission in Australia, Indonesia, Thailand, and Brazil.

Larval indices should be important to vector control efforts for at least 3 reasons. First, to apply larval control, it is necessary to find the larvae. Second, indices provide the means to prioritize locations or categories of larval habitats so that limited resources can be concentrated where they would have the greatest impact on disease transmission. Third, indices provide a means to evaluate the entomologic effectiveness of control measures. For operational agencies, the problem of finding an accurate larval index takes on a challenging aspect because of limits on funding and training.

The history of dengue vector control includes the creation of a large variety of larval indices, reflecting the need to compromise between the ideal and the practical. The ideal solution to larval surveillance is the complete count of every larva and pupa in every container of a community. The practical solution must take into account that sampling millions of residences may be necessary and that each residence may include more than a dozen containers. The various larval indices attempt to address this practical problem on a regional scale. The World Health Organization attempted to standardize practical larval indices in a seminal article describing the now famous container, house, and Breteau indices. These indices are based on simple determination of presence or absence of aedine larvae either in each container or somewhere in each house. Although some studies have shown that these indices are not accurate estimators of adult vector populations, other programs have used them successfully or continue to recommend their use. A great change came with Focks’ work during the 1990s, which described a method of counting pupae to estimate the number of female vectors per person in a community.

This article presents the results of applying a modified version of Focks’ sampling method and comparing it with results from traditional surveillance reported previously. By making complete counts of pupae and larvae in 10 houses per month, we were able to estimate the number of female vectors per house and the effects of the larval habitat on size of emerging female mosquitoes. We propose a phased approach to operational larval surveillance for dengue vector control in Thailand that would consist of frequent, simple larval surveillance and occasional pupal counts with wing measurements of emerging female Aedes aegypti. Highly trained personnel would perform complete counts of larvae and pupae at key locations. The data would be analyzed as a baseline for the locality to prioritize the importance of larval habitats and to assess the degree of vector control necessary to stop dengue transmission. Less highly trained operational personnel would perform routine surveillance of all containers in a community. By categorizing the abundance of aedine larvae in each container, these data could be used to target specific control efforts and to assess the efficacy of community-based vector control.

MATERIALS AND METHODS

Surveys were conducted in Hua Samrong subdistrict, Plaeng Yao district, Chachoengsao Province, Thailand, approximately 100 km east of Bangkok. Two kinds of sampling were conducted. First, small fish nets (approximately 20 × 15 cm with a long handle) were swirled through all containers in 3 villages in the hot season (February–April 1990), wet season (May–October 1990), and cool season (November 1990–January 1991). This sampling method captured only a portion of immature mosquitoes in each container. The other sampling method was complete filtering, which consisted of emptying every container in a house through a strainer and capturing all immature mosquitoes. Although more precise, this method was much more laborious and caused considerable disruption to a household. Complete filtering was ap-
plied to 10 houses per month for 1 year in Village 8 (total of 120 houses). Generally, only 1 or 2 houses could be sampled in a day so that the 10 houses were sampled throughout a month. Also the same house was never resampled during the year, partly to avoid further household disruption and partly to avoid making a modification that would influence subsequent sampling.

All pupae captured using these methods were taken back to the laboratory individually in 5-ml plastic tubes with loosely fitting caps. Adult mosquitoes were allowed to emerge, then transferred to a dry tube, where they died after approximately 24 hours. The adults were identified to species, and the result was recorded for the individual container producing the pupa. The wings of female *Aedes* were measured according to the method of Sunanochitrapon et al. Only *Ae. aegypti* (L.) is considered here, with *Ae. albopictus* (Skuse) to be treated in a separate publication.

Complete filtering produced data on the absolute number of larvae and pupae in a container. Containers were categorized according to type of container and type of cover (explained in Kittayapong and Strickman, with illustration of standard water jar and standard metal lid). The sources of water were divided into 4 categories: (1) Rain water that was collected accidentally; (2) rainwater that was collected intentionally, usually from a roof gutter with attached hose; (3) water drawn from a well; and (4) water taken from a pond or canal.

Comparisons of the number of larvae and pupae according to container type, cover type, and source of water were carried out on all containers sampled throughout the year. To make meaningful comparisons, only container types with >100 replicates (i.e., standard water jars, small water jars, and ant traps) were compared quantitatively. Because the kind of container had some influence over the number of larvae and pupae observed, the potential influence of covers on containers was examined only for standard water jars. Covers were categorized as absent, the standard metal cover, or any kind of cover (including the standard metal cover, metal trays, metal bowls, pieces of sheet metal, wooden covers, basket covers, plastic bowls, plastic sheet, pieces of hard board (masonite), or pieces of cement composite material). The potential influence of the source of water was examined by comparing standard water jars only, regardless of cover, and eliminating the small number of jars containing ground water. Because the data were not normally distributed, statistical comparisons were made by performing a series of pairwise comparisons with the Mann-Whitney *U* nonparametric test (GraphPad Prism 2.01, GraphPad Software Incorporated, San Diego, CA). Examination of each parameter involved only 3 comparisons; we believe it is unlikely that significant differences were detected where none existed.

The numbers of pupae and larvae were compared month to month, pooling data for all containers at all locations. These time series data were presented descriptively using as a measure of variation the 95% confidence limits calculated from means and SDs (GraphPad StatMate, San Diego, CA). The Breteau index was calculated for each month by multiplying the number of positive containers by [100/(number of houses sampled)] to compute the ratio of positive containers per 100 houses. The Breteau index was included for comparative purposes.

To get a monthly estimate of pupae per house, it was necessary to allow for variation in the number of containers sampled each month. The following series of equations describe how this calculation was accomplished.

**Eq. 1:** \( (P/C)_m = (TP_m)/(TC_m) \)

Where: \( TP_m \) = total pupae collected in 10 houses during 1 month (m)

\( TC_m \) = total containers sampled in 10 houses during 1 month (m)

**Eq. 2:** \( P/C = (\Sigma TP_m)/(\Sigma TC_m) \)

**Eq. 3:** \( D_m = (P/C_m)/(P/C) \)

Where: \( D_m \) = deviation in pupal count for a given month (m)

**Eq. 4:** \( P/H = (\Sigma TP_m)/(TH) \)

Where: \( TH \) = total number of houses in the village (= 120)

**Eq. 5:** \( P/H_m = D_m (P/H)/12 \)

Where: \( P/H_m \) = estimate of pupae per house in a given month (m)

The number of adult female *Ae. aegypti* per house in each month was estimated by 2 different methods. First, the accumulation of females for 30 days was calculated assuming that the number of pupae per house would remain the same during that period. The calculation also applied the assumptions that pupae require 48 hours to develop to adults and that 50% of the pupae were females. The accumulation of female mosquitoes per house was calculated with either 60% or 90% daily adult survival rate.

The model reported by Focks et al. was used to calculate another estimate of the number of female *Ae. aegypti* per house. As presented, this model requires input of number of pupae and water temperature to get an estimate of standing crop of female mosquitoes. We were able to use actual measurements of water temperature for these calculations. The minimum and maximum water temperatures were measured 3 times per week from June 1990 through February 1991 in each of 3 water jars located indoors, under a house, and outdoors. These 6 measurements were averaged by month to get a representative water temperature. The number of pupae per house for each month (Eq. 5: \( P/H_m \)) was estimated as described previously. The observed temperature was used to calculate linear interpolation between the 2°C intervals reported by Focks et al.

The estimate of female *Ae. aegypti* standing crop per house in each month was compared with the threshold number of mosquitoes per person to support a 10% increase in dengue transmission. For the calculation of threshold, we assumed that each house had 5 residents and that seroprevalence was 67% (reasonable because almost all adults in the community were immune to dengue). We were able to use actual air temperatures measured daily at the health station in Hua...
RESULTs

The productivity of larval habitats in Village 8 was measured by counting all of the larvae and pupae in containers at 10 houses each month (Figure 1). Seasonally the number of larvae per container was higher in May than in any other month, corresponding to the beginning of the wet season. The number of larvae decreased to its lowest level in the cool season (December–February). The number of pupae roughly paralleled the seasonal abundance of larvae, with highest numbers in May and June and the lowest number in February. Pupal abundance per container appeared to be nearly constant during the remainder of the year. The Breteau index followed similar seasonal trends, but the differences were not as pronounced.

The type of container apparently affected the total number of larvae or pupae to some extent (Table 1). The only statistically significant difference associated with the type of container was greater numbers of larvae in small water jars (mean 22.0 larvae per jar) than in standard water jars (mean 15.8 larvae per jar). The number of larvae in ant traps (mean 14.1 larvae per trap) was not significantly different from the other 2 kinds of containers. These differences might be considered more significant biologically when the relative volumes are taken into account. Larvae per liter can be approximated as 0.12 for standard jars, 0.62 for small jars, and 56.0 for ant traps.

The number of pupae was similar in the 3 kinds of containers, the means varying between 1.0 pupa per standard jar and 1.7 pupae per small water jar. Consideration might be given to the fact that smaller sites were more productive than the larger sites on the basis of pupae per liter (0.007 for standard jars, 0.05 for small jars, and 4.8 for ant traps).

Considering only standard water jars, covers apparently reduced the number of larvae and the number of pupae (Table 2). Regardless of the kind of cover, uncovered containers had more larvae (mean 20.7 larvae per container) and more pupae (mean 1.8 pupae per container) than covered containers (mean 12.9 larvae per container and 0.57 pupa per container).

The source of water also influenced the number of larvae and pupae in standard water jars (Table 3). Unintentionally collected rainwater produced significantly more larvae (mean 39.4 per jar) and pupae (mean 5.3 per jar) than intentionally collected rainwater (15.8 larvae and 0.43 pupa per jar) or well water (13.7 larvae and 1.0 pupa per jar).

The model estimate of Ae. aegypti females per house was closest to the calculation that assumed 90% survival per day (Figures 2 and 3). Using the results of the model, adult mosquitoes were most abundant in May and June and least abundant in December–February. Comparison of the estimate of mosquito abundance to the critical threshold for dengue transmission showed that an outbreak could have occurred at almost any time during the year. December and February were the only months when the estimated number of female Ae. aegypti was lower than the threshold for a 10% increase in transmission. The mean indoor temperature produced a lower threshold than the mean outdoor temperature except in April at the peak of the hot season, when outdoor temperatures were higher than indoor temperatures.

The nature of larval sites influenced the wing length of female Ae. aegypti emerging from pupae collected at the site (Figure 4). Certain uses of containers corresponded to larger or smaller mosquitoes. The largest mosquitoes came from sites used to provide water to animals or used for foot washing before entering a home. The smallest mosquitoes emerged from pupae collected from drinking water. The type of container was not as strongly related to size. Only cement containers and small water jars produced Ae. aegypti females with longer wings; other types of containers were similar to each other. As might be expected, containers with a greater number of larvae produced smaller mosquitoes than containers with fewer larvae. Also, uncovered containers produced larger mosquitoes than covered containers. The source of water did not have a large influence on size except that the small number of pupae collected from containers with water from ponds or canals produced adults with shorter wings. Finally, containers located inside a building produced smaller mosquitoes than containers located under a roof outdoors.

DISCUSSION

Collection of pupae for surveillance of Aedes vectors of dengue has been promoted as a more accurate index of female mosquitoes than traditional larval surveillance. The technique requires filtration of all water from all potential habitats to count every pupa in a home. The pupae are then reared to adults for identification. Potentially the technique provides multiple kinds of data about the vector population, including the number of pupae per household and the size of adult mosquitoes.

We were able to count all larvae and pupae in 10 houses per month within a Thai village as part of a larger study. As noted by Focks and Chadee in Trinidad, the nature of a container influenced its productivity. Our previous (September–October, 1989) surveillance efforts in the same village, which simply recorded the presence or absence of Aedes immatures, had shown that standard water jars accounted for 57% of infested sites and that small water jars accounted for
16% of infested sites. The current study using complete counts of larvae and pupae produced a similar conclusion (50% of immatures contributed by standard water jars, 22% by small water jars) to the previous survey. The statistics derived from complete counts of immature *Aedes* indicated that the 2 common types of water jars produced >70% of dengue vectors in Village 8.

Although classifying the containers by type would seem to be one of the most logical means of categorizing larval habitats, this categorization actually groups together a number of qualities that influence the mosquitoes. Presumably, this variation would create a larger error term and make differences more difficult to detect. Analyzing only categories with abundant replicates, we found that small water jars (generally used for pickling fish or vegetables) contained more larvae than either standard water jars or ant traps, but that none of the 3 kinds of containers varied significantly in their production of pupae. On a volume basis, ant traps appeared to be far more productive than the other containers, possibly signifying that these dirty sites contained sufficient nutrition to support more mosquito development.

Differences in larval and pupal production were much clearer when only standard water jars were considered. Any kind of cover was associated with significantly lower numbers of larvae and pupae, again consistent with the idea that sites capturing more sources of nutrition from the environment would favor aedine development. Standard water jars with unintentionally collected rainwater (basically, unused water jars left outdoors) contained more than twice as many larvae and 5–10 times as many pupae as jars with either intentionally

![Figure 1](https://example.com/figure1.png)
collected rainwater or well water. Unintentionally collected rainwater was not managed for any purpose and contained whatever nutrients that fell in the jar. Intentionally collected rainwater usually was used for drinking and kept clean. Well water was used for many purposes, possibly causing constant removal of nutrients. Standard water jars frequently were covered to keep the water cleaner (kinds of covers reviewed in Kittayapong and Strickman) . The standard metal cover (a commercial item similar to a trashcan lid) was associated with significantly fewer larvae and pupae than in uncovered jars. Behavioral experiments in the laboratory had shown that although Ae. aegypti actively sought the narrow gaps between the cover and the lip of the water jar to reach oviposition sites, the number of eggs deposited was less in covered jars. The physical barrier created by covers also might influence the number of larvae and pupae observed in covered jars.

This variation may reflect to some extent the survival rate of larvae in various containers. Presumably, one of the causes of a high ratio of pupae to larvae would be better conditions for survival. These conditions might include availability of food, favorable water temperature, or freedom from aquatic predators. The low rate of successful transition from larva to pupa (19.1%) observed by Dye in Bangkok suggests that an observed ratio of pupae to larvae rarely reaches a maximum value in the field.

The season of greatest larval and pupal abundance was the beginning of the rainy season in May and June. Larvae appeared to have a secondary peak of abundance in October. The seasonal pattern of pupal abundance was similar but less distinct, and the pattern of the Breteau index was even less distinct. Larval abundance may be affected more directly by seasonal effects, whereas seasonal effects on pupal abundance may be smoothed out by various influences on survival during larval development. The Breteau index is likely to be even less related to season because it does not measure the abundance of larvae or pupae in each container. Although the Breteau index is a much less precise measure than total counts or than a larval index based on categories of abundance, in this situation it appeared to be sensitive enough to detect the higher abundance in May and the lower abundance in December through February. What is more, the Breteau index reflected the generally high abundance of Ae. aegypti in Hua Samrong, as observed in a previous study.

### Table 1

Relation of 3 main (>100 samples) container types to total number of Ae. aegypti larvae and pupae sampled by filtering all water in all containers of 10 houses per month in Village 8, Hua Samrong subdistrict, Plaeng Yao District, Chachoengsao Province, Thailand, March 1990–February 1991

<table>
<thead>
<tr>
<th>Type of container</th>
<th>Mean ± SD (95% confidence limits)</th>
<th>Larvae</th>
<th>Pupae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard water jar</td>
<td>653</td>
<td>15.8 ± 42.24 (12.6–19.1)</td>
<td>1.0 ± 3.53 (0.7–1.3)</td>
</tr>
<tr>
<td>Small water jar</td>
<td>166</td>
<td>22.2 ± 53.07 (13.9–30.1)</td>
<td>1.7 ± 4.52 (1.0–2.44)</td>
</tr>
<tr>
<td>Ant trap</td>
<td>101</td>
<td>14.1 ± 25.79 (9.0–20.0)</td>
<td>1.2 ± 3.52 (0.5–1.9)</td>
</tr>
</tbody>
</table>

* Significance of comparisons using Mann-Whitney U test: standard water jar versus small water jar, P = 0.038; standard water jar versus ant trap, P = 0.060; small water jar versus ant trap, P = 0.056.
† Significance of comparisons using Mann-Whitney U test: standard water jar versus small water jar, P = 0.063; standard water jar versus ant trap, P = 0.009; small water jar versus ant trap, P = 0.8157.

### Table 2

Influence of covering standard water jars on total number of Ae. aegypti larvae and pupae sampled by filtering all water in all containers of 10 houses per month in Village 8, Hua Samrong subdistrict, Plaeng Yao District, Chachoengsao Province, Thailand, March 1990–February 1991

<table>
<thead>
<tr>
<th>Type of cover</th>
<th>Mean ± SD (95% confidence limits)</th>
<th>Larvae</th>
<th>Pupae</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>241</td>
<td>20.7 ± 43.97 (15.2–26.3)</td>
<td>1.8 ± 4.51 (1.2–2.4)</td>
</tr>
<tr>
<td>Standard metal</td>
<td>294</td>
<td>12.3 ± 40.36 (7.7–16.9)</td>
<td>0.59 ± 3.08 (0.2–0.9)</td>
</tr>
<tr>
<td>Any cover</td>
<td>412</td>
<td>12.9 ± 40.98 (9.0–16.9)</td>
<td>0.57 ± 2.72 (0.3–0.8)</td>
</tr>
</tbody>
</table>

* Significance of comparisons using Mann-Whitney U test: none versus standard metal cover, P = 0.0033; none versus any cover, P = 0.0024; standard metal cover versus any cover, P = 0.0264.
† Significance of comparisons using Mann-Whitney U test: none versus standard metal cover, P = 0.0027; none versus any cover, P = 0.0032; standard metal cover versus any cover, P = 0.7346.

### Table 3

Influence of source of water in standard water jars on total number of Ae. aegypti larvae and pupae sampled by filtering all water in all containers of 10 houses per month in Village 8, Hua Samrong subdistrict, Plaeng Yao District, Chachoengsao Province, Thailand, March 1990–February 1991

<table>
<thead>
<tr>
<th>Source of water</th>
<th>Mean ± SD (95% confidence limits)</th>
<th>Larvae</th>
<th>Pupae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintentional rain</td>
<td>19</td>
<td>39.4 ± 56.46 (12.2–66.6)</td>
<td>5.3 ± 8.90 (1.0–9.6)</td>
</tr>
<tr>
<td>Intentional rain</td>
<td>216</td>
<td>15.8 ± 45.73 (9.7–21.9)</td>
<td>0.43 ± 1.39 (0.2–0.6)</td>
</tr>
<tr>
<td>Well water</td>
<td>190</td>
<td>13.7 ± 32.88 (10.5–16.9)</td>
<td>1.0 ± 3.40 (0.7–1.4)</td>
</tr>
</tbody>
</table>

* Significance of comparisons using Mann-Whitney U test: unintentional rain versus intentional rain, P = 0.007; unintentional rain versus well water, P = 0.0186; intentional rain versus well water, P = 0.0832.
† Significance of comparisons using Mann-Whitney U test: unintentional rain versus intentional rain, P = 0.0066; unintentional rain versus well water, P = 0.0212; intentional rain versus well water, P = 0.1377.
Trends in the number of adult female Aedes were similar, whether calculated from the number of pupae and 90% daily adult survival or from Focks' model. Both models resulted in a distinctive peak in May and June. Using 90% daily adult survival, there was a second peak in October and November. Focks' model did not produce this secondary peak because it took the cooler temperatures of the season into account. The seasonal pattern becomes much less distinct under the assumption of 60% daily adult survival. Based on the mark-release-recapture experiments carried out in Village 6, daily survival of *Ae. aegypti* in the area of Hua Samrong is nearly 90% during the rainy season, closely matching Focks' model.

Focks' model of the number of female vectors necessary to support a 10% increase in dengue transmission given 67% immunity in the human population and monthly reintroduction of the virus produces interesting results compared with the number of female vectors calculated from the number of pupae per container. The threshold is lower than the calculated number of vectors for every month except December and February. Favoring transmission of dengue, the threshold tended to decrease at the same time as the number of female vectors tended to increase. The model depends on temperature to estimate extrinsic incubation time of the virus in mosquitoes so that the source of temperature data could be important. We compared mean indoor temperature, mean outdoor temperature, and overall mean temperature. Although mosquito populations in Hua Samrong were usually higher than the threshold regardless of the source of temperature data, indoor temperature resulted in a lower threshold than outdoor temperature during all months except April. If these calculations were being used to estimate the minimum level of vector control necessary to stop transmission, the indoor temperature would result in the perception of a need for more thorough vector control. The actual temperature to which female mosquitoes are exposed is a research need for more accurate estimates of dengue transmission risk.

Many different aspects of the larval habitat affected the wing lengths of *Ae. aegypti* emerging from pupae. As might be expected, most of these properties can be related to probable levels of larval nutrition in the habitat. Containers used to provide water to chickens produced the largest mosquitoes and containers used for drinking water produced the smallest ones. Water for chickens probably contained a great deal of foreign material compared with drinking water intentionally maintained to protect its cleanliness. The mean wing lengths of mosquitoes from the field ranged from <2.2 mm (collected from groundwater) to 2.7 mm (collected from chicken water). *Aedes aegypti* collected from the same area and reared in the laboratory under optimal conditions had a mean wing length of 3.0 mm. Evidently, mosquitoes in the field in Village 8

![Figure 3](chart.png)

**FIGURE 3.** Comparison of a model estimate\(^\text{10}\) of female *Aedes aegypti* per house each month with calculated threshold\(^\text{10}\) of mosquitoes per house to sustain a 10% increase in dengue transmission, assuming 67% of people are immune. The threshold was calculated from mean indoor temperature, mean outdoor temperature, and mean indoor and outdoor temperatures. The scale of the vertical axis is truncated at 25 to emphasize differences when mosquitoes were less abundant.
were generally under nutritional stress. Local conditions relieving this stress in a single house or in a group of houses could result in larger mosquitoes in a local area.

The susceptibility of *Ae.aegypti* to dengue virus infection has been related to 3 nongenetic factors: changes in temperature; changes in larval nutrition; and changes in larval population density. All of these factors influence the size of emerging adults. Larger *Ae.aegypti* females are apparently better vectors in terms of their physiologic capability to acquire dengue infection orally and their persistence in feeding successfully. The tendency of smaller females to feed more often could be interpreted as contributing to increased vectorial capacity because of more chances to infect humans. Greater feeding frequency also might decrease vectorial capacity because of the increased risk of death from host defensive behavior before completion of the extrinsic incubation period. Less directly, larger female *Ae. aegypti* might contribute to a higher level of dengue transmission in an area because larger mosquitoes are more fecund.

Larval surveillance is a necessary part of any integrated program of dengue vector control. Detailed knowledge of the kinds of containers commonly infested with larval vector spe-

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**FIGURE 4.** Wing lengths of female *Aedes aegypti* emerging from pupae collected from household containers in Villages 6, 8, and 9 from March 1990 to February 1991. Within each graph, categories not sharing a common lower case letter were significantly different at the 95% level. Error bars represent the 95% confidence limits, and diamonds are the mean values. For container use: $f = 2.21; df = 29/2.216; P = 0.0002$; CHICK, chickens to drink, $n = 32$; PIG, pigs to drink, $n = 68$; FOOT, washing feet before entering a home, $n = 95$; ST DK, stored for drinking, $n = 25$; NONE, no household purpose; WASH, household washing, $n = 660$; KITCH, various uses in kitchen, $n = 122$; DK/CK, drinking and cooking; BATH, bathing, not in bathroom, $n = 83$; DRINK, drinking, $n = 61$. For container type, $f = 1.72; df = 11/2.266; P = 0.0625$; CMNT, any cement container, $n = 70$; SM JR, small ceramic water jar, $n = 421$; MISC, miscellaneous discarded items, $n = 129$; BASIN, large cement sink used for clothes washing or reservoir for flushing toilets, $n = 261$; LG JR, large cement water jar, $n = 20$; ST JR, standard size ceramic water jar, $n = 1,035$; ANT, ant trap, a ceramic device providing a water barrier to ants, $n = 261$; COCO, coconut shell, $n = 38$; TIRE, discarded tire, $n = 35$. For larval abundance, $f = 2.28; df = 2.282; P = 0.022$; LO DENS, container with 1–9 immature *Aedes*, from either complete filtering or fish net sampling; HI DENS, container with $\geq 10$ immature *Aedes*. For cover type, $f = 4.89; df = 13/2.270; P < 0.0001$; NONE, no cover, $n = 1,874$; STD, commercial metal cover for standard water jar, $n = 189$; PL BWL, container covered with plastic bowl, $n = 28$; WOOD, cover made from wood, usually slats, $n = 87$; TRAY, container covered with metal tray, $n = 40$. For water source, $f = 7.53; df = 3/2.280; P = 0.0001$; WELL, water drawn from a well, $n = 1,805$; RAIN, water unintentionally accumulated from rain, $n = 288$; COL, intentionally collected rain water, $n = 177$; GRD, water taken from a pond or canal, $n = 14$. For container position, $f = 4.21; df = 3/2.279; P = 0.0056$; U RF, under a roof, but not in a building, $n = 775$; BTH, in a bathroom, $n = 422$; OUT, outdoors, $n = 580$; IN, inside a building, $n = 508$. 

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cies provides targets for treatment and source reduction. Quantitation of the number of larvae in different containers can be used to prioritize treatment efforts based on the relative attractiveness of sites to ovipositing females. Complete counts of larval and pupae produce data for prioritization based on the actual productivity of each site. Measurement of the wing length of individual females emerging from field-collected pupae could add yet another level of precision to estimates of dengue risk, if further experiments confirm that larger Aedes aegypti are more potent vectors.

Complete counts of immature stages and measurements of female wing length require greater effort and cost for collection and analysis of data. Even in a research project, we found that filtering every container throughout 1 Thai village was impossible to accomplish during a short period of time. Despite the difficulty and as pointed out by Focks et al., complete counts produced data with great practical implications. By sampling 10 houses per month, we saw that conditions apparently contributing to better larval nutrition (lack of a cover, lack of attempts to keep water clean, water sources with more foreign material) supported production of greater numbers of larger mosquitoes. Calculations of the number of female mosquitoes per house based on the number of pupae used as a comparison with Focks’ model estimate of the number of vectors necessary to support expanding transmission of dengue. These comparisons showed that the village in our study contained enough mosquitoes to sustain dengue transmission throughout at least 9 months of the year. To stop transmission in May, it would have been necessary to reduce the population of Aedes aegypti by >90% (from a calculated level of 49 females per house to <5 females per house).

The results of this study suggest several practical measures to improve dengue vector control in Southeast Asia. First, simple surveillance of containers for presence or absence of Aedes larvae is valuable and practical wherever vector control is applied. With little extra effort, the surveillance can produce a quantitative estimate by scoring the abundance of larvae from netted collections and summarizing data as a “larval index.” Public health personnel from a higher administrative level could perform total counts of larvae and pupae at representative locations, retaining the emerging adults for wing measurement. These data could be interpreted to produce regional prioritization of container types for larval control. The data also might suggest methods for reducing productivity of certain kinds of containers, for example, by encouraging cleansing of dishes used to provide water for chickens. Finally, because local dengue transmission varies considerably over short distances, pupal counts might provide an accurate method of determining whether vector control is being applied adequately to stop a local dengue outbreak.

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