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Community-Based Control of *Aedes aegypti* By Using *Mesocyclops* in Southern Vietnam

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Abstract. We previously reported a new community-based mosquito control strategy that resulted in elimination of *Aedes aegypti* (Linn.) in 40 of 46 communes in northern and central Vietnam, and with annual recurrent total costs (direct and indirect) of only $0.28–$0.89 international dollars per person. This control strategy was extended to four provinces in southern Vietnam in Long An and Hau Giang (2004–2007) and to Long An, Ben Tre, and Vinh Long (2005–2010). In a total of 14 communes with 124,743 residents, the mean ± SD of adult female *Ae. aegypti* was reduced from 0.93 ± 0.62 to 0.06 ± 0.09, and the reduction of immature *Ae. aegypti* averaged 98.8%. By the final survey, no adults could be collected in 6 of 14 communes, and one commune, Binh Thanh, also had no immature forms. Although the community-based programs also involved community education and clean-up campaigns, the prevalence of *Mesocyclops* in large water storage containers > 50 liters increased from 12.77 ± 8.39 to 75.69 ± 9.17% over periods of 15–45 months. At the conclusion of the study, no confirmed dengue cases were detected in four of the five communes for which diagnostic serologic analysis was performed. The rate of progress was faster in communes that were added in stages to the program but the reason for this finding was unclear. At the completion of the formal project, sustainability funds were set up to provide each commune with the financial means to ensure that community-based dengue control activities continued.

INTRODUCTION

The container breeding mosquito, *Aedes aegypti*, is recognized as the major global vector of dengue viruses, causing approximately 50 million infections, 500,000 cases of dengue hemorrhagic fever, and at least 12,000 deaths annually.[1] We previously reported a mosquito control strategy for Vietnam[2] that incorporated four elements: a combined vertical and horizontal approach that depends on community understanding and leadership; prioritized control according to the larval productivity of major habitat types; use of predacious copepods of the genus *Mesocyclops* as a biological control agent; and delivery of this agent by communal activities of health collaborators, school children, and the public. During 1998–2000, community-based vector control programs were established in six communes in the northern provinces of Nam Dinh, Hung Yen and Hai Phong (n = 49,647 persons)[3] and were then expanded to another 37 communes (n = 309,730 persons) by 2003.[2] During 2000–2003, we reported elimination of *Ae. aegypti* from two of three communes in central Vietnam,[4] which together with the northern results, constituted elimination of *Ae. aegypti* from 40 of 46 communes.

On the basis of these results, we suggested that this strategy was suitable for Vietnam and elsewhere, where the major sources of *Ae. aegypti* are large water storage containers and where there is no risk of exacerbating parasitic infections such as *Dracunculus*. During 2007 and 2008, we revisited northern and central Vietnam, respectively, and evaluated the sustainability of these programs, seven (Nam Dinh) and four and a half (Khanh Hoa) years after formal project activities had ceased. Community-based strategies were well sustained in three communes evaluated with annual recurrent total costs (direct and indirect) of $0.28–$0.89 international dollars per person.[5]

This current study outlines our results in southern Vietnam where up to 80% of dengue cases are reported each year, and where *Ae. aegypti* populations may be more abundant. After successful application of this community-based biological control strategy using *Mesocyclops* in 46 northern and central province communes through Vietnam, we hypothesize that this strategy is equally applicable to southern Vietnam.

MATERIALS AND METHODS

In 2004, we initiated the community-based strategy in two communes in Long An and Hau Giang Provinces, and in 2005, an additional 12 communes were added progressively in Long An, Vinh Long and Ben Tre Provinces. These provinces lie within the Mekong delta, and can be reached by road after 1.5–3 hours travel south from Ho Chi Minh City.

Site selection and community survey. Communes were selected on the basis of frequent dengue, a committed health staff, a concerned community, a container type configuration predisposed to large water storage, and therefore suitability for *Mesocyclops* inoculation. During June 2004–2007, community-based programs were developed in the communes of Tan Binh (Hau Giang Province) and Phuoc Dong (Long An Province), and Tan An commune (Long An Province) was maintained as an untreated control. In October 2005, a larger program was initiated in Long An and two other provinces (Ben Tre and Vinh Long) and this ran until April 2010 (Figure 1). Twelve communes were selected for interventions from those participating in an Australian managed water supply scheme, the Cuu Long Delta Rural Water Supply and Sanitation Project, starting with three model communes, Binh Hoa Bac (Long An), Thanh Tri (Ben Tre), and Chanh Hoi (Vinh Long) during March 2006–April 2009. After April 2009, the communes assumed responsibility for these programs and were assisted by sustainability funding.

All communes are classified as being within the Mekong Delta, which is notable for its year round tropical climate, its

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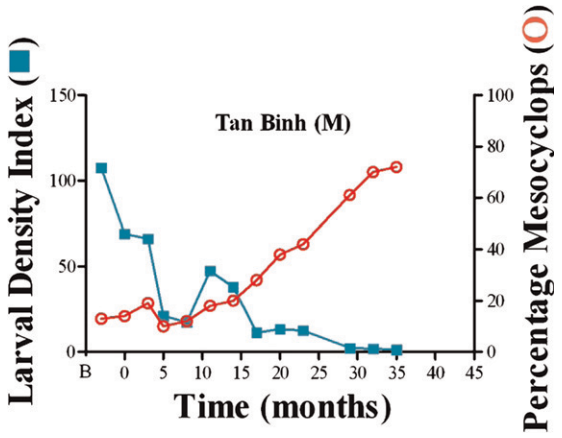

FIGURE 1. Prevalence of *Mesocyclops* in relation to the larval density index for Tan Binh commune, Hau Giang province, Vietnam, 2004–2007.

flatness, and on average not more than one meter above sea level. The amount of land inundated with water varies throughout the year, with the summer rains bringing annual flooding to low lying areas. The region is criss-crossed with a maze of canals and is agriculturally focused for rice production, producing approximately half of the annual output of Vietnam according to the Vietnamese Ministry of Natural Resources. The inhabitants are largely Vietnamese, with limited ethnic Khmer in some regions. All communes that participated in our project activities are in low-lying areas. In most cases, transportation throughout the region is by road, but in provinces such as Hau Giang and Vinh Long, travel by waterways can also be common. Thus, it was more difficult to service households in these provinces than in those in central and northern Vietnam.

Baseline knowledge, attitude, and practice (KAP) surveys were undertaken on 100 or 200 randomly chosen households in each commune to gain an understanding of the community knowledge about dengue disease, risk, and control options. Unoccupied households were revisited. However, if a house was unoccupied on the second visit, or the householder declined to participate in the study, then the neighboring house was selected for survey. The KAP surveys were repeated annually to gauge community opinion.

Constructing community-based programs. For each commune, community management committees (CMCs) were selected initially by position of office. These positions included Director of the Provincial Preventative Medical Center, Vice-Director of the Commune People's Committee, Secretary of Provincial Preventative Medical Center, Director of the District Health Service, Director of Commune Health Service, principal of commune schools, women's union representative, youth union representative and persons initiated in 2005 in water supply project areas, and the Director of the Provincial Center for Rural Water Supply and Sanitation. This group comprised 81 persons over a seven-year period.

The collaborator network of 619 persons was selected by the CMCs on the basis of individual standing within the community, location within the hamlet, and their availability to undertake assigned tasks. Upon selection of the CMC and collaborator networks, each commune received a three-day training workshop on the project objectives and methods. The workshops involved identification of mosquito larvae and adults, and *Mesocyclops* (more accurately large cyclopoids), and basic knowledge on dengue fever and dengue hemorrhagic fever. All participants underwent pre-workshop and post-workshop tests to demonstrate their competence. Each workshop finished with the disbursement of collaborator kits, household recording books, the house list for each collaborator, and an activity schedule for the next quarter. Each collaborator was given responsibility for approximately 50 households, for which he or she received a monthly stipend of up to 60,000 Vietnamese dollars (VND) ($3.25 United States dollars [USD]) for a task that took 2–4 days, and CMC members were paid 100,000 VND ($5.40 USD).

The CMCs developed a collaborator training manual in the form of a collection of training courses, notes, and activities that were provided by project staff. In addition, community project officers (CPOs) were selected from collaborating health institutes and were responsible for field activities, the provision of technical and other advice, and undertook skills audits of CMC capacity to ensure they were equipped to manage the network. Each CPO was responsible for 1–2 communes, depending on community progress.

Each month, collaborators submitted data on number of households visited, prevalence of *Aedes* and *Mesocyclops* to the CMC and to CPOs. At the Dengue Project Office in Ho Chi Minh City, community attributes were geoprocessed by using Microsoft (Redmond, WA) Access and ArcGIS (ESRI, Redlands, CA) to create maps of household location, water supply infrastructure and terrain, which was incorporated into a web-based decision support tool that assessed efficacy of control, household coverage, and work effort. This system was used monthly as an evidence-based reporting system to focus discussion among CPOs, CMCs, and collaborators. Data quality was checked quarterly by a team of health professionals (including the CPO) and besides the above, included survey of at least 100 households for mosquito immature forms and adults, and for *Mesocyclops.*

One hundred fifty-three schoolteachers from 15 primary and 9 secondary schools were also targeted for training. An information session was held within each commune to introduce teachers to dengue fever/dengue hemorrhagic fever, the community-based vector control model, and the role that schools and students may play within it. As a result, schools usually added dengue education into their curriculum and into extracurricular activities by participating with *Mesocyclops* inoculation and community clean up campaigns.

With the collaborator networks in place, the communities were mobilized commencing with *Mesocyclops* inoculation into key containers throughout the communes and cleanup campaigns in each commune. These key containers became sites for distribution of *Mesocyclops* by collaborators during their monthly visits to each household.

For the staged program in Long An, Ben Tre and Vinh Long, survey work commenced in three communes, Binh Hoa Bac, Thanh Tri and Chanh Hoi, respectively, during the dry season of March 2006 (these were called the model communes), and three sets of three communes (called extension phase 1, 2, and 3 or E1, E2, and E3) were added during the wet season, 18 months later in September 2007 (E1 = Binh Thanh in Long An, Thoi Lai in Ben Tre, and Dai Hoa Loc in Ben Tre), 21 months later in December 2007

(E2 = Tan Thanh in Long An, Phu Thinh, and Song Phu in Vinh Long), and 29 months later in August 2008 (E3 = My Thanh Dong in Long An, Chanh An in Vinh Long, and Vang Quoi Dong in Ben Tre). The programs (including a pre-intervention and preparatory period) in the extension communes E1, E2, and E3 were conducted for 30, 26, and 19 months before handover to the communities with sustainability fund support. This program includes a preparatory period of approximately three months where baseline (B in the figures) entomologic and KAP surveys were conducted and CMC and collaborators selected and trained before program initiation.

The rationale behind the staged approach was to expand the original model communes into neighboring ones by using local expertise for organization, local training, and exchange aided by CPO input. Many of those serving on the model CMCs held wider jurisdiction to district or provincial level, and therefore were also able to service the needs of the extended communes.

Quantitative surveys. Approximately three months before implementation, baseline (B in the figures) household surveys were conducted for mosquito immature forms and for adults (see below), and for *Mesocyclops.* Mean prevalence of *Mesocyclops* was defined as the percentage positive in containers > 50 liters. The KAP surveys were conducted and the CMC and collaborators were selected and trained before program initiation.

During the intervention, surveys for *Aedes* and *Mesocyclops* were done quarterly in 100 randomly selected households to measure efficacy of *Aedes* control in relation to prevalence of *Mesocyclops.* Control efficacy was defined as 1 – (no. III/IV instars remaining divided by pre-intervention survey numbers) × 100.

To assess the absolute numbers of III/IV instar and pupal *Aedes* spp., samples were taken from small containers by using a pipette, from medium to large containers by using a five-sweep sampling technique with a 20 cm diameter and 33 cm deep net of 100 μm mesh,[6] and from any wells by using funnel traps.[7,8] Third/IV instars were counted, transferred to storage jars containing 4% formaldehyde, and transported to the laboratory for species identification by using a stereomicroscope. Standing crops of immature forms were then estimated from sample yields by using correction factors according to container type.[6] This factor was expressed as a larval density index (the average number of larvae per house). An adult density index was used to describe the average number of female *Ae. aegypti* per house on the basis of 15-minute aspirator collections of adult mosquitoes resting indoors on clothes, walls, and under beds.

The KAP surveys (n = 36) were conducted before implementation to ascertain the knowledge base and to gain community acceptance for an intervention, and during the final year to understand behavioral and knowledge changes. For model communes, KAPs also were conducted annually to audit stated community behavior on dengue control against actual practice. To reduce recall bias, exclusion criteria were persons < 18 years of age and persons without the cognitive ability to participate in the interview.

Qualitative surveys. The KAP surveys were supported by detailed focus group discussion (n = 21) in the model communes, and aided by the provision of educational materials when requested. Four themes specified the key areas in which feedback and impressions were needed from each target group to inform all project partners as to how the model communes were performing. The focus group discussion questions posed were different for each of the target groups because the questions considered the different roles participants had within the community, and how this may affect their level of exposure and interest within the project. The research themes were knowledge and understanding of dengue and dengue hemorrhagic fever as a communicable disease; impressions of roles; working relationships and levels of collaboration; and *Mesocyclops* as an intervention. Findings from the focus group discussions were broken up into each of five community groups: CMC, collaborators, householders, teachers, and students.

Disease surveillance. Suspected dengue patients satisfied a standard case definition.[3] For the first program in Tan Binh and Phuoc Dong communes, case data confirmed by using an in-house Pasteur Institute of Ho Chi Minh City IgM antibody capture enzyme-linked immunosorbent assay kit were compared with those for an untreated control at Tan An commune. As with the subsequent program, active case detection was conducted by collaborators and communal health staff, and blood samples were sent to provincial laboratories and Pasteur Institute of Ho Chi Minh City for testing and confirmation. For the staged program, blood from the three model communes, Binh Hoa Bac, Thanh Tri and Chanh Hoi, were processed and their incidence rates were compared with incidence rates of surrounding untreated communes from year 3 (2009) of the intervention. Moreover, for strengthening the laboratory capacity, we randomly selected 30–40 serum samples per province during March–June 2008 to conduct quality assurance against a standard set by the Pasteur Institute of Ho Chi Minh City.

Sustainability funds. The rationale behind sustainability funding was to provide the community with funds (usually 5,000-20,000 UDS) for investment. Proceeds from such investment were returned to communities to fund (or partly fund) the stipends of CMC and collaborators post-project. Funds for this purpose were specifically included as a line item in grants, and community discussions about sustaining these dengue control activities were implemented by CPOs during the final grant year for each commune.

In June 2007, small income generating initiatives were implemented in Phuoc Dong (Long An) and at Tan Binh (Hau Giang). The CMCs were tasked with making a final proposal to the project executive for approval, taking into account return on investment and risk. In May 2009, an independent consultant team was engaged to look at the possible options for investing the sustainability funds for the other communes in Long An, Ben Tre, and Vinh Long, and to set out a possible implementation plan for each commune. The consultants looked at investing the fund in a savings account at a bank by using the fund for a loan to one company, or creating a micro credit fund. They assessed the feasibility, potential returns, risk, and the capacity to implement. After April 2009, when the project officially ended in model communes, Binh Hoa Bac in Long An, Thanh Tri in Ben Tre, and Chanh Hoi in Vinh Long, the community assumed responsibility for the program post-project, and was assisted by returns from the sustainability funding. Communities from the extension communes E1, E2, and E3 also assumed responsibility at the end of each term.

RESULTS

***Mesocyclops* and vector surveys.** The key containers in southern provinces were standard jars > 100–200-liter capacity, which comprised approximately 67–73% of total containers, and large water storage tanks, usually with 1,000-liter capacity tanks comprising another 17–23%. Collectively, these two container types were producing approximately 90% of the standing crop. Both of these categories were treated with *Mesocyclops*. Discarded items, buckets, ant traps, aquaria, vases, and ponds produced the remainder and were subject to clean-up campaigns or other treatments, e.g., ant traps and salt.

There were five *Mesocyclops* spp. collected in the pre-intervention surveys in all 16 communes: *M. aspericornis* (Daday, 1906), *M. ogunnus* (Onabamori, 1957), *M. thermocyclopoides* (Harada, 1931), and *M. affinis* and *M. woutersi* (Van de Velde, 1987) at a mean ± SD prevalence of 12.77 ± 9.92%.

The mean ± SD larval density index before the intervention was 117.7 ± 87.8 (n = 16) but after the final survey, it was 2.2 ± 2.4 (n = 14) with an average control efficacy of 98.8%. In the final survey, adult *Ae. aegypti* were absent in 6 of 14 communes, and Binh Thanh had no adults or immature forms (Table 1). Fourteen communes were involved in community-based control using *Mesocyclops* (Figures 1–4), and two untreated control communes were maintained at Tan An, Long An (Figure 2) and in Tan Loi Tan, Ben Tre (Figure 3).

At Tan Binh in Hau Giang (Figure 1), these data indicate slow-to-moderate progress for 15 months with respect to *Mesocyclops* inoculation and immature control. Small numbers of larvae (larval density index = 1.1) and adults (adult density index = 0.3) were present in June 2007 when *Mesocyclops* prevalence was 72%. In Long An Province, a similar trend was evident where *Mesocyclops* prevalence ended at 72.2–79.8% at Phuoc Dong (larval density index = 1.5, adult density index = 0.2), but Binh Hoa Bac, Tan Thanh, and My Thanh Dong had small larval indices of 0.3–1.3 and no adults. In Binh Thanh (larval density index and adult density index = 0), *Mesocyclops* prevalence reached 87.6% (Figure 2). The other model communes, Thanh Tri in Ben Tre (Figure 3) and Chanh Hoi in Vinh Long (Figure 4), also made moderate progress compared with extension communes that often showed rapid implementation judged by *Mesocyclops* prevalence of 75.2–97.1% (Thoi Lai, Dai Hoa Loc and Vang Quoi Dong) (Figure 3) or prevalence of 61.2–73.5% for Song Phu (larval density index = 5.9, adult density index = 0) and Phu Thinh and Chanh An (Figure 4). *Mesocyclops* inoculation in the extension E1–E3 communes

TABLE 1

Summarized results of community-based *Mesocyclops* programs run in 14 communes in South Vietnam, 2004– 2010 (with two untreated controls), baseline and final *Aedes aegypti* densities, and *Mesocyclops* prevalence

			Ae. aegypti density		Percentage	
Locality	Population	Date	Adult	Larval	Control	*Mesocyclops*
Hau Giang						
Tan Binh	22,014	June 2004	1.3	107.6		13.0
		June 2007	0.3	1.1	99.0	72.0
Long An						
Phuoc Dong	13,891	June 2004	1.4	118.2		6.0
		June 2007	0.2	1.5	98.7	74.0
Tan An*	7,149	June 2004	2.3	149.6		3.0
		June 2007	0.8	67.9		16.0
Binh Hoa Bac	8,558	Mar 2006	0.3	15.0		21.0
		Feb 2010	0	1.3	86.7	72.2
Binh Thanh	3,148	Sep 2007	0.7	116.9		12.0
		Mar 2010	0	0	100	87.6
Tan Thanh	5,586	Dec 2007	0.2	25.4		18.0
		Jan 2010	0	0.3	98.8	79.8
My Thanh Dong	7,436	Aug 2008	0.5	78.1		4.0
		Feb 2010	0	0.7	99.9	78.9
Ben Tre						
Thanh Tri	8,070	Mar 2006	1.0	294.1		7.8
		Feb 2010	0.1	6.8	99.8	76.3
Tan Loi Thanh*	7,114	Mar 2006	1.4	124.8		8.6
		Feb 2010	0.2	10.4		6.7
Thoi Lai	7,763	Sep 2007	1.0	244.2		7.0
		Mar 2010	0.04	0.5	99.9	75.2
Dai Hoa Loc	8,432	Sep 2007	0.8	227.3		10.3
		Mar 2010	0.03	0.1	99.9	97.1
Vang Quoi Dong	5,186	Aug 2008	2.0	205.9		5.4
		Feb 2010	0.1	2.1	98.9	77.6
Vinh Long						
Chanh Hoi	8,743	Mar 2006	0.7	24.9		31.0
		Feb 2010	0	2.4	90.4	61.1
Song Phu	9,217	Dec 2007	0.4	25.4		10.0
		Mar 2010	0	5.9	77.8	61.2
Phu Thinh	10,224	Dec 2007	0.5	20.1		16.1
		Mar 2010	0.1	6.4	68.2	73.5
Chanh An	6,475	Aug 2008	0.6	106.3		27.0
		Feb 2010	0.1	1.9	98.2	73.2

*Untreated communes.

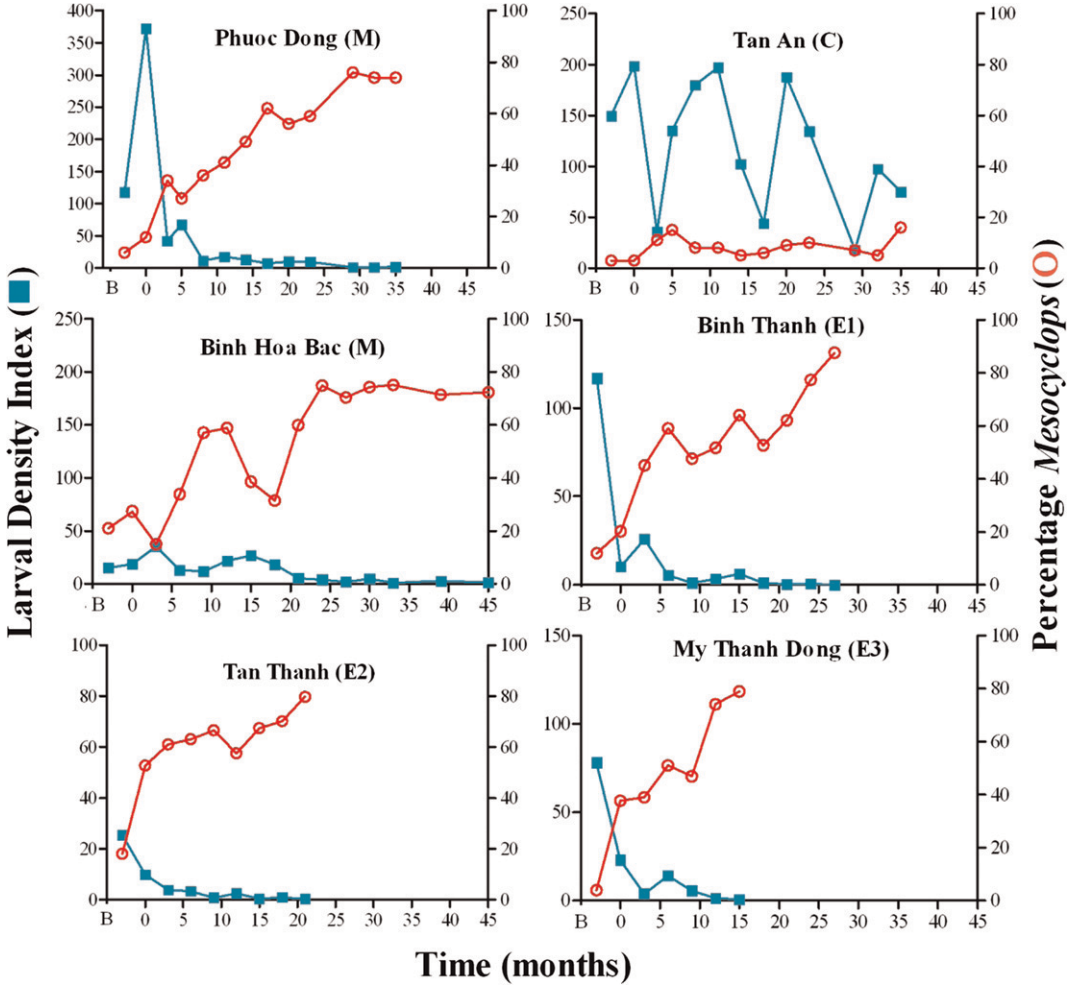

FIGURE 2. Prevalence of *Mesocyclops* in relation to the larval density index for five intervention communes compared with Tan An as a control, Long An Province, Vietnam, 2004–2010.

commenced during the wet season during August–December when jars contained water, making inoculation more effective.

After 15–45 months of community action that also involved health education and removal of discarded material, the mean ± SD prevalence of *Mesocyclops* was 75.69 ± 9.17%. No adult *Ae. aegypti* were collected in five communes, and one commune had no adults or larvae. However, from the *Mesocyclops* prevalence listed above, there was no clear trend that resulted in elimination of *Ae. aegypti*.

The two untreated control communes, Tan An (Figure 2) and Tan Loi Thanh (Figure 3), displayed seasonal effects where *Ae. aegypti* abundance was reduced from the end of the wet through the dry season. Although the larval density index at the start and end of the surveys for Tan An, 149.6 and 67.9 (June 2004 and June 2007) are probably acceptable in terms of annual variation. However, the larval density index for the other control, Tan Loi Thanh (124.8 in March 2006, 10.4 in February 2010), is unusual. Several communes (Phuoc Dong, Binh Thanh in Figure 2 and all communes in Figure 3,) were marked by early reductions in the larval density index when *Mesocyclops* prevalence was ≤ 20. This finding is unlikely to be a treatment effect, although it is conceivable that other community activities may have also contributed to this reduction.

Knowledge, attitude, and practice. Mean ± SD are presented only for baseline knowledge before the community-based programs commenced compared with levels achieved at the finish of each of 12 programs (n = 24) in Long An, Ben Tre and Vinh Long Provinces (Table 2). Data from another 12 KAP questionnaires are not included. From analyses by chi-square test, knowledge levels improved significantly ($P = 0.006$ to < 0.001) for 12 of 14 questions. For question 16, knowledge of dengue significantly improved ($P < 0.001$) but not for diarrhea ($P = 0.915$) and parasitic disease ($P = 0.095$) because nothing was presented. As expected, use of flocculants such as chloramine and alum (question 17) to clean water was reduced over time as reliance on river water decreased with installation of new water infrastructure such as tanks and taps.

As with the previous programs,[3,4] respondents knew little about the application of *Mesocyclops* initially (question, 0.7 ± 0.9%) but were knowledgeable afterwards (88.7 ± 8.7%). After the community-based program and *Mesocyclops* use had been explained to residents (questions 14 and 15), there was a high degree of willingness to be part of the dengue control program (92.2 ± 7.7%), including *Mesocyclops* inoculation (95.6 ± 4.2%).

Community programs. Communication played a key role in the strategy and showed an outreach to > 90% of residents.

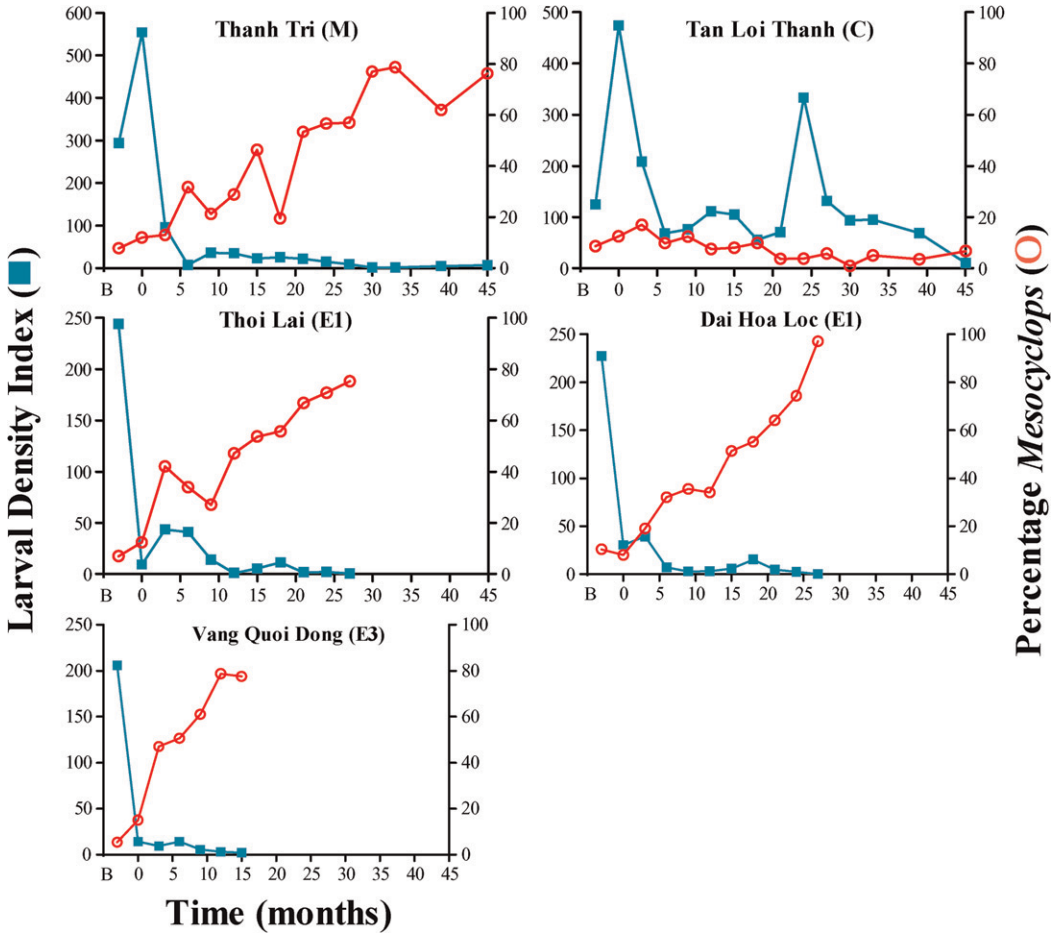

FIGURE 3. Prevalence of *Mesocyclops* in relation to the larval density index for four intervention communes compared with Tan Loi Tan as a control, Ben Tre Province, Vietnam, 2006–2010.

Frequently participants of focus group discussions (n = 21) would refer to the information and education posters distributed across the community as a key communication tool, and the posters acting as an effective visual reminder for householders to undertake project activities. The drivers of the programs were CMC members, collaborators, and householders.

Knowledge and understanding of dengue/dengue hemorrhagic fever. The CMC members from the commune health centers gave presentations to schools on the dangers of dengue. These lectures were well received and pupils recognized these CMC members as experts. All of the CMCs expressed satisfaction with their relationships with the CPOs and the collaborators, and reported it as being strong and healthy.

The CMC discussion groups were asked about their impressions of the project after three years. Across the CMC focus groups, they each articulated that change in the community's attitudes and knowledge of the project had taken place, but such change can take time, as indicated by *Mesocyclops* prevalence especially in the model communes (Figures 1–4) as follows.

"People now understand why collaborators visit, but previously people were not interested or knew very little. Now after three years, householders know the methods and know how to prevent dengue." CMC, Chanh Hoi The women householders expressed a clearer comprehension and appreciation on the benefits that the project brought to their families. "This project works for the family; 100% of the effort is for family" Female householder, Chanh Hoi Impressions of Roles. Collaborators also expressed a strong sense of pride in having the opportunity to engage with the community: "I am happy with my role, I feel proud to be a collaborator."

"We are the first people to communicate to the community about dengue prevention" Female Collaborator, Thanh Tri.

When asked about their role within the project, female householders from Chanh Hoi responded by providing a rank order of importance. They stated collaborators as the most important in the project, ranking 10, with householders as 9. Householders attributed the positive and significant results of the project to the collaborators. They commented on how education and communication from the collaborators had played a significant role in reducing dengue risk for the community: "Collaborators do their job very well. They do a very good job in communicating to the people. There were a lot of sick people in the past. The reduction in disease means people are very happy." Female Householders, Chanh Hoi Some thought that the householder was more important than the collaborator.

"It is the responsibility of each household to prevent dengue disease for the community – the collaborators just help us to do that." Male Householder, Binh Hoa Bac.

Working relationships and level of collaboration. The KAP results (Table 2) indicated the strength of householder

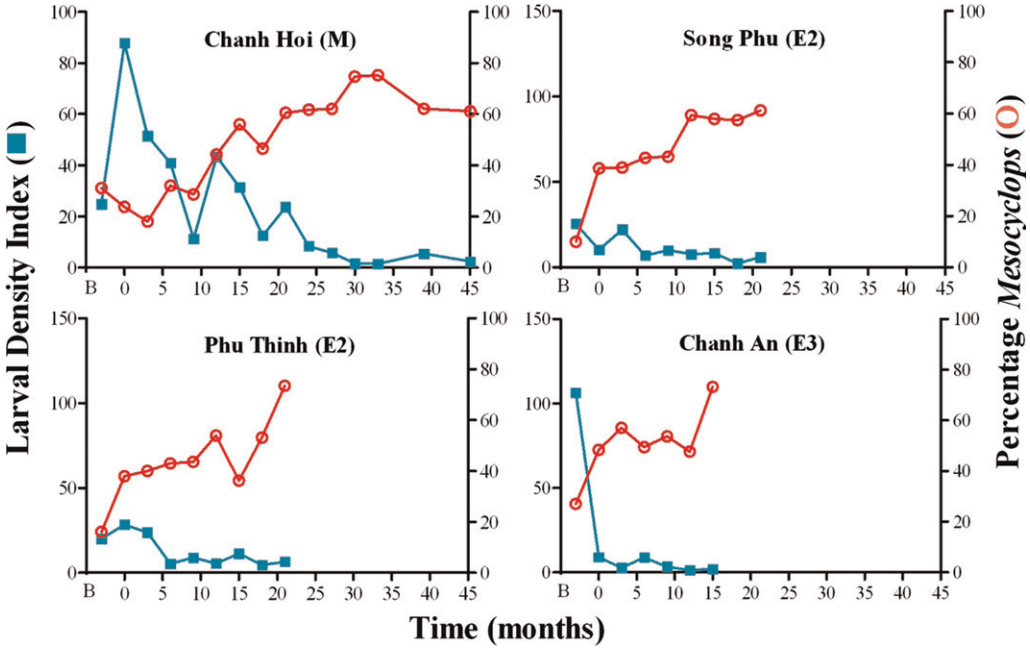

FIGURE 4. Prevalence of *Mesocyclops* in relation to the larval density index for four intervention communes, Vinh Long Province, Vietnam, 2006–2010.

participation, with only a minority of households disinterested. With the increased knowledge gained from project activities, householders were also more conscious of keeping their surroundings clean and taking further measures to prevent dengue, such as active participation in community meetings. All householders reported that they carried some uncertainty regarding the activities at the beginning in relation to safety and risk to their water sources. However, this was replaced by knowledge and acceptance.

Teachers regarded the community-based programs as useful, beneficial, and productive. Apart from the lessons, the main activity was at assembly, which could include singing, dancing, or performing a role-play about dengue. School activities, such as quizzes, dengue plays, and competitions on dengue knowledge, had a large impact on increasing community knowledge. Students were rewarded with notebooks and pens when their families had no *Aedes* larvae present in their water containers for three consecutive visits. Students became proactive and conducted activities at home and shared knowledge with family and neighbors. School activities led to pupils to become more involved in dengue within the community. Pupils were given a blank timetable that they could use to fill in the time and day of each subject they undertook throughout the year. The timetable also had a checklist for undertaking dengue activities at the household level, and this was often referred to in conjunction with the poster distributed to all households. Some schools opted to make their own educational materials, and magazines and posters highlighted the dangers of dengue, the benefits of *Mesocyclops*, and the options to householders and the community for mosquito control.

TABLE 2

Knowledge, attitude, and practice responses to standard questionnaire from residents of 12 communes in Long An, Ben Tre, and Vinh Long Provinces, Vietnam, 2006–2010

	Question	Time (% mean ± SD)				*P*
		Before		After		
4	Have you ever heard about dengue	87.1	8.8	98.0	2.5	< 0.001
5	Know the key symptoms of dengue	28.2	10.3	72.0	8.4	< 0.001
6	Know the causes of dengue	15.9	6.0	63.2	13.6	< 0.001
7	Know dengue mosquito	52.4	17.3	82.8	16.2	< 0.001
8	Know biting time of dengue mosquito	35.2	16.7	67.2	19.9	< 0.001
9	Know breeding sites of dengue mosquito	60.4	21.0	88.7	7.9	< 0.001
10	Agreed that dengue is a fatal disease	81.5	11.1	92.8	5.4	0.004
11	Know dengue can be prevented	73.6	10.7	93.3	5.1	< 0.001
12	Heard about *Mesocyclops*	1.5	1.5	91.0	5.6	< 0.001
13	Know about application of *Mesocyclops*	0.7	0.9	88.7	8.7	< 0.001
14	Agreed to put *Mesocyclops* in water containers	82.7	12.6	95.6	4.2	0.003
15	Willing to take part in dengue control activities	80.6	10.7	92.2	7.7	0.006
16	Know about waterborne diseases					
	Diarrhea	83.7	8.4	83.4	8.6	0.915
	Parasitic disease	14.9	7.5	21.5	10.7	0.095
	Dengue	19.5	6.0	47.2	16.5	< 0.001
17	Used additives to clean water	24.0	22.1	13.8	8.5	0.152

Primary pupils also presented plays or role plays about dengue fever to the school and also had dengue as a topic for discussion with parents on parent-teacher nights. Messages about dengue and mosquito control were broadcast during inter-school sporting events also involving parents, and pupils were rewarded for correct answers. Secondary pupils focused more in depth on the science of dengue fever and the primary vector, with some creating a play about the biological control of dengue. Teachers often tested students on their knowledge of the dengue curriculum. Thus a culture was created.

Attitudinal change was evident in the students themselves. The students felt strongly that they played an important role in the project in sometimes accompanying collaborators and having responsibility for 4–5 houses. Teachers reported that students would return to school asking for more *Mesocyclops* to replenish their household stocks, and about mosquito identification.

"Elementary students who are very little will catch a mosquito and ask me if that mosquito is the one that transmits dengue or not. I see that even young children now know, and so do their parents. Therefore I think the project is very successful." Teacher, Chanh Hoi.

Repeatedly across all groups, unions were identified as another forum by which dengue activities were discussed and prevention measures were recommended. Good relationships between the unions and community members appeared to be maintained because all communes mentioned being able to frequently and comfortably engage with the different unions at various times of need or query. Specific engagements included women sourcing the women's union, or both sexes accessing or referring to the Red Cross Union, and children reported referring to the Youth Union. Some men mentioned accessing the Farmers Union and the Army Veterans Union.

Mesocyclops as an intervention. Householders expressed ownership and stated that they believed the collaborator network needed to continue if project results were to be sustained, and this sentiment was agreed to by collaborators: "People will continue doing the activities themselves, however they will not be as good as the collaborators, because people need to go out and earn money for their life and other demands in life that will pull them away." Male Householder, Thanh Tri. "I will continue to do this forever as this is a project for the community." Male collaborator, Binh Hoa Bac.

Disease surveillance. The number of cases varied markedly in the pre-intervention years 1999–2003 for Tan Binh, Phuoc Dong, and Tan An from 0 to 265.8/100,000 (Table 3). Because an acceptable reduction of the larval density index at Tan Binh (Figure 1) was not achieved for 15 months after commencement, and that for Phuoc Dong (Figure 2) was not achieved for approximately 10 months, any attribution to an early control effect should be treated cautiously, but data for 2007 of 0/100,000 for Tan Binh and for Phuoc Dong compared with 69.9/100,000 for the untreated Tan An indicate successful control ($\chi^2 = 40.0$, degrees of freedom [df] = 1, $P < 0.001$). During 2009 for Binh Hoa Bac, the dengue incidence rate of 0 cases per 100,000 persons was significantly lower than in the surrounding Duc Hue district, which had an average of 42.7 cases/100,000 persons ($\chi^2 = 40.7$, df = 1, $P < 0.001$). In 2009, Thanh Tri also registered no confirmed dengue cases, and the incidence rate in this commune was significantly less than that in the surrounding Binh Dai district, which had an average of 150.3 cases/100,000 ($\chi^2 = 148.4$, df = 1, $P < 0.001$). Dengue incidence was generally lower than in the surrounding district in previous years, possibly because *Ae. aegypti* numbers were reduced five months after the program started, or a combination of factors including the randomness of dengue.

In 2009, 16 confirmed dengue cases in the Chanh Hoi commune was equivalent to a dengue incidence rate of 183.0 cases/100,000 persons, which was significantly lower than the incidence rate in the surrounding Mang Thit district (average = 311.7 cases/100,000 persons; $\chi^2 = 33.03$, df = 1, $P < 0.001$). Subsequent investigation by the provincial preventive health center indicated that some or all of these cases were imported.

By 2009, serologic surveillance of dengue infection had been established and improved at all health levels such as sampling skills of commune health staff in applying a modified case definition; dengue case detection from fever cases ranged from 7.7% in Ben Tre to 11.9% in Vinh Long during five months (March–July 2008); and the dengue IgM antibody-capture enzyme-linked immunosorbent assay capacity in provincial laboratories and the Pasteur Institute had 80%, 90%, and 95% concurrence in Vinh Long, Long An, and Ben Tre, respectively.

Sustainability funds. In June 2007, small income generating initiatives were implemented in Phuoc Dong (Long An) and Tan Binh (Hau Giang). The CMCs were tasked with making a final proposal to the project executive for approval, taking into account return on investment and risk. As an outcome of CMC recommendations, Phuoc Dong invested 3,080 USD

TABLE 3

Dengue case incidence per 100,000, confirmed by MAC-ELISA, in intervention (Tan Binh, Phuoc Dong, Binh Hoa Bac, Thanh Tri, and Chanh Hoi) communes compared with controls (Tan An commune and Duc Hue, Binh Dai, and Mang Thit districts), Vietnam*

Year	Tan Binh	Phuoc Dong	Tan An (control)	Binh Hoa Bac	Duc Hue (control)	Thanh Tri	Binh Dai (control)	Chanh Hoi	Mang Thit (control)
1999	104.5	0	14.0						
2000	59.1	50.3	98.0						
2001	36.3	122.3	265.8						
2002	9.8	0	0						
2003	13.6	43.1	111.9						
2004	145.4	70.8	559.5						
2005	50.0	0	14.0						
2006	9.8	0	14.0	187.0	79.5	12.0†	4.4	0	NA
2007	0	0	69.9	11.7	34.7	0	36.6	240.2	125.3
2008				23.7	27.5	12.0†	41.0	160.1	118.4
2009				0	42.7	0	150.3	183.0†	311.7

*Community-based interventions (gray shading) began in June 2004 and in March 2006. MAC-ELISA = IgM antibody capture enzyme-linked immunosorbent assay; NA = not available.
†Local and imported cases were not separated.

(218,000,000 VND) into a private business, Thang Long Commerce and Construction, with the balance of 780 USD (13,000,000 VND) used to buy two tricycles for rubbish collection. The monthly interest from the loan and from rubbish collection totaled 193 USD (3,216,000 VND), which was sufficient for continuation of 66 collaborators and 4 CMC members in project activities after August 2008.

In Tan Binh, the CMC decided to facilitate loans to government workers within the commune initially, but was extended to collaborators in year 2 and the entire community beyond that. The interest rate returned 3,467,000 VND (208 USD) to pay the monthly incentives for 73 collaborators and 4 CMC workers after August 2008.

As of April 2009, model communes Binh Hoa Bac (Long An), Thanh Tri (Ben Tre), and Chanh Hoi (Vinh Long) continued activities under the management of the CMC and used funds generated by the allocation of a sustainability fund of 18,634 USD each, paid in August 2008. Previously CMCs had decided to invest their funds in high interest savings accounts with local banks, but reduced interest rates when the global financial crisis threatened the community model. This reduction generally meant that either the allowances for CMCs and collaborators had to be reduced, or the same amount had to be paid to reduced numbers.

A specialist consultant team regarding sustainability funding engaged in May 2009 set out a possible implementation plan for each commune. The consultants looked at investing the fund in a savings account at a bank, using the fund for a loan to one company, or creating a micro credit fund. Commune leaders resolved to leave the fund in a savings deposit with their nominated bank and deal with the problems created by a lower return.

DISCUSSION

Our community-based strategy[2] included a combination of a professionally driven (top-down) element coupled with empowerment of communities to take charge of their destinies (bottom-up).[9] The results achieved were caused by local ownership at the institutional and community level, and aided by sound technical advice. The collaborator meetings also brought indirect skill development as they enabled exposure to other disciplines that the collaborators did not readily access: "Through the meetings I have been able to learn about project planning and implementation." Collaborators also understood the significance of reporting on time with accurate data. Given that the "project is about the health of people" they understood that their reports needed to "accurately reflect the actual number of water jars that are in the household". They demonstrated a broad understanding of where their work fitted within the wider framework of the project but it also provided them with broader employment skills.

In March 2010, the project received a final external review by Vietnamese health professionals.[10] Overall, the project was judged to achieve its objectives with high relevance, efficiency, effectiveness, and sustainability. The project also brought about changes in long-term impact to target populations and improve individual competence and institutional capacity, although the question of long-term returns from sustainability funds to meet recurrent costs was not resolved.

The review panel considered implementation and scaling up of the model. There were four key findings derived from this study. First, participation of local authorities and community was a key for success. More progress and better effectiveness would be achieved at the commune level in which the local authority was engaged and could provide specific support. Second, schoolchildren could be considered as collaborators because they were active in participation of community activities and had influence on their parents and families with respect to preventive measures against dengue. Third, a multisectoral approach integrating vertical and horizontal systems and incorporating epidemiologic and entomologic surveillances was necessary in designing and implementing a community program on dengue prevention and control. Fourth, inoculation of *Mesocyclops* was considered a good practice because of its inexpensiveness, ease in use, and high and sustainable effectiveness.

We concur with these findings. Although we have provided technical advances with quantitative sampling and decision-support tools, the major reason for success lies at commune level with local leadership by the CMCs to guide collaborators who educated and motivated householders on dengue vector control, but also serviced some of their needs. The qualitative research via focus group discussion was important in focusing opinion and in developing ownership, usually by year 3. This ownership was strong when the CMCs were entrusted to make financial decisions to ensure program sustainability, and this also was the case for northern and central communes that completed our programs.[5]

Persons in southern Vietnam are recognized as being more independent and having some language differences compared with persons from the north, and the terrain throughout the Mekong delta can be difficult to traverse because of rivers, tributaries, and canal systems. This difficulty made it more arduous for collaborators to achieve the desired coverage of households. Since our original programs in northern[3] and central Vietnam,[4] there always has been discussion about quality of collaborator effort and lack of an objective system to provide appropriate evidence.

The development of a web-based decision support tool[10] became desirable to deal with commune level interventions (usually 5,000–10,000 persons), but absolutely essential when nine communes were added to our project in an 11-month period during September 2007–August 2008. The web-based decision support tool provided data that measured progress in *Mesocyclops* inoculation, densities of *Ae. aegypti*, level of household coverage, and provided analysis. After this tool was introduced in 2009, CPOs were able to convey monthly data in a format that was understandable to managers, collaborators, and communes alike. Issues of collaborator quality and outputs of team members have been a basis for contention for years, and this evidence-based system removed any basis for argument.

The decision support system can be modified further by consideration of terrain and the variable numbers and spatial heterogeneity of water storage containers in each commune. On the basis of data from the Binh Hoa Bac, Chanh Hoi, and Thanh Tri communes, the numbers of containers that collaborators were required to inspect each month in each zone was subject to a 4.6–5.2-fold variation.[10] Consequently, the effort required from different volunteers varied considerably, but the system allowed rectification.

The results were surprising with respect to progress and the efficacy of control. From data in Figures 1–4 and focus group

discussions, it seemed clear that it could take some time for communities to embrace new concepts, but once accepted it was also clear that a high efficacy of control could be achieved quickly. Because of district level communication and a local groundswell of knowledgeable helpers, acceptable control was achieved in 15 months in some extension communes. Our results indicate that after establishing a model program, progress could be rapid through entire districts, given a wet season commencement. Those programs that ran for 36–45 months commenced in March during the dry season, or in June at the beginning of the wet season, when many jars were without water and therefore went untreated until they refilled with wet season rain.

Although standard jars and other water storage containers provided a clear target for control, originally we were concerned about seemingly high numbers of larvae and whether *Mesocyclops* predation rates would be sufficient. For the 16 southern communes, mean ± SD numbers of third and fourth instars were 117.7 ± 87.8 mainly in 200-liter jars and 1,000-liter tanks compared with 46.7 ± 40.6 mainly in tanks and 130–300-liter jars in central Vietnam,[4] and 106.0 ± 83.8 mainly in concrete tanks in northern Vietnam.[3]

Although our team has been involved in four successful community-based dengue projects since 1998, this was our initial experience with Mekong Provinces. In a total of 14 communes with 124,743 residents, the mean ± SD density of adult female *Ae. aegypti* was reduced from 0.93 ± 0.62 to 0.06 ± 0.09, and reduction of immature numbers of immature *Ae. aegypti* averaged 98.8%. By the final survey, no adults could be collected in 6 of 14 communes, including Binh Thanh commune, which did not have adults or immature forms. Results could be improved in some extended communes, e.g., Song Phu, Phu Thinh, with additional time. Dengue transmission was halted or reduced in all five communes in which diagnostic serologic monitoring was performed.

Because of the random nature of dengue and the lack of extensive confirmed notification data, it was difficult to ascribe a *Mesocyclops* prevalence that correlated with absence of *Ae. aegypti* and therefore absence of dengue. With 61% *Mesocyclops* prevalence at Chanh Hoi and Song Phu during 2008–2009, surveys indicated no adult *Ae. aegypti*, but dengue was present at Chanh Hoi. This finding likely indicates the insensitivity of 15-minute aspirator collections. In 2006–2007, Tan Binh had a low *Ae. aegypti* density (adult density index = 0.3, larval density index = 1.1), a *Mesocyclops* prevalence of 72%, and a dengue incidence of 6.8/100,000 population but dengue was not recorded at Binh Hoa Bac with the same prevalence of *Mesocyclops*, and no adult *Ae. aegypti*, and a larval density index of 1.3. These data likely indicate is that a *Mesocyclops* prevalence > 75% is sufficient to exact a high level of control, but because minimum thresholds have not been established, we cannot say what is necessary to halt dengue transmission. However, on the basis of our previous successes in northern and central Vietnam,[3,4] elimination of *Ae. aegypti* can be achieved by these community-based programs and will result in elimination of dengue. This result supports the strategy of the National Dengue Control Program and should provide our southern partners at the Pasteur Institute of Ho Chi Minh City with a large scale community-based vector control model suitable for introduction into the 20 provinces under their jurisdiction.

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