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Sustainability and Cost of a Community-Based Strategy Against *Aedes aegypti* in Northern and Central Vietnam

Brian H. Kay,* Tran T. Tuyet Hanh, Nguyen Hoang Le, Tran Minh Quy, Vu Sinh Nam, Phan V. D. Hang, Nguyen Thi Yen, Peter S. Hill, Theo Vos, and Peter A. Ryan

Australian Centre for International and Tropical Health, Queensland Institute of Medical Research, Brisbane Queensland, Australia; School of Population Health, University of Queensland, Brisbane, Queensland, Australia; Vietnam Administration of Preventive Medicine and Environmental Health, Ministry of Health, Hanoi, Vietnam; National Institute of Hygiene and Epidemiology, Hanoi, Vietnam; Hanoi School of Public Health, Hanoi, Vietnam; Institute of Malariology, Parasitology and Entomology, Quy Nhon, Vietnam

Abstract. We previously reported a new community-based mosquito control that resulted in the elimination of *Aedes aegypti* in 40 of 46 communes in northern and central Vietnam. During 2007 and 2008, we revisited Nam Dinh and Khanh Hoa provinces in northern and central Vietnam, respectively, to evaluate whether or not these programs were still being maintained 7 years and 4.5 years after formal project activities had ceased, respectively. Using a previously published sustainability framework, we compared 13 criteria from Tho Nghiep commune in Nam Dinh where the local community had adopted our community-based project model using *Mesocyclops* from 2001. These data were compared against a formal project commune, Xuan Phong, where our successful intervention activities had ceased in 2000 and four communes operating under the National Dengue Control Program with data available. In Khanh Hoa province, we compared 2008 data at Ninh Xuan commune with data at project completion in 2003 and benchmarked these, where possible, against an untreated control commune, Ninh Binh, where few control activities had been undertaken. The three communes where the above community-based strategy had been adopted were rated as well-sustained with annual recurrent total costs (direct and indirect) of $0.28–0.89 international dollars per person.

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: (1) a combined vertical and horizontal approach that depends on community understanding and leadership, (2) a prioritized control according to the larval productivity of major habitat types, (3) the use of predacious copepods of the genus *Mesocyclops* as a biological control agent, and (4) the use of communal activities of health collaborators, school children, and the public to deliver *Mesocyclops*. From 1998 to 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 people)[3] and then, were expanded to another 37 communes (N = 309,730 people) from 2000 to 2003.[2] We reported the elimination of *Ae. aegypti* in 38 of 43 communes with only small numbers of larvae detected in the other communes. From 2000 to 2003, we reported the elimination of *Ae. aegypti* from two of three central communes,[4] which, together with the northern results, constituted elimination of *Ae. aegypti* from a total of 40 of 46 communes. Based on these results, we suggested that this strategy was suitable for Vietnam and applicable elsewhere, where the major sources of *Ae. aegypti* are large water-storage containers and there is no risk of exacerbating parasitic infections such as *Dracunculus*. In their commentary on the strategy, Hales and van Panhuis[5] correctly pointed out that this strategy was not a universal answer to the dengue problem but suggested that it could make an important difference to rural communities.

The maintenance of these community-based dengue control activities in areas in Vietnam where *Ae. aegypti* and dengue have been eliminated is a potential challenge in terms of delivery of long-term public health benefits. In our previous paper,[6] we recognized that there was little consensus on the operational definition of sustainability, and we developed a framework from which to objectively score any post-project activities. With the aim of establishing whether or not these community-based dengue control programs represent effective long-term solutions for the prevention of dengue, we revisited two communes in the Xuan Truong district of Nam Dinh in northern Vietnam to evaluate if the 1998–2000 program was still being maintained 7 years later in 2007. Additionally, we visited one commune in Khanh Hoa province in central Vietnam in 2008 where project activity had ceased in 2003. The communes for evaluation were chosen by the independent field evaluators on the basis of post-project age and availability of logistical support. Two communes (Xuan Phong and Ninh Xuan) were previously part of our community-based control project, whereas one commune (Tho Nghiep) was started up locally 1 year after we had left the district.

MATERIALS AND METHODS

The study areas. *North Vietnam.* Xuan Truong District in Nam Dinh Province (20°16′ N, 106°20′ E) lies approximately 100 km southeast of Hanoi and covers an area of 111.2 km^2; it has a population of 172,906 people who are mainly involved in agriculture. About 40% of the people were using piped water, whereas the remaining 60% relied on rain and well water stored in large containers, mainly > 500-L box tanks. For households that were using piped water, most of them used this source of water for drinking purposes only and still used rain and well water at the same time for other purposes such as bathing and washing. From 1990 to 1999, dengue occurred as major epidemics in the district, and 396 cases and 6 deaths in 1993, 259 cases in 1995, and 656 cases in 1998 (Ministry of Health, unpublished data) were reported.

*Address correspondence to Brian H. Kay, Australian Center for International and Tropical Health, Queensland Institute of Medical Research, Royal Brisbane Hospital, Brisbane, Queensland 4029, Australia. E-mail: brian.kay@qimr.edu.au

Our previous publication[6] included an evaluation of Xuan Phong commune (designated hereafter as North Project Commune [NPC]), which was used for framework evaluation purposes. *Ae. aegypti* had been eliminated from Xuan Phong by the final year of our community-based project in March 2000, but in 2007, we also evaluated Tho Nghiep commune in which the local community extended our model post-project to eliminate *Ae. aegypti* by April 2003.[2] Tho Nghiep was designated as North Extended Commune (NEC). As intervention activities occurred to varying degrees in all communes in Nam Dinh, our most appropriate negative-control data were drawn from four communes where some dengue education and control activities had been implemented under the National Dengue Control Program (NDCP) from 2000 in Trung Dong, Minh Tan, Dai Thang, and Lien Minh (designated as North Control Communes [NCC]). Although specific dengue-control activities had only begun in Lien Minh from 2006, the commune had also been subject to an environmental clean-up program since 1998.

Central Vietnam. In 2008, we evaluated a previous project commune, Ninh Xuan (Central Project Commune [CPC]; 12°30′32″ N, 109°02′22″ E) in Khanh Hoa province on the southern central coast where our project terminated in 2003, and we compared these data with those for neighboring Ninh Binh commune (12°29′14″ N, 109°05′20″ E) where no formal dengue control had occurred (Central Control Commune [CCC]). There are two distinct climatic seasons in the region; the rainy season lasts from April to December, whereas the other months are dry. Houses ranged from single story with unsealed floors and yards to multistory houses with sealed floors and concrete yards. There was no piped water supply in the communes. The primary source of household water was rainwater stored in tanks and jars in the wet season and/or groundwater from wells.

During the final 2 years of the project (2002–2003), no dengue cases were reported from CPC.[4] In comparison, dengue cases were widely distributed in other locations throughout the province (Khanh Hoa: incidence rate = 56–115 cases per 100,000 per year) and district (Ninh Hoa: incidence rate = 13–130 cases per 100,000 people per year), including CCC where the incidence rate was 65–112 cases per 100,000 people per year (Ministry of Health, unpublished data).

Study design. Independent researchers previously not associated with the intervention strategy conducted the sustainability evaluations. The post-project data for the communes were collected from monthly collaborator visitation and sampling records for the communes that were supplemented by data from district and provincial health centers, Institute Pasteur Nha Trang, and the National Institute of Hygiene and Epidemiology, Hanoi. These included annual dengue-case data, entomological parameters, knowledge, attitude and practice (KAP) results from the end of the interventions, types and frequency of control activities during the project implementation and after project completion, and budget allocation and actual expenditure for control activities after the control projects had been completed.

Assessment of project sustainability. A cross-sectional descriptive study was conducted to determine the level of residual community dengue-control activity as well as the KAPs in relation to dengue fever (DF) and dengue hemorrhagic fever (DHF) control; community members in the study communes and those directly involved in the project at different administrative levels were surveyed. Entomological surveys were used to determine the productivity of different containers in terms of III/IV instars for both *Ae. aegypti* and *Ae. albopictus*. These containers were also assessed to determine the prevalence of the biological control agent, *Mesocyclops*. Both qualitative and quantitative methods were used in the study.

The following comparisons were made. (1) In the north, 13 criteria were evaluated for a NPC (Xuan Phong) and a NEC (Tho Nghiep), which were referenced against scores for four communes that were not involved in the original community-based *Mesocyclops* project. (2) In the central coast, a CPC (Ninh Xuan) was referenced against a CCC (Ninh Binh) where no regular dengue program occurred; controls were used to benchmark sustainability criteria.

Qualitative component. *S*ample size for the qualitative component was based on previously published studies.[7–9] For NPC and NCC, 6–10 people participated in each of three focus-group discussions, whereas each of four focus groups at CPC and CCC had 10 participants.

Participants for in-depth interviews were purposely selected based on their relevance to the research questions and their positions and involvement in the previous control projects. A total of 26 key informants ($N = 16$ for the north and $N = 10$ for the center) involved in the project activities were selected, and they included project managers at the national level, community project officers, project officers from the provincial centers of preventive medicine, project officers from district health centers, representatives from two different communal people's committees, health staff from different communal health centers, and heads of different primary/secondary schools. Focus-group discussions included heads of households or their spouses, and another group involved collaborators (NEC, NCC, and CPC) or village health workers if there was no specific structured dengue program (CCC). In-depth interviews were based on guiding questions, which differed minimally from the open-ended questions used in the focus-group discussions, to facilitate free expression and create dynamic discussion. Purposeful sampling and data triangulation between these two methods were used to create qualitative rigor in the data, and in some cases, these data could be compared with the quantitative data. Data were subjected to inductive thematic analysis based on the grounded theory approach, which was driven by and based on the original accounts of the respondents.[8]

Quantitative component. The participants of the KAP surveys were representatives of the households in which entomological surveys were conducted. To reduce recall bias, exclusion criteria were (1) people aged < 18 years old and (2) people without the cognitive ability to participate in the interview. In March 2007 in northern Vietnam and January 2008 in central Vietnam, systematic random samples of 100 houses were chosen for entomological and KAP survey subjects in each commune (in total, $N = 300$ and 200, respectively). This was done to verify the monthly records of collaborators. 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. To assess the standing crop of III/IV instar and pupal *Aedes* spp. and the prevalence of *Mesocyclops*, samples were taken from small containers using a pipette, from medium to large containers using a five-sweep sampling technique with a 20-cm diameter

and 33-cm deep net of 100-μm mesh,[10] and from wells using funnel traps.[11,12] III/IV instars were counted, transferred to storage jars containing 4% formaldehyde, and transported to the laboratory for species definition using a stereomicroscope. Standing crops of immatures were then estimated from sample yields using correction factors according to container type.[10] This was expressed as a larval density index (the average number of larvae per house), whereas *Mesocyclops* prevalence was recorded as a percentage of wet > 50-L containers. Adult density index was used to describe the average number of female *Ae. aegypti* per house based on 15-minute aspirator collections of adult mosquitoes resting indoors on clothes, on walls, and under beds. Using a previously published KAP survey format,[3,4] stated community behavior on dengue control was checked against actual practice.

In the NCC, the Breteau Index (number of infested containers per 100 households) was still being used as an immature prevalence criterion, and records of *Mesocyclops* prevalence were unavailable. Available data were used for comparison, but qualitative and quantitative procedures as described above were also applied to Lien Minh commune in January (KAP) and March 2007 (container survey). Because CCC had been used as an untreated control during the project, larval density data were available for 2000–2003, but thereafter, no data were available until the January 2008 survey was done.

Data analysis. All statistical analyses were completed using Stata 8.0 (StataCorp, College Station, TX). As a statistical basis for establishing differences between periods or localities, quantitative data were analyzed using χ^2 tests, and 95% confidence intervals (CI) were calculated. For the NPC, this entailed comparing data at project completion in March 2000 with results from KAP and household surveys in January and March 2007, respectively. For the NEC, this involved comparing baseline data between March 2002 and April 2003 with data for January and March 2007. For CPC and CCC, this involved comparisons between final project data for October 2002 to June 2003 with January 2008 (Table 1).

Sustainability score. We used 13 criteria[6] listed in Tables 2 and 3 grouped under three headings: (A) maintenance of health benefits achieved through the initial project, (B) continued delivery of project activities, (C) long-term capacity building in the recipient community. The level of sustainability was scored using a standard five-interval rating system (1–1.5 = regressive, 1.5–2.5 = not sustained, 2.5–3.5 = moderately sustained, 3.5–4.5 = well-sustained, and 4.5–5 = highly sustained). For the northern communes, two researchers (T.T.T.H. and T.M.Q.) scored each criterion separately (a maximum of 5 points for each), and in the absence of any major disparities, their scores were averaged to give a final rating. For the central communes, one researcher (N.H.L.) relied on her personal assessment.

Program costs. At the communal level, direct costs included stipends for collaborators and commune-management committees and supplies for schools and collaborators, whereas other funds were expended by national (mainly in the first year) and provincial health authorities for monitoring and evaluation and for clean-up campaigns. Because the collaborator stipends fell short of a realistic wage, missed opportunity costs were estimated based on reported incomes that would have otherwise been earned by the collaborators. All costs were calculated in Vietnamese Dong (VND) but were also reported in international dollars according to the 2007 purchasing power parities conversion rate (1 International Dollar = 6,520 Vietnamese Dong).[13]

RESULTS

Data for each of the sustainability criteria are summarized for the northern communes, and NPC and NEC are benchmarked against NCC (Table 2); for central communes, CPC was benchmarked against a negative control, CCC (Table 3).

Sustainability assessment for northern Vietnam. Table 2 shows maintenance of health benefits using criteria A1–A4. Because dengue is sporadic and not annual in the north, the presence of new dengue cases did not provide useful data on program efficacy. For NPC, we have previously reported the absence of both *Ae. aegypti* and *Ae. albopictus* after completion of project activities in March 2000[3] and the absence of *Ae. aegypti* in March 2007.[6] For NEC in March and June 2002, when community-based dengue-control activities were initiated, the density indices for III/IV instars were 22 and 105 per house, adult female *Ae. aegypti* indices were 0.5 and 0.6, and *Mesocyclops* prevalence in large water storages was 17% and 18%, respectively. *Ae. aegypti* was absent from April 2005 after *Mesocyclops* prevalence had been maintained in 80–86% of large containers for 2 years. This contrasted against the four NCC where Breteau indices up to 38 occurred and higher numbers of discarded containers were present.

KAP was higher in NPC and NEC compared with NCC, especially with respect to the importance of collecting discarded items and inoculating *Mesocyclops*. With respect to the most trustworthy source of information, most respondents in the three northern study communes (83.3–93.3%) believed in their health workers, and a considerable proportion believed in audio–visual media (45.0–83.3% in television and 28.0–57.4% in radio). Trust in audio–visual media had changed significantly from 1999 to 2007 (χ^2 = 65.1; $P < 0.001$). Meanwhile, other communication tools, such as leaflets, had low effect on the community (4.8–9.0%), which was consistent with opinions during the project activities from 1998 to 2000. Regular visits from health workers were considered important, because 77.0% and 80.0% of respondents in NPC and NEC, respectively, appreciated the community work conducted by these collaborators in health education and environmental supervision. In addition, health collaborators were reported by 80.4–90.0% of respondents to be active in reinoculating *Mesocyclops* into water containers of households. As a result, 56.7–66.3% of respondents approached them first for additional *Mesocyclops*.

Project activities (criteria B1–B5) were best delivered by NPC and NEC compared with control communes. The KAP survey in 1999[3] showed that 76.6% of households in NPC received monthly visits from collaborators. Seven years after the project ceased, 59% of the respondents in Xuan Phong reported continuing monthly household visits. Although this was significantly lower than the 76.6% visitation rate during the project period ($\chi^2 = 17.2$; $P < 0.001$), it was still greater than rates in Tho Nghiep (NEC) and Lien Minh (CCC), which were 48.1% and 24.3%, respectively.

The frequency of household visits made by health workers/collaborators was strongly related to the knowledge of respondents about the cause of DF/DHF (χ^2 = 63.48; $P < 0.001$), the route of transmission ($\chi^2 = 52.64$; $P < 0.001$), mosquito vectors (χ^2 = 78.28; $P < 0.001$), mosquito biting time (χ^2 = 36.97;

TABLE 1
Characteristics of dengue control programs and study communes, Nam Dinh and Khanh Hoa provinces, Vietnam

Communes	Population	Houses	Main activities	Budget
North				
Project commune (Xuan Phong)	10,100	2,550	Entomological and KAP surveys, training for project staff and 18 collaborators, inoculation of *Mesocyclops*, community environmental clean-up campaigns, health education, and communication for community.	Locally run from 2000; microcredit scheme post-project plus other funding.
Extended commune (Tho Nghiep)	12,000	2,546	Entomological surveys, clinical surveillance system, training for a communal health worker and 23 collaborators, inoculation of *Mesocyclops*, community clean-up campaigns, health education, and communication for community.	Locally run from March 2002 after project cessation in 2000; some funding from NDCP.
NDCP communes ($N = 4$)	40,463	9,668	Clinical surveillance system, collaborator system for visitation, community clean-up campaigns, and communication activities through television, loudspeaker, and local meetings.	National NDCP funding from various starting dates.
Central				
Project commune (Ninh Xuan)	11,110	1,855	Collaborator system for visitation, inoculation of *Mesocyclops*, community clean-up campaigns, and community and collaborator education meetings.	Microcredit funding post-project; local funds plus national funding from NDCP.
Untreated commune (Ninh Binh)	10,856	2,311	Quarterly visitation by local authorities, periodic cleaning of jars, introduction of some fish, regular replacement of water in vases, and elimination of discarded containers.	No dedicated funds for dengue vector control

$P < 0.001$), and mosquito resting site ($\chi^2 = 70.22$; $P < 0.001$). The frequency of household visits also influenced the respondents' beliefs about the preventability of the disease. Householders that health workers/collaborators visited one time per month were more likely to believe that DF/DHF could be prevented ($\chi^2 = 28.5$; $P < 0.001$).

In NPC, *Mesocyclops* prevalence in March 2007 compared with December 1999 (80.3% versus 82.6%) was not significantly different ($P = 0.12$) but significantly greater ($\chi^2 = 4.85$; $P < 0.05$) than at NEC (55.4%). More discarded items were also collected, and school pupils were educated on dengue and its control. The quantities of discards collected at NPC and NEC were 23.0 and 18.5 tonnes, respectively, in 2004, 19.0 and 3.7 tonnes in 2005, and 7.0 and 2.95 tonnes in the first 6 months of 2006. There was no data available for Lien Minh in 2004 and 2005, but for the first 6 months of 2006, the quantity of discards collected at this commune was 0.9 tonnes, which was much lower than for NPC and NEC. NPC and NEC maintained specific monthly meetings and records, whereas those at the control communes were more general and irregular.

Long-term capacity building was strongly maintained in NPC and NEC compared with NCC (criteria C1–C4). Managers and collaborators at Xuan Phong and Tho Nghiep benefited from continuous work and a training program provided through a timely feedback system, whereas the system in the control communes relied on annual training and multipurpose monthly meetings. The design of the original project at NPC originally included a small project fund of VND 70 million (reported as $4,666 U.S. or 10,736 international dollars in 2005), which started in April 2001.[2] After community deliberation, money was invested as a loan to a food-processing company, which created monthly interest of approximately VND 490,000 (75.20 international dollars). Approximately 72% of this amount ensured a monthly allowance of VND 20,000 (3.07 international dollars) for each collaborator, and the balance was used for other dengue-control activities such as communication, health education, and school activities. From 2000 to 2005 in NEC, each collaborator received VND 25,000 (3.83 international dollars) per month from local sources, including the People's Committee. However, since 2006, the collaborator stipend was reduced to VND 8,000 per month (1.23 international dollars). Collaborators were still committed to their assigned tasks, although they wished for a greater incentive. Those at NCCs received VND 20,000–25,000 (3.07–3.83 international dollars) per month.

Sustainability assessment for the central commune. Table 3 shows that health benefits were superior in CPC compared with CCC (criteria A1–A4). From 2004 to 2007, suspected dengue cases were reported from the project commune in 2005 and 2007 but not in 2004 or 2006 (75 cases over 4 years; incidence rate of 169 cases per 100,000 people per year). This was significantly lower than the rate in the control commune (119 cases over 4 years; incidence rate of 274 cases per 100,000 per year; $\chi^2 = 11.12$; $P < 0.05$). Compared with overall incidence rates from the provincial and district levels (267 and 353 cases per 100,000 per year, respectively), the incidence rate in Ninh Xuan was significantly lower (provincial: $\chi^2 = 16.13$; $P < 0.001$; district: $\chi^2 = 34.27$; $P < 0.001$) during the post-project period (2004–2007); however, the rate in the untreated control commune (Ninh Binh) was not significantly different from the provincial rate ($\chi^2 = 0.09$; $P = 0.77$), although it was significantly less than the district rate ($\chi^2 = 7.54$; $P < 0.05$).

In the September 2000 baseline survey at CPC, the larval density index was 24.66 per house ($N = 100$), and in June 2003, when the project officially ended, it was 0.11. Data for June 2004, May 2005, and January 2008 indicated densities of 0.1, 0.3, and 1.51 ($N = 100$), respectively. Adult indices showed a reduction from 0.13 females per house in September 2000 to 0.01 in June 2003; thereafter, there was a reduction to 0 in June 2004 and May 2005 but an increase to 0.03 in January 2008. By comparison with the CCC, larval and adult density indices varied from 9.60 to 46.98 and from 0.12 to 0.84, respectively, from September 2000 to June 2003, but in January 2008, they were 17.8 and 0.12, respectively. During the January 2008 survey, there were large differences in abundance between CPC (153 III/IV instars in two box tanks, two small jars, and six ant traps) and CCC (1,783 III/IV instars in 45 positive containers [box tanks = 70.3% of total numbers; jars = 11.8%; vases = 9.0%; ant traps = 4.3%; wells = 3.4%), although the numbers of wet containers ($N = 348$) were similar.

TABLE 2

Summarized assessment of the sustainability of the new dengue strategy at Xuan Phong commune (NPC) compared with Tho Nghiep (NEC) and benchmarked against four control communes in northern Vietnam (January to March 2007)

	Criteria	Xuan Phong project commune	Tho Nghiep extended commune	Control communes
A1	New DF cases	No local cases since 2000; 3 imported cases in 2003.	No local or imported cases since 2000.	No local cases since 2003; imported cases until 2006.
A2	Entomological indices	All indices for *Ae. aegypti* = 0; *Ae. albopictus* density index (DI) for larvae = 0.07.	All indices for *Ae. aegypti* = 0; *Ae. albopictus* DI for larvae = 2.68.	Breteau indices for *Ae. aegypti* = 0–38; adult density indices = 0–0.3. *Ae. albopictus* present.
A3	Number of containers for *Aedes*	Negative for *Ae. aegypti* (N = 200). Key containers are box tanks and wells; discards decreased and remained low.	Negative for *Ae. aegypti* (N = 235). Key containers are box tanks and wells; discards decreased and remained low.	*Ae. aegypti* immatures present in 2 of 4 communes (N = 157–357). Key containers are box tanks and wells; discards increased.
A4	KAP of householders	98% of respondents heard of DF/DHF (95% CI = 93.0–99.8%); 50% knew symptoms of DF (95% CI = 39.7–60.3%); 82% knew that the vector was striped mosquitoes (95% CI = 72.6–89.1%); 74.5% knew that collecting discards destroys mosquito habitats (95% CI = 64.4–82.9%); 76.2% (95% CI = 65.7–84.8%) reported inoculation of *Mesocyclops*.	97.1% of respondents heard of DF/DHF (95% CI = 91.8–99.4%); 45.5% knew symptoms of DF (95% CI = 35.6–55.8%); 79% knew that the vector was striped mosquitoes (95% CI = 69.0–86.8%); 57.6% knew that collecting discards destroys mosquito habitats (95% CI = 47.2–67.4%); 60.5% (95% CI = 49.3–70.8%) reported inoculation of *Mesocyclops*.	93.5% of respondents heard of DF/DHF (95% CI = 87.1–97.4%); 43.6% knew symptoms of DF (95% CI = 33.7–53.8%); 48% knew that the vector was striped mosquitoes (95% CI = 36.9–59.5%); 25% knew that collecting discards destroys mosquito habitats (95% CI = 17.0–34.4%); 0–2.3% reported inoculation of *Mesocyclops*.
B1	Continued activities of collaborators on DF control	59% (95% CI = 49.4–68.6%) of households received a monthly visit by collaborators	48.1% (95% CI = 38.5–57.7%) of households received a monthly visit by collaborators.	24.3% (95% CI = 16.5–33.5%) of households received a monthly visit by collaborators.
B2	Continued placement of *Mesocyclops* in large water containers	80.3% *Mesocyclops* in large containers.	55.4% *Mesocyclops* in large containers.	30–68% of large containers with either fish or *Mesocyclops;* 24.8% inadvertently inoculated *Mesocyclops* into big containers.
B3	Continued elimination of *Aedes* breeding sites	94% (95% CI = 87.4–97.8%) reported regular collection of discards, mainly for eliminating breeding sites; 2006 total = 7,000 kg discards collected.	96.1% (95% CI = 90.4–98.9%) reported regular collection of discards, mainly for eliminating breeding sites; 2006 total = 2,950 kg discards collected.	97.1% (95% CI = 92.0–99.4%) reported regular collection of discards, mainly for a cleaner living environment; 2006 total = 900–2,870 kg discards collected.
B4	Continued activities of schools/social organizations	4,600 pupils educated on DF; 12,000 person times received talks on DF.	800 pupils educated on DF; 2,500 person times received talks on DF.	556 pupils educated on DF; 500 person times received talks on DF.
B5	Continued functioning of reporting system	Regular monthly meetings. Record books maintained. Suggestions praised by project leadership, and timely feedback provided.	Regular monthly meetings. Record books maintained. Suggestions praised by project leadership, and timely feedback provided.	Meetings monthly but mainly multi-purpose; record books maintained at a reduced level.
C1	Human resource development for DF control	Adequate training for CMC, health staff, and 18 collaborators, each covering 141 households. Continuous work and assessment program.	Training for CMC, health staff, and 18 collaborators, each covering 141 households. Continuous work and assessment program.	Some training for CMC, health staff, and 9–23 collaborators covering 107–150 households. Annual collaborator training.
C2	Maintaining budget allocated for DF control	Microcredit fund ensured each collaborator received a monthly incentive of VND 20,000. Small amount for other DF control activities, management fee, etc.	From 2002 to 2005, each collaborator received a monthly incentive of VND 25,000. From 2006, this decreased to VND 8,000/month.	Each collaborator received monthly incentive of VND 20,000–25,000.
C3	Maintaining diverse, inclusive citizen participation in DF control	Active participation of health workers, volunteers, school teachers and pupils, householders, Women's Union, and Youth Union.	Active participation of health workers, volunteers, school teachers and pupils, householders, Women's Union, and Youth Union.	Less participation of collaborators and schools; active participation of householders and Women's Union in collecting discards without full realization of impact on DF control.
C4	Maintaining leadership base for DF control	Head of CHC, Vice Head of CPC, and head of school formed strong leadership that was maintained after project ended.	Head of CHC, Vice Head of CPC, and head of school maintained strong leadership after provincial initiation.	Head of CHC, Vice Head of CPC, and head of school provided leadership for DF control.

KAP data from January 2008 for CPC (N = 100) were compared with results from October 2002 and results from CCC (N = 100) for January 2008, because no previous KAP surveys had been undertaken. General knowledge of dengue was higher at CPC than CCC (χ^2 = 12.82; $P < 0.001$). In CPC, however, householder knowledge regarding DF/DHF symptoms was significantly lower than that reported in the final KAP survey in 2002 (χ^2 = 52.99; $P < 0.001$). The results of the 2008 surveys also showed that the proportion of KAP interviewees in CPC who retained the knowledge about the

TABLE 3

Summarized assessment of the sustainability of the new dengue strategy at Ninh Xuan commune (CPC) benchmarked against untreated Ninh Binh commune (CCC) in central Vietnam (January to March 2008)

	Criteria	Ninh Xuan (project commune)	Ninh Binh (untreated control commune)
A1	New DF cases	2004: 0 cases; 2005: 53 suspected cases; 2006: 0 cases; 2007: 22 suspected cases	2004: 13 suspected cases; 2005: 36 suspected cases; 2006: 4 suspected cases; 2007: 66 suspected cases
A2	Entomological indices	DI for adults = 0.03; DI for larvae = 1.51. Large containers with *Mesocyclops* = 36%.	DI for adults = 0.12; DI for larvae = 17.8. Large containers with *Mesocyclops* = 4.2%.
A3	Key containers for *Ae. aegypti*	Key containers were tanks < 500 L, small jars, and ant traps. No discarded containers	Key containers for *Ae. aegypti*: wells, tanks > 500 L, tanks < 500 L, standard jars ≥ 100 L, small jars, ant traps, and flower vases. 12 discarded containers detected.
A4	KAP of householders on DF/DHF control	99% of respondents (95% CI = 97.05–100%) heard of DF/DHF; 60.6% (95% CI = 55.98–70.24%) knew the correct symptoms of DF; 98% (95% CI = 95.21–100%) knew the dengue vector was striped mosquitoes; 68.7% (95% CI = 59.55–77.83%) knew that collecting discarded containers can eliminate mosquito breeding sites; 21.2% (95% CI = 13.16–29.26%) reported *Mesocyclops* used for larval control.	97% of respondents (95% CI = 93.55–100%) heard of DF/DHF; 35.1% (95% CI = 25.55–44.55%) knew the correct symptoms of DF; 62% (95% CI = 59.33–78.45%) knew the dengue vector was striped mosquitoes; 44.3% (95% CI = 34.44–54.22%) knew that collecting discarded containers can eliminate mosquito breeding sites. No respondents reported application of *Mesocyclops* as larval control method.
B1	Continued activities of collaborators on DF control	Maintained all assigned tasks but less frequently; 48% (95% CI = 31.21–57.79%) of households received monthly visits	No activity.
B2	Continued placement of *Mesoscyclops* in large water containers	36% *Mesocyclops* in large containers.	4.2% *Mesocyclops* in large containers.
B3	Continued elimination of *Ae. aegypti* breeding sites	55% (95% CI = 45.2–64.8%) of respondents collected discarded containers regularly; 45% (95% CI = 35.2–54.8%) cleaned water containers regularly.	30% (95% CI = 20.88–39.12%) of respondents collected discarded containers regularly; 22.7% (95% CI = 14.63–31.37%) cleaned water containers regularly.
B4	Continued activities of schools/social organizations	Four clean-up campaigns in 2007 were carried out with school teachers and pupils; 52 community meetings were conducted in 2007.	No activity.
B5	Continued activities of a reporting system	Continued monthly collaborators' meetings and recorded activities at households.	No activity.
C1	Human resource development for DF control	CMC provided ongoing guidance but no formal training. A CMC member (commune health-center head) was trained annually at one-day district-wide NCDP workshops.	No activity.
C2	Maintaining budget for DF control	Microcredit fund covered each collaborator's monthly incentive of 30,000 VND (4.60 international dollar) and some other community activities, management fees, etc.	No activity.
C3	Maintaining diverse, inclusive citizen participation in DF control	Maintained active participation of health workers, collaborators, school teachers and pupils, householders, Women's Union, and Youth Union.	No activity.
C4	Expanding leadership base for DF control	CMC formed strong leadership for DF control and maintained it after the project ceased.	No activity.

dengue mosquito (called the striped mosquito) was still high after 4.5 years (98.4% versus 98% in other communes), and it was significantly higher than that in CCC (68.9%; $\chi^2 = 29.87$; $P < 0.001$). However, the knowledge of the biting habits of the dengue vector was higher in CPC in October 2002 than in January 2008 (96.3% versus 48.5%). Householders' understanding of other factors such as resting habits of dengue mosquitoes, habitats of larvae, and dengue vector-control methods was similar to the results in October 2002.

In terms of dengue vector-control practices in the communes, the proportion of householders who reported cleaning water containers and removing discarded containers as larval control methods did not differ significantly in CPC 4.5 years after project completion ($\chi^2 = 0.004$; $P = 0.95$), but there was a significant reduction in the proportion of participants that continued to introduce *Mesocyclops* (78.5% versus 21.2%).

The most trustworthy source of dengue information was similar to sources cited in the north. Most participants in CPC and CCC indicated that health workers and collaborators were the most believable (91% and 94%, respectively). Frequent visits by collaborators were considered by all respondents to encourage CPC householders to be involved in dengue vector-control activities. The collaborators were reported to mobilize family members to take action against dengue vectors (57%), provide education on dengue (62%), reinoculate *Mesocyclops* in household water containers (55%), and guide householders to practice simple dengue vector-control methods (80%). In addition, 67% of surveyed householders asked their collaborators when they needed additional *Mesocyclops*.

In CPC after the project officially ended in June 2003, activities continued (criteria B1–B5). The commune-management committee (CMC; $N = 4$) and collaborator network ($N = 20$)

continued their routine activities in mobilizing the community, mainly through monthly visits with householders but also through informal contact at households and public places. Collaborators and CMC members reported that the workload associated with these activities was reduced, mainly as a result of an increase in the community's perception and knowledge on dengue and dengue vector control and the willingness of the householders to undertake control measures themselves. During the project, an average of 94% of households in the CPC had been visited monthly by collaborators, but by January 2008, this was reduced to 48% with an additional 41% reporting quarterly visitation. Although there was a decrease in the frequency of collaborator visits, householders' knowledge of dengue vector behavior, including larval habitats ($\chi^2 = 0.01$; $P = 0.93$) and resting places ($\chi^2 = 3.7$; $P = 0.056$), was maintained. Qualitative data from focus-group discussions and in-depth interviews indicated that the collaborators focused mainly on dengue vector-control activities with the householders rather than educating the community about dengue disease.

The KAP surveys in January 2008 showed that 21.2% of respondents in CPC reported that they introduced *Mesocyclops* into their water containers as a larval control method, although this was significantly lower than that reported in October 2002 (78.5%). Tanks < 500 L, tanks > 500 L, jars (130–300 L), drums, and wells were judged suitable for treatment. *Mesocyclops* prevalence was significantly higher in CPC (36%) compared with CCC (4%) in January 2008, although the rate in CPC in 2008 was lower than that observed at the end of the project in 2003 (48.4%). According to the KAP surveys in 2008, 55% of householders reported that the collaborators regularly reinoculated *Mesocyclops* into containers during their visits, possibly indicating that the collaborators were responsible for the maintenance of *Mesocyclops* in the households. However, in group interviews, some householders reported that they maintained *Mesocyclops* themselves.

At CPC, the KAP data from January 2008 indicated that 77.3% of respondents reported cleaning their water containers regularly and 68.7% reported elimination of discarded containers, similar to the data from December 2002 (cleaned containers: $\chi^2 = 0.58$; $P = 0.44$; discarded containers: $\chi^2 = 0.004$; $P = 0.95$). In January 2008, no discarded containers were found in CPC, whereas 12 were detected in CCC.

At CCC, 50.5% of the respondents reported that they cleaned their water containers regularly, and 44.3% reported they cleaned discarded containers to eliminate *Ae. aegypti* breeding sites at their own houses. These proportions were significantly lower than at the CPC at the same time (cleaned containers: $\chi^2 = 24.16$; $P < 0.001$; discarded containers: $\chi^2 = 42.04$; $P < 0.001$). The findings were consistent with the fact that although CPC householders actively applied a variety of methods for eliminating *Ae. aegypti* breeding sites at their own houses, the householders in the CCC mainly waited for local authorities to encourage them to be involved in commune-wide clean-up campaigns.

At the CPC, the Women's Union, Youth Union, and Farmers' Union also played an important role in mobilizing the community to take action against dengue vectors to supplement the collaborator activities; 4.5 years after the project completion, these crucial activities were still continuing.

Control activities were reported by collaborators to a Communal Project Management Committee (CPMC), which met monthly but also acted when urgent issues arose. The Vice-Chairman of the Commune People's Committee and the Head of the Commune Health Center were assigned as Head and Deputy-Head of the CPMC, respectively. As with the NPC and NEC, collaborators at the CPC would report unusual infestation levels or problems immediately, and these issues were often dealt with by the management through visitation or by proposing solutions. In NPC and NEC, management used a quality-assurance program administered through spontaneous visitations.

Long-term capacity building (criteria C1–C4) at CPC was not as strong as at NPC and NEC. There were no formalized training courses post-project for the collaborators and other CMC members except for informal guidance.

In 2003, a microcredit scheme was initiated at CPC (VND 60 million equivalent to $4,000 U.S. or 9,202 international dollars) where the CMC invested in a local brick-production business at a monthly interest rate of 1.2%. The interest funded monthly allowances for the CMC and the collaborators, and it provided funds for loudspeaker announcements and photocopying of report forms. Other expenses or indirect costs for clean-up campaigns, printing of posters and leaflets, and basic entomological equipment including sweep nets were incurred by the community. Diverse citizen participation was maintained by the leadership groups that were aided by other key Women's and Youth Union members and the Provincial and District Health Centers. When these people gained sufficient understanding from the project team, then a process of community engagement was driven mainly through health collaborators and schoolchildren to household level. This process created ownership, especially with decision making, and created opportunities for diverse parts of the community to develop new skills and gain importance through leadership and identity. Whereas the CMCs remained intact to deliver clear and consistent programs, the leadership group at CPC was reduced from nine to four persons (Chair, Vice-Chair, and two school principals). No expansion from the original project commune occurred, which is in contrast to the north.

Program cost. The recurrent annual cost at NPC was VND 40 million (6,134 international dollars) with an additional 10% used for start-up costs incurred in the first year. Two-thirds of the costs were attributed to missed opportunity costs of collaborators at three times the amount of their allowance.

From 2002 to 2007 in NEC, the recurrent annual cost was VND 70 million (10,736 international dollars) with an additional 1% used for start-up costs incurred in the first year. In the first few years of the program, opportunity costs constituted 85% of the total cost, and this increased to 90% in the latter 2 years when the allowance for collaborators was reduced from VND 25,000 to VND 8,000. Opportunity costs were a large share of total cost in NEC compared with NPC, because collaborators spent 4 days instead of 2 days per month on project activities.

At CPC, direct costs for maintenance of community activities during the post-project period were estimated to be VND 13.2 million; of this amount, the microcredit fund provided 66%, and the balance was provided by the local authority, the regional Pasteur Institute, and the NDCP. Indirect costs associated with in-kind contributions by local health staff and school teachers was estimated at VND 7 million per year, amounting to a total of VND 20.2 million per year (3,098 international dollars).

Recurrent annual project costs ranged from 0.28 international dollars per person at CPC to 0.61 international dollars per person in NPC to 0.89 international dollars per person in NEC.

Sustainability rating. At NPC, there was only one disparity in the ratings given by the two researchers, which resulted in sustainability scores of 4.38 and 4.46 of 5.00 (mean = 4.42). Small differences in 6 of 13 scores for NEC resulted in sustainability scores of 3.92 and 3.46 of 5.00 (mean = 3.69), whereas the rating for CPC was 4.20. This resulted in well-sustained classifications for all communes.

DISCUSSION

Rifkin[14] has reviewed the paradigms associated with community participation and concluded that many disease-control programs were professionally driven and target oriented toward specific health goals (top-down approach), sometimes with community consultation. Another approach involves empowerment (bottom-up) in which people are given the opportunity to take charge of their destinies. Our strategy includes elements of both approaches, but the major reason for success lies at commune level; local leadership by the CMCs guide the collaborators who undoubtedly educate and motivate householders but also service some of their needs.

Although the new community-based dengue-control strategy using *Mesocyclops* undoubtedly has achieved professionally set health goals of *Ae. aegypti* eradication in the north, it is more difficult to claim a reduction or cessation in morbidity because of the epidemic nature of dengue there.[11] However, no vector implies no dengue. In contrast, the central province of Khanh Hoa has a high incidence of dengue, but cases were absent from CPC (Ninh Xuan) from 2002 to 2004 and 2006, when dengue occurred in the control commune as well as the district and province. The fact that 75 suspected cases were recorded in Ninh Xuan during 2005 and 2007 suggests that a larval density index of 0.3–1.51 per household is not sufficient to prevent transmission, although these cases were not serologically confirmed and travel histories were not investigated.

Although true negative-control communes were unavailable in Nam Dinh, our measures of program efficacy relied on comparison of sustainability criteria for Xuan Phong (the original project commune) and a local expansion commune (Tho Nghiep) against a background where some dengue-relevant activities were being carried out. There is a substantial body of evidence, both quantitative and qualitative, which indicates that 7 years after project cessation this strategy is well-institutionalized in these northern communes. This suggests the third stage of sustainability or niche saturation.[15] Activity continued 4.5 years after project cessation in central Ninh Xuan, albeit operating at a reduced level compared with that for 2003; however, it is at a considerably higher level than at the untreated control, Ninh Binh. As in Thailand,[16] our study showed the direct linkage between the frequency of collaborator visitation and knowledge of dengue prevention and practice.

Among the overall 13 criteria used in this study to assess sustainability, the first nine were measured both quantitatively and qualitatively; the remaining four, categorized as long-term capacity building in the recipient communities, were evaluated using a qualitative approach. The latter could have been done quantitatively by examining human-resource records and budgets. All three communes were rated as well-sustained.

The criteria received equal weighting in our evaluation, because all offer the opportunity to assess level of sustainability. This is different from analysis of underlying factors, which may pre-dispose motivation (or otherwise) where one factor, for example, may be sufficient to cause mobilization. In the north, several informants recalled the great suffering in the 1990s outbreaks and the effect of severe dengue disease on both health and the economy, whereas at Ninh Xuan, collaborators gained prestige and affection from the community for their activities, which was illustrated by 91% support in the KAP survey. This was the major motivational reason.

> *"I am really proud of being a collaborator. I have prestige in the community so it is easy for me to conduct any activities. Such a great pride. Why they follow and listen to us, not anyone else? … The children in my village call me "Mr. Meso," I am so glad to hear that …" (Focus Group Discussant 1, ID 9, male, collaborator).*

At Ninh Xuan, there was also a perception of disease resurgence. Collaborators fitted their duties with dengue control into other responsibilities on nutrition, immunization, and family planning, and this was considered easy. Undoubtedly, the creation of local microcredit schemes toward the end of the original projects in 2000 and 2003 were important catalysts for sustained activities at Xuan Phong and Ninh Xuan. However, the stipend paid from local investment, although helpful to the family incomes of collaborators, was not the motivation for doing these tasks. In Tho Nghiep, when the communal budget was cut in 2006, collaborator activities continued. In Xuan Phong, during the project implementation phase (1998–2000), each collaborator was responsible for monthly inspections of about 100 houses, delivery of health-education messages, and reporting of any suspected dengue cases to the communal health center. They also assisted with periodic clean-up campaigns and the distribution of *Mesocyclops*, and they were paid VND 25,000 per month, which was equivalent to 3.83 international dollars.

> *"This monthly allowance was sufficient to encourage collaborators to continue implementing their tasks" (informant 5, male, 56 years old).*
>
> *"However, they were enthusiastic in their community work and performed well, because they took on this job not for money, but for the sake of community health" (informant 11, male, 55 years old).*

In view of its broad adoption by Xuan Phong and Tho Nghiep residents (and reportedly, the entire district of Xuan Truong), this suggests that the strategy should be rolled out more fully into the NDCP communes. However, our findings indicate that more technical instruction is needed for these latter communes, particularly on *Mesocyclops* use, quantitative entomological surveys, and container habitats of *Ae. aegypti*; however, the combination of predacious fish and copepods as an intervention tool (e.g., at Lien Minh) is having some degree of success. For our central province intervention communes,[4] an average prevalence of 71% *Mesocyclops* in large containers, mainly tanks and jars, was sufficient to eliminate *Ae. aegypti*, but we cannot estimate the effect of environmental sanitation or increased community knowledge on the effectiveness of these multi-faceted interventions. However, from a public health perspective, there is little point in inoculating

Mesocyclops into large water-storage vessels without these complementary activities.

At the three communes, the annual costs of maintaining this community-based strategy ranged from 0.28 to 0.89 international dollars per head to protect each person from dengue infection. This would seem to be a prudent investment for Vietnam, because the average direct and indirect cost of treating one child with dengue hemorrhagic fever in Ho Chi Minh City was reported as $61 U.S. (approximately VND 915,000[17] or 140 international dollars).

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Authors' addresses: Brian H. Kay and Peter A. Ryan, Australian Centre for International and Tropical Health, Queensland Institute of Medical Research, Royal Brisbane Hospital, Brisbane, Queensland, Australia, E-mail: brian.kay@qimr.edu.au. Tran T. Tuyet Hanh, Hanoi School of Public Health, Ba Dinh, Hanoi, Vietnam. Nguyen Hoang Le and Nguyen Thi Yen, National Institute of Hygiene and Epidemiology, Hai Ba Trung, Hanoi, Vietnam. Tran Minh Quy, Institute of Malariology, Parasitology and Entomology, Quy Nhon, Vietnam. Vu Sinh Nam, Administration of Preventive Medicine and Environmental Health, Ministry of Health, Hanoi, Vietnam. Phan V. D. Hang, 10 Alley, 186 Doican St., Ba Dinh District, Hanoi, Vietnam. Peter S. Hill and Theo Vos, School of Population Health, University of Queensland, Herston, Queensland, Australia.

Reprint requests: Brian Kay, Queensland Institute of Medical Research, Royal Brisbane Hospital, Brisbane, Queensland 4029, Australia, E-mail: brian.kay@qimr.edu.au.

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