

COMMUNITY PARTICIPATION AND APPROPRIATE TECHNOLOGIES FOR DENGUE VECTOR CONTROL AT TRANSMISSION FOCI IN THAILAND

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ABSTRACT. A community-based dengue vector control trial was conducted at transmission foci in Plaeng Yao District, Chachoengsao Province, eastern Thailand. Implementation was done by the local community in collaboration with local administration, public health, and school authorities. Our cost-effective approaches combined a source reduction campaign with appropriate vector control technologies applied within the foci (within 100 m around the foci) and also within schools attended by children from the treated areas. Vector management measures by local government included cleanup campaigns before the rainy season followed by a routine garbage pickup during the rainy season. Locally made screen covers for water jars, a combination of local *Bacillus thuringiensis* subsp. *israelensis* and *Mesocyclops thermocyclopoideus* (copepod), and locally made lethal ovitraps were appropriate technologies used by the community in this campaign. The success of our intervention was evidenced by the significant reduction of dengue vectors and dengue hemorrhagic fever cases in treated areas compared with untreated areas.

KEY WORDS *Aedes aegypti*, *Bacillus thuringiensis*, copepod, community participation, dengue, lethal ovitrap, vector control

INTRODUCTION

Dengue fever (DF) and dengue hemorrhagic fever (DHF) are considered important reemerging arboviral diseases in many tropical parts of the world. The pathogen consists of 4 serotypes of dengue virus designated as DEN1, DEN2, DEN3, and DEN4 (Gubler 1987). In Thailand, epidemic dengue was first recognized in 1958 and since then, the disease has become widely accepted as one of the major public health problems (Nimmannitya 1978, Kantachuvessiri 2002). The largest outbreak of DHF in Thailand occurred in 1987 with 174,825 cases and 1,007 deaths reported (Ungchusak and Kunasol 1988, Sucharit 1993). Unless the current trend of epidemics is reversed, DHF will remain a public health problem in Thailand (WHO 1999).

Aedes aegypti is the major vector of dengue in most countries, and dengue virus has frequently been isolated from field-caught *Ae. aegypti* adults (Smith et al. 1971, Gubler 1987, Thavara et al. 1996). This introduced mosquito was first found in Thailand in 1907 and has now spread throughout the country. Larval developmental sites are found close to human dwellings, because it prefers clean water in many types of domestic containers, especially typical water storage jars and cement bath basins (Kittayapong and Strickman 1993a, Strickman and Kittayapong 2002).

Because dengue has 4 viral serotypes and a quadravalent vaccine is still not available, control efforts in Thailand have focused on controlling mosquito vectors. From the initial program in the 1960s, vector control for dengue by the Ministry of Public Health has concentrated on insecticide spraying to control adults and on temephos (1% Abate sand granule) to control larval stages. However, despite intensive vector control programs and established vector surveillance strategies countrywide, the successful suppression of dengue transmission has not been fully achieved as indicated by the number of reported cases in Thailand over the past 10 years (exceeded 30,000/year). This rate may be due to weaknesses in program management or to a lack of control efficiency. The lack of efficacy of ultra-low volume and thermal fog application techniques has led to a reevaluation of recommended strategies for prevention and control of *Ae. aegypti* ranging from integrated approaches to community participation (Gubler and Clark 1996). In addition, the consequences of the intensive use of insecticides has caused insecticide resistance in many insects, including mosquitoes, and insecticide residues retained in the food chain affect many life forms, including soil bacteria and plants (Hemingway and Ranson 2000).

For these reasons, the trend in dengue vector control has shifted from the use of chemical-based control to biological-based control and source reduction and environmental management through community participation. The latter approach has showed success in a few developing countries (Nam et al. 1998, Wang et al. 2000, Kay et al. 2002, Nam et al. 2005) and is presently being promoted in several countries where dengue

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is a public health problem. In Thailand, attempts to control dengue through community participation have failed (Panthumachinda et al. 1986, Ungchusak and Kunasol 1988). In this article, we report a cost-effective successful vector control intervention with emphasis on the integrated biological and physical control methodologies and the community participation approach.

MATERIALS AND METHODS

Geographic information system (GIS) mapping of study villages and larval-positive houses

Our study area is located in Plaeng Yao District of Chachoengsao Province in the eastern part of Thailand. This area is composed of several rural and semirural villages that are of typical Thai composition. The pilot treatment village (village 10) is located in the Hua Sam Rong Subdistrict, whereas the control village (village 7) is located in the Wang Yen Subdistrict. The treatment village could be subdivided into 3 groups of aggregated houses separated by rice fields, irrigated canals, and small roads. The location of houses in both treatment and control villages was recorded using a Leica GS5+ global positioning system (GPS) unit (Leica Geosystems Inc., Torrance, CA). A GIS map of the villages was created using the digital-based map of the Royal Thai Survey Department of Thailand (scale of 1 = 50,000) and the ArcView program (ESRI, Redlands, CA). Larval surveys were carried out in both study villages by using the methods described in Strickman and Kittayapong (2002). Larval-positive houses and the number of larvae sampled were recorded and integrated into the GIS map.

Cost-effective vector control methodologies at community level

For the intervention program to be cost-effective, vector control was conducted only in dengue foci in the treatment village during the rainy season, when the peak transmission occurs in Thailand. Dengue foci were defined as a group of houses within a 100-m radius of case houses that had IgM- and IgG-positive students (Kittayapong et al., unpublished data). The areas outside of dengue foci were groups of houses within a 100-m radius of the house that had no IgM- and IgG-positive students (=controls). Integrated biological and physical control methodologies were implemented by the community with emphasis on controlling breeding sites of immature vectors. The most abundant breeding containers in most typical Thai villages are water storage jars of various sizes, especially the standard-sized water jars (200–250 liters). These water jars were treated with 3 types of screen

covers designed according to the purpose and tradition of water use in the community (Kittayapong and Strickman 1993b). Permanent breeding containers other than water jars were treated with a combination of locally produced *Bacillus thuringiensis* subsp. *israelensis* (*Bti*) and the local copepod *Mesocyclops thermocyclopoidea* as described in Chansang et al. (2004). These domestic containers were classified into 8 categories as follows: 1) cement bath basins, 2) foot-bath basins, 3) basins or drums for animal use and for watering plants, 4) hygiene jars, 5) flower vases, 6) ant traps, 7) plastic or metal drums, and 8) miscellaneous containers. A single application of locally made lethal ovitraps was the method used to reduce the population of adult *Ae. aegypti* vectors that were not killed in the immature stages. The lethal ovitrap model used in this study was a modification of the model developed by Zeichner and Perich (1999). Ovitrap consisted of black plastic cups (500-ml capacity) with permethrin-impregnated ovistrips rolled inside the cup. When used, the cup was filled with clean water to attract *Ae. aegypti* females to lay their eggs on the ovistrips. During the control intervention period, 2–5 lethal ovitraps were placed in each house. The ovistrips were replaced monthly, and the old ovistrips were brought back to the laboratory where the dead mosquitoes were identified and the number of eggs laid in the ovistrips was recorded.

Apart from using these simple vector control methodologies, source reduction and cleanup campaigns were organized just before the rainy season to reduce any discarded containers that could become potential breeding sites for mosquito vectors. This campaign was a collaboration between household members in the community and local administration, public health, and school authorities. The routine weekly garbage pickup was organized by the local administrative authority after the cleanup campaign and continued through the rainy season.

Approach for community participation and health education

In any community-based vector control intervention, community participation is the key to the success of the programs. Because participation of the community in Thailand is usually influenced by leaders or other key people, convincing these key people to take responsibility for dengue control in their community was the important first step to obtain community participation in our program. Key people in the community were the heads of villages and schools, the Local Administrative Authority, and the Local Public Health Office. These leaders were convinced about the seriousness of the disease and the necessity of disease control and

prevention. During an intervention, designated key people actively monitored vector control activities in the targeted dengue foci. The personnel who helped apply vector control methodologies at the household level and in schools were health volunteers and students, respectively.

General education about the symptoms of the disease, the biology of the mosquito vectors, and the methodologies for controlling these dengue vectors were implemented in the targeted community and schools. In our program, public health volunteers were responsible for dengue vector control in the 10–15 houses surrounding their own homes. They also were the people who delivered health education materials to these households' neighbors. The specific training of health volunteers to produce and distribute vector control tools such as screen covers as well as to learn how to apply the vector control products properly was the key factor for the success of this intervention program.

RESULTS

Larval surveys were conducted in both treatment and control villages to obtain baseline data before vector control activities commenced. Results are shown in Fig. 1. The abundance of larvae was compared inside and outside of transmission foci and between treatment (village 10, Hua Sam Rong Subdistrict) and control (village 7, Wang Yen Subdistrict) villages. Larval abundance ranged from 0 to 889 per house in village 10 and from 0 to 1,418 per house in village 7. The average number of larvae per house in village 10 was 234.56 ± 27.32 in dengue foci and 132.57 ± 17.41 outside of dengue foci. These differences were significant ($t = -3.297$, $df 150$, $P = 0.001$).

After an application of integrated vector control methodologies, a reduction of immature vectors as well as a decline in dengue cases was evident in the treated areas. The reported DHF case rates in the treated and untreated villages were 265.25 versus 217.86 per 100,000 population, respectively, in the year before intervention compared with 0 versus 322.23 per 100,000 population, respectively, in the year after intervention.

Figure 2 illustrates the efficiency of all 3 types of screen covers for water jars as well as the combination of copepods and *Bti* for controlling *Aedes* larvae in breeding containers. The use of 3 types of screen covers could prevent development of immature mosquito vectors up to 100% if they were used properly (Fig. 2a). An efficiency of the bag covers for utility water jars varied according to the behavior of people in the community. In this study, the use of a combination of copepods and *Bti* in breeding containers other than water

jars was first evaluated at the community level. The major breeding containers suitable for this control approach were small and large bathroom basins. Figure 2b illustrates the control efficiency of this approach in different types of water containers other than drinking, storage, and some utility water jars. The control efficiency of a combination of copepods and *Bti* fluctuated the most in small hygiene jars used in bathrooms. The water in hygiene jars was used up quickly preventing sustainable copepod populations in these types of containers so *Aedes* eggs retained on the jars could hatch and develop as soon as new water was added.

Apart from controlling immatures, locally made lethal ovitraps were used as the backup control against surviving adult mosquito populations in the treated areas. The total number of 406 lethal ovitraps was distributed in the treatment villages. When the percentages of positive ovitraps with *Ae. aegypti* eggs were determined, the lethal ovitraps showed good efficacy under field conditions. The percentage of ovitraps that contained *Aedes* eggs when traps were first placed among natural breeding sites (66.3%) decreased from 49.6% after the first application to 10.4% at the termination of the study (Fig. 3). Our data show that locally made lethal ovitraps could successfully suppress populations of adult female *Ae. aegypti* for up to about 1 month without changing the permethrin-impregnated paper strips. The reduction in the number of egg-positive traps in subsequent months because of the mosquito population decline demonstrated the efficiency of the lethal ovitraps when placed in each house in the focal areas. This result indicates that lethal ovitraps with an appropriate concentration of permethrin can successfully compete with other domestic oviposition sites.

DISCUSSION

The incidences of dengue hemorrhagic fever in Thailand have increased cyclically from the first recognized outbreak in 1958. The policy of dengue vector surveillance and control in Thailand has changed since the 1980s, and vector control methodologies have been redirected to integrated control strategies with more emphasis on community participation. In this community-based vector control program, integrated biological and physical control methodologies with least chemical insecticides were used by the community.

In Thailand, clay water storage jars are the most productive breeding sites for *Ae. aegypti* in rural and semirural areas. Thus, the proper covering of these types of water containers is important in reducing the vector population. Strickman and Kittayapong (1993) reported the development of immature *Ae. aegypti* in stan-

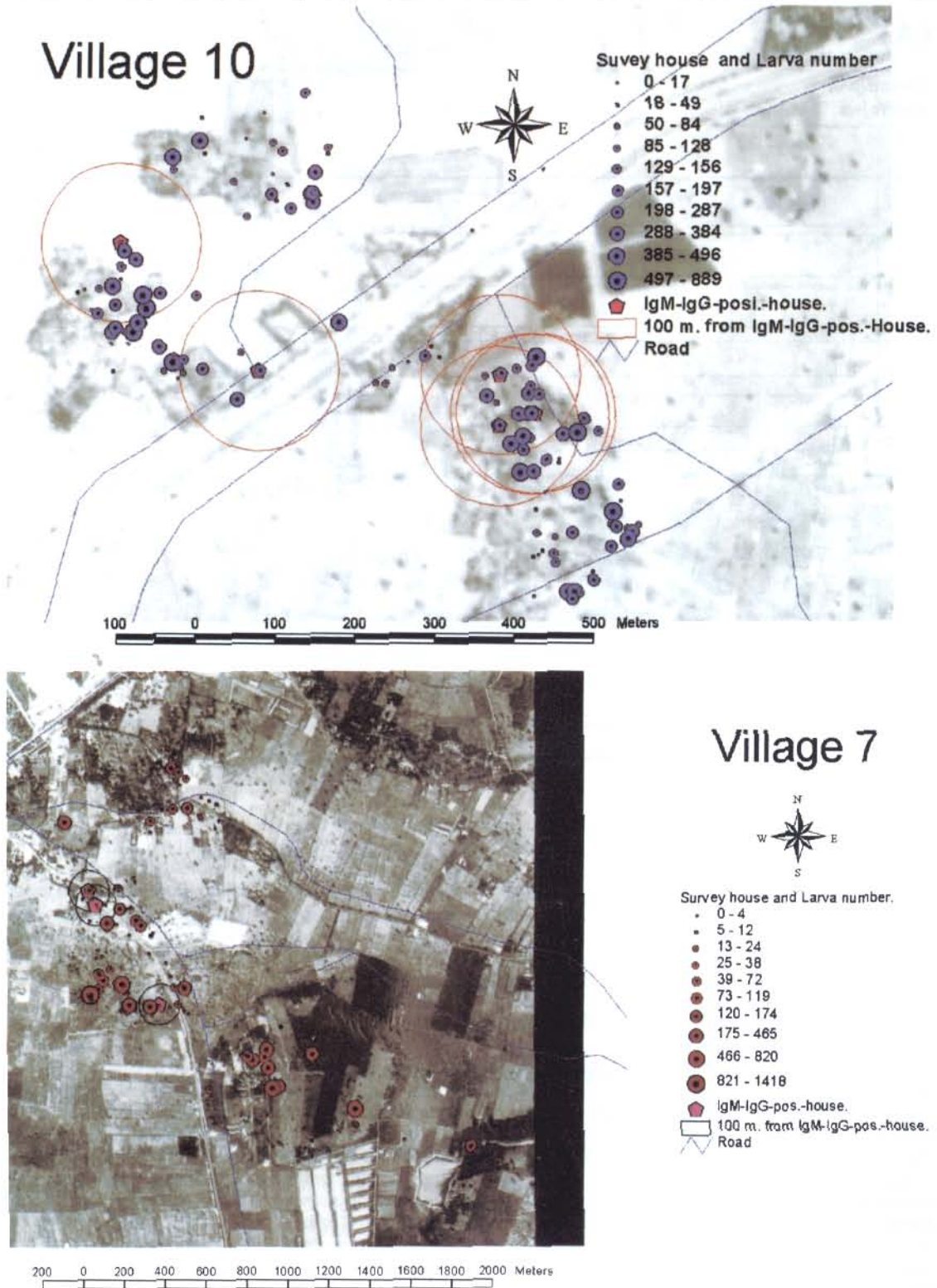
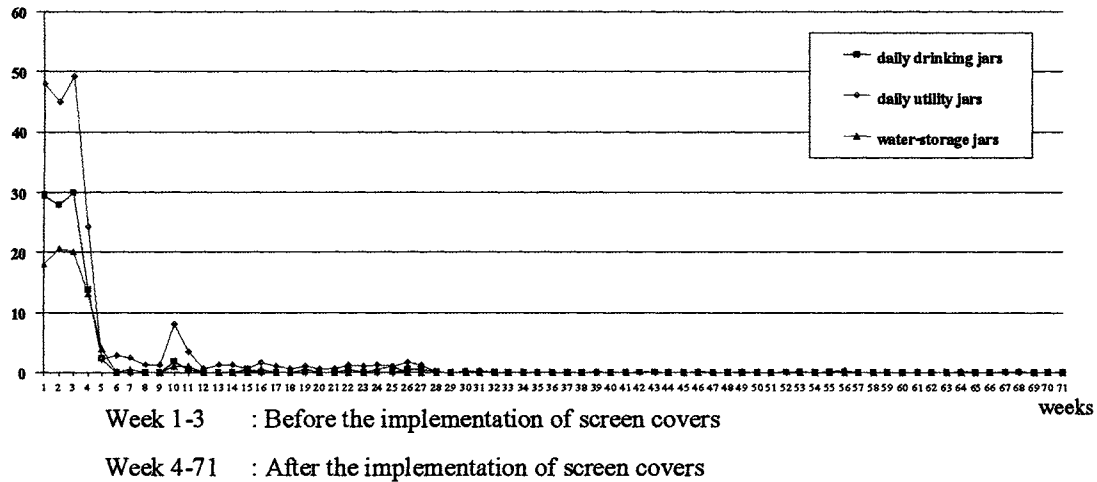


Fig. 1. Geographic information system mapping of houses and larval survey in the treatment (village 10, Hua Sam Rong Subdistrict, top) and the control (village 7, Wan Yen District, bottom) villages in Plaeng Yao District, Chachoengsao Province Thailand

(A)

Percentage of positive jars



(B)

Percentage of positive containers

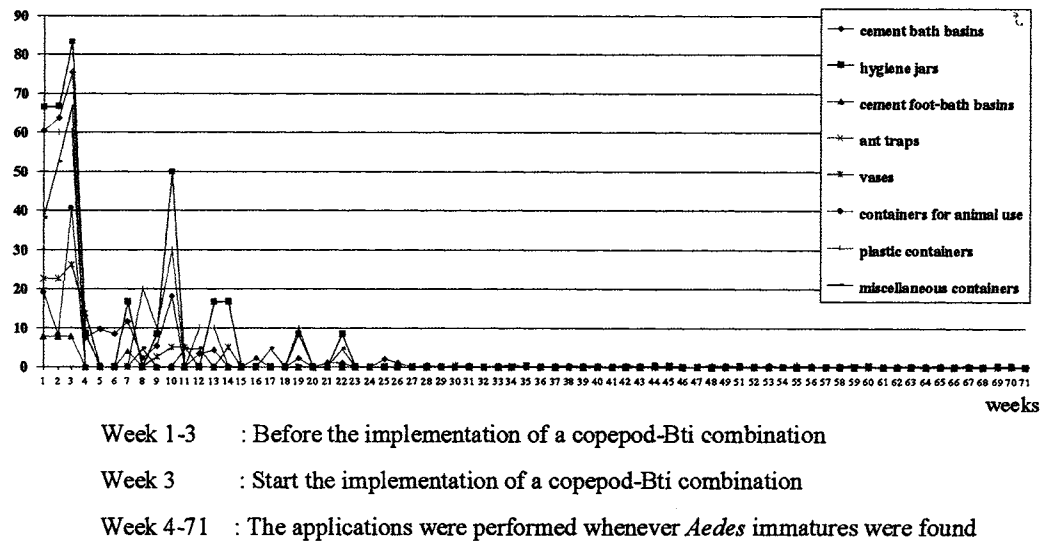


Fig. 2. Reduction of immature positive containers after application of vector control measures: (A) Screen covers for water jars. (B) Combination of *Bacillus thuringiensis* subsp. *israelensis* (Bti) and *Mesocyclops thermocycloides* (copepod).

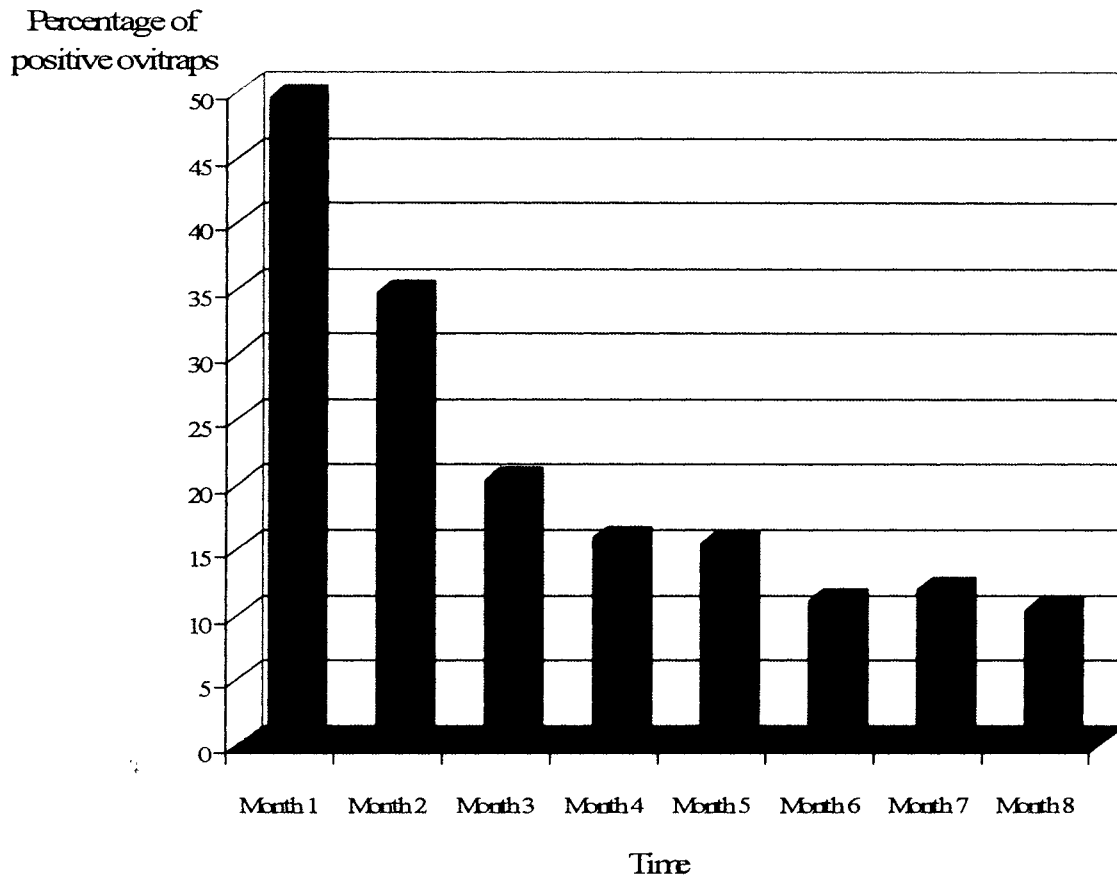


Fig. 3. Percentages of lethal ovitraps with *Aedes* eggs in treated areas in Hau Sam Rong Subdistrict, Plaeng Yao District, Chachoengsao Province, Thailand ($n = 406$).

dard-sized water jars that were permanently covered with an aluminum lid. This then led to the development of 3 simple types of screen covers suitable for the purpose of water jar use and the water use pattern of householders (Kittayapong and Strickman 1993b). In this intervention program, it was found that the cap covers for storage water jars could completely prevent the production of *Aedes* vectors, whereas the efficiency of the flap covers depended on the proper closing of the flap after taking water from the jars. The bag covers for utility water was less efficient in comparison with the other 2 types of screen covers, because it depended solely on the behavior of people in the community. If the inverted bag covers were regularly lifted out after the end of the day, no larvae and pupae could develop in the utility jars. However, if people in the community were careless and did not lift the bag covers for several days, larvae and pupae developed inside the bag and emerged as adults.

A combination of copepods and *Bti* was used to control *Aedes* immatures in other types of breeding containers in this intervention. Theoretically, integrated control should not only reduce

initial mosquito populations but also confer long-lasting control via the biological control agents introduced (Riviere et al. 1987). Although the 1st wk of mosquito reduction was largely due to the immediate effects of the *Bti* toxin, the subsequent weeks of reduction were principally due to copepod predation upon early instars. *Bacillus thuringiensis* subsp. *israelensis* is appropriate for combining with copepods because it does not harm the copepods and rapidly kills mosquito larvae, especially the older larvae of *Ae. aegypti*, which feed at a high rate on the toxic crystals of *Bti*. In contrast, copepods required more time to increase their population and exert predator pressure on the larval population. If older instars were present during the initial inoculation, they would likely escape predation and later emerge as adults (Marten 1990). In contrast to *Bti*, the efficacy of copepods was more persistent after the establishment period. A previous study by Tietze et al. (1994) showed that when *M. longisetus* was integrated with *Bti*, *Bacillus sphaericus*, and methoprene, the combination provided better mosquito reduction than either copepods or other control agents alone. Chansang et al. (2004) also

confirmed that the use of the copepod *M. thermocycloides* in concert with liquid *Bti* suspension for *Ae. aegypti* control in water jars gave the best results for long-term control compared with application of *Bti* alone or copepods alone. In some field trials, *Mesocyclops* was lost from water containers when all the water was removed for use or when containers were cleaned (Marten et al. 1994). Reapplication of these control agents was necessary to achieve control of *Aedes* vectors. Our results similarly showed that *M. thermocycloides* was lost from some containers and that reapplication was necessary. In Lao People's Democratic Republic, after releasing *M. guangxiensis* into 142 containers and 20 wells in a rural village, only 7% of the water containers had copepods after 1 month and 0% after 6 months postinoculation (Jenning et al. 1995). In French Polynesia, *M. aspericornis* was released together with the larvorous fishes *Gambusia affinis* and *Poecilia reticulata* into mosquito breeding sites in 1 village for controlling *Ae. aegypti*, *Ae. polynesiensis*, and *Culex quinquefasciatus*. Results showed that the impact of copepods in water tanks, drums, and wells was inconsistent, apparently depending on the availability of microfaunal diet for growth of copepod nauplii (Lardeux et al. 1992). However, these studies contrasted with that of Nam et al. (1998) who reported that *Ae. aegypti* disappeared from 400 houses in one village in Vietnam and has not reappeared after treating with *Mesocyclops* in combination with community participation. In Thailand, an experiment under seminatural conditions demonstrated that some community-based products such as rice grains and leaves could be a supplementary food for copepods after releasing them in permanent breeding containers (Kosiyachinda et al. 2003).

Apart from the normal ovitraps used for detection, collection, or surveillance of mosquito populations, several models of ovitraps have been modified in various types for the purpose of mosquito control. Chan et al. (1977) modified the surveillance ovitrap into a lethal trap for *Aedes* vector control in an urban environment. Our lethal ovitraps were modified from the trap developed by Zeichner and Perich (1999). The substrate used by Zeichner and Perich (1999) for allowing female mosquitoes to oviposit was a heavy-weight velour strip (2.54×11 cm), whereas we used 7.7×21 -cm filter paper strip. The mortality rate of female mosquitoes in their study was 45.0% compared with 97.5% in our study. We suspected that the large size of the permethrin-impregnated paper resulted in an expanded area of contact with the poison. In Rio de Janeiro, Brazil, ovistraps treated with deltamethrin provided 89% mortality of *Ae. aegypti* adults and >99% mortality of larvae after the lethal ovitraps were used for 1 month in

field trials (Perich et al. 2003). The study by Marques et al. (1996) showed that ovitraps were positive even in the presence of natural breeding sources. Similarly, our lethal ovitraps competed well with other domestic containers, including the most preferred breeding habitats, i.e., water jars and ant traps. Chan (1973) suggested that eradication of mosquito vectors could be achieved and would theoretically be most rapid when domestic habitats were first reduced to a minimum by intense integrated control, and lethal ovitraps were 1 of the devices used in the control program.

To obtain sustainability of an integrated vector control program, community participation and community ownership need to be emphasized (Gubler 1989). In Thailand, the 1st community-based control program was not sustained, possibly because of the high degree of program operation by the public health authorities and the lack of partnership from the targeted community (Gubler and Clark 1996). In our community-based program, a combination of horizontal (bottom-up) and vertical (top-down) approaches was merged to obtain immediate success. Although the program was highly successful in controlling dengue vectors and in reducing dengue transmission in the study area, the sustainability of the program is unclear and a challenge to local authorities (Spiegel et al. 2005). At present, some components of our community-based program, i.e., the weekly garbage pickup, have become routine management by the Local Administrative Authority with the financial support from individual households. This operation also is expanding to neighboring communities. In addition, the local government now allocates some money for production and distribution of screen covers for preventing development of immature vectors in water jars in the nearby communities. However, the long-term success of the program and the level of involvement of the communities need to be evaluated over time.

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REFERENCES CITED

- Chan KL. 1973. The eradication of *Aedes aegypti* at the Singapore Paya Lebar International Airport. In: Chan Y-C, Chan K-L, Ho B-C, eds. *Vector control in Southeast Asia*. Singapore: Sen Wah Press.
- Chan KL, Ng SK, Tan KK. 1977. An autocidal ovitrap for the control and possible eradication of *Aedes aegypti*. *Southeast Asian J Trop Med Public Health* 8:56-62.
- Chansang U, Bhumiratana A, Kittayapong P. 2004. Combination of *Mesocyclops thermocyclopoides* and *Bacillus thuringiensis* ssp. *israelensis*: a better approach for the control of *Aedes aegypti* larvae in water containers. *J Vector Ecol* 29:218-226.
- Gubler DJ. 1987. Dengue. In: Monath TP, ed. *Epidemiology of arthropod-borne viral disease*. Boca Raton, FL: CRC Press. p 223-260.
- Gubler DJ. 1989. *Aedes aegypti* and *Aedes aegypti*-borne disease control in the 1990s: top down or bottom up. *Am J Trop Med Hyg* 40:571-578.
- Gubler DJ, Clark GG. 1996. Community involvement in the control of *Aedes aegypti*. *Acta Trop* 61:169-179.
- Hemingway J, Ranson H. 2000. Insecticide resistance in insect vectors of human disease. *Annu Rev Entomol* 45:371-391.
- Jenning CD, Phommasack B, Sourignadeth B, Kay BH. 1995. *Aedes aegypti* control in the Lao People's Democratic Republic, with reference to copepods. *Am J Trop Med Hyg* 53:324-330.
- Kantachuevssiri A. 2002. Dengue hemorrhagic fever in Thai society. *Southeast Asian J Trop Med Public Health* 33:56-62.
- Kay BH, Nam VS, Tien TV, Yen NT, Phong TV, Diep TVB, Ninh TU, Bektas A, Aaskov JG. 2002. Control of *Aedes* vectors of dengue in three provinces of Vietnam by use of *Mesocyclops* (Copepoda) and community-based methods validated by entomologic, clinical, and serologic surveillance. *Am J Trop Med Hyg* 66:40-48.
- Kittayapong P, Strickman D. 1993a. Distribution of container-inhabiting *Aedes* larvae (Diptera: Culicidae) at a dengue focus in Thailand. *J Med Entomol* 30:601-606.
- Kittayapong P, Strickman D. 1993b. Three simple devices for preventing development of *Aedes aegypti* larvae in water jars. *Am J Trop Med Hyg* 49:158-165.
- Kosiyachinda P, Bhumiratana A, Kittayapong P. 2003. Enhancement of the efficacy of a combination of *Mesocyclops aspericornis* and *Bacillus thuringiensis* var. *israelensis* by community-based products in controlling *Aedes aegypti* larvae in Thailand. *Am J Trop Med Hyg* 69:206-221.
- Lardeux F, Riviere F, Sechan Y, Kay BH. 1992. Release of *Mesocyclops aspericornis* (Copepoda) for control of larval *Aedes polynesiensis* (Diptera: Culicidae) in land crab burrows on an atoll of French Polynesia. *J Med Entomol* 29:571-576.
- Marques CC, Marques GR, de Brito M, dos Santos-Neto LG, Ishibashi VC, Gomes FA. 1996. Comparative study of larval and ovitrap efficacy for surveillance of dengue and yellow fever vectors. *Rev Saude Publica* 27:237-241.
- Marten GG. 1990. Elimination of *Aedes albopictus* from tire piles by introducing *Macrocyclus albidus* (Copepoda, Cyclopidae). *J Am Mosq Control Assoc* 6:689-693.
- Marten GG, Borjas G, Cush M, Fernandez E, Reid JW. 1994. Control of larval *Aedes aegypti* (Diptera: Culicidae) by cyclopoid copepods in peridomestic breeding containers. *J Med Entomol* 31:36-44.
- Nam VS, Yen NT, Kay BH, Marten GG, Reid JW. 1998. Eradication of *Aedes aegypti* from a village in Vietnam, using copepods and community participation. *Am J Trop Med Hyg* 59:657-660.
- Nam VS, Yen NT, Phong TV, Ninh TU, Mai LQ, Lo LV, Nghia LT, Bektas A, Briscoe A, Aaskov JG, Ryan PA, Kay BH. 2005. Elimination of dengue by community programs using *Mesocyclops* (Copepoda) against *Aedes aegypti* in central Vietnam. *Am J Trop Med Hyg* 72:67-73.
- Nimmanitaya S. 1978. Dengue haemorrhagic fever in Thailand. *Asian J Infect Dis* 2:19-21.
- Perich MJ, Kardec A, Braga IA, Portal IF, Burge R, Zeichner BC, Brogdon WA, Wirtz RA. 2003. Field evaluation of a lethal ovitrap against dengue vector in Brazil. *Med Vet Entomol* 17:205-210.
- Phanthumachinda B, Samutrapongse W, Phan-Urai P, Boonyabuncha S, Matchum B. 1986. Approaches for community participation in *Aedes aegypti* control, Phanus Nikhom District, Chonburi Province. *Dengue Newsletter, WHO/SEARO*, 13:55-61.
- Riviere F, Kay BH, Klein JM, Sechan Y. 1987. *Mesocyclops aspericornis* (Copepoda) and *Bacillus thuringiensis* var. *israelensis* for the biological control of *Aedes* and *Culex* vectors (Diptera: Culicidae) breeding in crab holes, tree holes and artificial containers. *J Med Entomol* 24:425-430.
- Smith TJ, Winter PE, Nisalak A, Udomsakdi S. 1971. Dengue control on Samui Island in the gulf of Thailand. II. Virological studies. *Am J Trop Med Hyg* 20:715-719.
- Spiegel J, Bennett S, Hattersley L, Hayden MH, Kittayapong P, Nalim S, Wang DNC, Zielinski-Gutierrez E, Gubler D. 2005. Barriers and bridges to prevention and control of dengue: the need for a social-ecological approach. *EcoHealth* 2:273-290.
- Strickman D, Kittayapong P. 1993. Laboratory demonstration of oviposition by *Aedes aegypti* in covered water jars (Diptera: Culicidae). *J Med Entomol* 30:947-949.
- Strickman D, Kittayapong P. 2002. Dengue and its vectors in Thailand: introduction to the study and seasonal distribution of *Aedes* larvae. *Am J Trop Med Hyg* 67:247-259.
- Sucharit S. 1993. Epidemiological situation of dengue in Thailand. *Trop Med* 35:173-177.
- Thavara U, Tawatsin A, Phan-Urai P. 1996. Dengue mosquito vectors at a tourist attraction, Ko Samui, in 1995. *SEA J Trop Med Public Health* 27:160-163.
- Tietze NS, Hester PG, Shaffer KR, Prescott SJ, Schreiber ET. 1994. Integrated management of waste tire mosquitoes utilizing *Mesocyclops longisetus* (Copepoda: Cyclopidae), *Bacillus thuringiensis* serovar. *israelensis*, *Bacillus sphaericus* and methoprene. *J Am Mosq Control Assoc* 10:363-373.
- Ungchusak K, Kunasol P. 1988. Dengue haemorrhagic fever in Thailand. *Southeast Asian J Trop Med Public Health* 19:487-490.

- Wang CH, Chang NT, Wu HH, Ho CM. 2000. Integrated control of the dengue vector *Aedes aegypti* in Liu-Chiu Village, Ping-Tung County, Taiwan. *J Am Mosq Control Assoc* 16:93-99.
- WHO [World Health Organization]. 1999. *In Depth External Review of Dengue/DHF Prevention and Control Programme in Thailand*, 25 March-10 April 1999. New Delhi, WHO Regional Office for Southeast Asia.
- Zeichner BC, Perich MJ. 1999. Laboratory testing of a lethal ovitrap for *Aedes aegypti*. *Med Vet Entomol* 13:234-238.