IMPACT OF EDUCATION ON KNOWLEDGE, AGRICULTURAL PRACTICES, AND COMMUNITY ACTIONS FOR MOSQUITO CONTROL AND MOSQUITO-BORNE DISEASE PREVENTION IN RICE ECOSYSTEMS IN SRI LANKA

JUNKO YASUOKA,* THOMAS W. MANGIONE, ANDREW SPIELMAN, AND RICHARD LEVINS
Department of Population and International Health, Department of Biostatistics, and Department of Immunology and Infectious Diseases, Harvard School of Public Health, Boston, Massachusetts

Abstract. Mosquito-borne diseases are a major public health threat in Sri Lanka. A 20-week pilot education program to improve community knowledge and mosquito control with participatory and non-chemical approaches was developed, implemented, and evaluated using pre-educational and post-educational surveys in two intervention and two comparison villages. Correlates of baseline knowledge were sex, number of family members, ratio of family members with malaria history, school education level, and availability of electricity at the residence. Participation in the educational program led to improved knowledge of mosquito ecology and disease epidemiology, changes in agricultural practices, and an increase in environmentally sound measures for mosquito control and disease prevention. The variety of actions at the post-educational stage were determined by improved knowledge, but not by sociodemographic characteristics. Such community-based educational interventions are effective in increasing understanding and active involvement in mosquito control and disease prevention in rice ecosystems regardless of sociodemographic characteristics.

INTRODUCTION
Mosquito-borne diseases, including malaria, dengue, Japanese encephalitis, and filariasis, are major public health problems in Sri Lanka.1 Despite mosquito control efforts since 1945, malaria has been unstable and characterized by periodic epidemics with large spatial and temporal differences in transmission dynamics.2,3 During the 1990s, the national case load fluctuated from 150,000 to 400,000 cases per year (Antimalaria Campaign of Sri Lanka, unpublished data), and the foci of the disease shifted spatially from year to year.4

Several studies have described health and economic impacts of malaria in Sri Lanka. A study in the northern dry zone assessed the opportunity cost of labor days lost due to malaria for a year from 1994 to 1995 and found that the economically active age group (14–60 years of age) lost 1.8% of working days and that the loss was concentrated in agricultural seasons. The annual economic loss per household was US$15.56 for malaria, which was approximately one-fourth of total economic loss for all diseases. Children were found to have lost 10% of school days during high transmission seasons.5 Another study in a southern dry zone reported that repeated attacks of malaria had an adverse impact on the school performance of children 6–14 years of age.6

The main reasons mosquito and disease control efforts have not been successful in Sri Lanka include continued dependency on chemical spraying; the lack of intersectoral cooperation, which makes environmental and engineering-based interventions difficult; and the lack of environmentally sound mosquito control activities with community participation.7,8 Even after Sri Lanka experienced sharp increases in malaria incidence due to drastic ecologic changes caused by massive deforestation for irrigated rice cultivation in the 1980s,9 the country’s malaria control efforts stayed narrowly focused and have relied heavily on governmental interventions. In addition, civil unrest temporarily ceased malaria control operations and contributed to the resurgence of malaria.10 Interest in formulating a non-chemical approach has grown during the last three decades because of the limitations of chemical use, including insecticide resistance of mosquitoes, health risks for human and domestic animals, and the disturbance of the natural balance such as predator-prey relationships. In addition, the high cost of chemicals and the necessity of repetitive interventions have made it more difficult to sustain the insecticide-based control methods, especially in resource-poor regions.11 These limitations and previous failures of chemical use, together with the lack of sustainability of top-down mosquito and disease control projects and a heavy reliance on unstable foreign aid, have raised an awareness of the importance of community-based approaches that require no external funding and put no financial burden on the community.

In other countries, community perceptions regarding causation, transmission, prevention, and treatment have been found to be the main sociocultural factors that influence disease control.12,13 To plan and conduct effective interventions, it is crucial to increase the accuracy of community knowledge about vector ecology and disease epidemiology and the extent of mosquito control and disease prevention measures taken by residents. However, few studies have been carried out in Sri Lanka regarding community knowledge and perceptions of mosquito-borne diseases. One study interviewed a newly resettled population that experienced a malaria epidemic caused by the development of an agricultural system and homesteads to assess the coping-strategies and the cost implications,14 while another study in the northern dry zone reported household responses to malaria and their costs.15 Although community knowledge of malaria has been said to be better in Sri Lanka than in most other countries,7 whether this knowledge has been used to take actions for disease prevention is not known. No systematic studies have been carried out to evaluate community knowledge and actions for mosquito control and mosquito-borne disease prevention in Sri Lanka.

This study evaluated the effectiveness of a community-based education program with participatory and non-chemical approaches and measured its initial impact on knowledge, agricultural practices, and community actions for
mosquito control and mosquito-borne disease prevention. Data obtained from two surveys before and after the intervention in both the intervention and comparison villages were compared to identify any changes caused by the education program. The factors assessed for change included correlates of knowledge of mosquito ecology and mosquito-borne disease epidemiology and of actions that villagers took for mosquito control and disease prevention. Potential confounders such as villagers’ living environment, economic status, or educational backgrounds were examined to ensure that differences in knowledge levels and observed actions taken were valid. Based on the results of the above analyses, the importance of and strategies for future community education will be discussed.

MATERIALS AND METHODS

Study sites. Two villages in Sri Lanka were selected as intervention villages for the educational intervention: Pahala Talawa (8.28°N, 80.31°E) in the Anuradhapura district in the north and Kiri Ibbanwewa (6.37°N, 80.95°E) in Uda Walawe in the south. Both villages are in the dry zone, where precipitation is less than 2,000 mm per year. These regions are mainly rice ecosystems and had the highest incidence of malaria in the country (average annual number of microscopically confirmed malaria cases in both areas exceeded 40 per 1,000 persons from 1989 to 1994).

One comparison village was selected for each intervention village. The comparison villages were chosen based on similarity in terms of geographic conditions (e.g., land use, vegetation, land area, and elevation), climatic conditions (e.g., precipitation and temperature), malaria incidence and seasonal pattern, population structure, and economic status. Furthermore, the absence of communication among residents between the intervention and comparison village was considered. It was determined that Kumbukgahawewa and Habaraluwewa were the best comparison villages for Pahala Talawa and the Kiri Ibbanwewa, respectively. The success of the ecological match between the intervention and comparison villages was demonstrated by an entomological survey, which was conducted in Kiri Ibbanwewa and Habaraluwewa for 1.5 years between October 1, 2002 and March 31, 2004. Species composition and the number of occurrence of each aquatic insect species and mosquito species were highly correlated between major habitat types in the two villages. Each comparison village was 1.5 km and 4 km apart from its respective intervention village.

Educational intervention. A curriculum for a 20-week pilot education program, mainly targeting rice farmers, was developed and implemented in the two intervention villages, Pahala Talawa (from October 14, 2003 to March 4, 2004) and Kiri Ibbanwewa (from October 16, 2003 to February 2, 2004) by the joint effort of the lead author, agriculture experts of the Mahaweli Authority of Sri Lanka and regional officers of the Anti-Malaria Campaign. The major characteristics of the curriculum were 1) it incorporated environmentally sound methods for mosquito control that required no expense; 2) it mainly consisted of participatory exercises in the field, not indoor lectures; 3) educational components, except mosquito control and disease prevention, were based on the Integrated Pest Management approach and its Farmer Field School; and 4) no monetary incentives were given to participants to attend the program. In each village, 75 households were randomly selected, and a household chief, his spouse, or a family member of each household whose age was ≥ 18 years participated in the program. Participants were divided into groups of 25 and attended weekly four-hour meetings in the field. As facilitators of the program, three field officers of the Mahaweli Authority of Sri Lanka were selected in each northern and southern intervention village based on their previous achievements in coordinating agricultural practices in the regions and experiences in facilitating educational meetings for farmers. The program focused on participatory exercises such as identifying mosquito breeding sites in their villages, studying mosquito life cycle by raising mosquito larvae at home, identifying mosquito genera at both larval and adult stages, observing mosquito predators in rice ecosystems, ecosystem analysis in and around paddy fields, a role play regarding mosquito-borne disease transmission, and practicing mosquito control methods both at residences and in the field.

Baseline data collection. Baseline data were collected from October 14 to 17, 2003 through household interviews with 75 residents in each of the intervention and comparison villages. In the intervention villages, prospective participants in the educational intervention participated in the survey. In each comparison village, 75 households were randomly selected, and a household chief, his spouse, or a member of the household who was ≥ 18 years of age participated in the survey. The objective of the survey was to obtain baseline data regarding villagers: 1) agricultural practices; 2) basic information about family members, including mosquito-borne disease history; 3) information on the living environment and housing conditions; 4) knowledge about mosquito ecology and mosquito-borne disease epidemiology; and 5) recent actions taken for mosquito control and mosquito-borne disease prevention.

The survey was developed in English by the lead author and translated into Sinhalese by two local agriculture experts. It was piloted by three villagers in Pahala Talawa in January 2003 to determine if all items were understandable, if there were appropriate answers for each question, and to discover how comfortable villagers felt taking the survey. In each north and south region, approximately 20 surveyors from the local government and university were hired and trained to conduct the survey.

Evaluation: follow-up survey. The follow-up survey was conducted in the four villages between February 16 and March 10, 2004. A total of 142 villagers in the intervention villages and 143 villagers in the comparison villages participated in the whole process of the study from baseline to follow-up. Fifteen villagers (eight from the intervention villages and seven from the comparison villages) were lost to follow-up after participating in the baseline survey mainly because they moved and were excluded from analyses that dealt with knowledge and/or actions at follow-up. Knowledge of mosquito ecology and mosquito-borne disease epidemiology were assessed in the follow-up survey, using the same questions as the baseline survey. Actions for mosquito control and mosquito-borne disease prevention were also measured to detect changes caused by the educational intervention. In addition, questions regarding changes in agricultural practices that were made since the baseline survey were asked retrospectively to rice farmers.

After conducting the follow-up survey, the trained survey-
ors observed water storage containers and coconut shells discarded as garbage inside residences and in the respondents’ yards as to whether each container and coconut shell was protected from mosquito oviposition. In addition, the presence or absence of mosquito larvae was recorded by the surveyors as objective measures of the impact of education on villagers’ mosquito control actions and their effectiveness. This monitoring was compared with the survey based self-report to test whether the changes in knowledge and actions reported by respondents were consistent with the actual condition of the residence. Through these analyses, the link between knowledge, actions, and respondents’ effectiveness in keeping their residences free of mosquito breeding risk were examined.

**Measures.** Two additive knowledge indices and an action index were developed to quantify respondents’ knowledge of mosquito ecology and disease epidemiology and the variety of actions they took for mosquito control and mosquito-borne disease prevention (Table 1). The mosquito ecology knowledge index was developed based on respondents’ answers to questions regarding mosquito food, life stage, development time, breeding sites, and natural enemies of mosquito larvae. Correct answers for questions about mosquito food, life stage, and development time were given one point, respectively. Scores for breeding sites and natural enemies were given according to the number of correct sites or species respondents named (none = 0, ≤ median = 1, > median = 2). These scores (from 0 to 7) were added up to create the index, and the logic of combining these items was confirmed by a high Cronbach’s alpha reliability score (0.89). 17

The mosquito-borne disease epidemiology knowledge index was developed based on answers regarding names, symptoms, and transmission routes of malaria, Japanese encephalitis, dengue, and filariasis, and the names and morphologic characteristics of mosquito genera that transmit each disease. Each correct answer was given one point up to a maximum of four points. The total points across the five items became the index score, ranging from 0 to 20 points. The logic of combining these items was confirmed by a high Cronbach’s alpha reliability score (0.87).

The action index was created based on the variety of mosquito control and mosquito-borne disease preventive measures that villagers took during the previous cultivation season with one point scored for each action taken. Scores ranged from 0 to 9.

**Statistical analysis.** All survey data were coded by the lead author, entered by a research assistant, and then double-checked by the lead author to ensure accuracy. Ten sociodemographic characteristics of the study population were assessed as potential confounders of the relationships between the respondent’s participation in the education program and his or her knowledge and actions. Potential confounders included age, final education grade, the number of family members, ratio of family members with and without malaria history, sex, occupation, malaria history of the respondent, whether the respondent’s family received a government subsidy for low-income households, availability of electricity at the residence, and materials of residence walls. Each characteristic was compared between the intervention and comparison villages, using two-sample t-tests for continuous variables and chi-square tests for categorical variables, to search for potential confounders. Any characteristic that was significantly different between the two intervention versus the two comparison villages was considered a potential confounder.

The impact of education on knowledge and actions for mosquito control and mosquito-borne disease prevention was analyzed using a one-tailed paired t-test that compared each index at baseline and follow-up for both the two intervention villages combined and the two comparison villages combined. In addition, indices at follow-up were analyzed with multiple linear regression by participation status in the education program, controlling for each index score at baseline and any potential confounders.

Changes in the variety of actions to reduce mosquito density or prevent mosquito-borne diseases were compared between the intervention and comparison villages. Multiple logistic regression was used to obtain the odds of taking each action at follow-up, controlling for the potential confounder and whether the action was taken at baseline.

Additional variables were available at follow-up when rice farmers retrospectively reported changes in their agricultural practices, which were likely to reduce mosquito density. Changes in agricultural practices were analyzed, using chi-square tests that compared the intervention and comparison villages. Multiple logistic regression was used to examine the impact of education on herbicide and pesticide use. The odds of using no chemicals or decreasing the amount of chemicals were calculated by participation status, controlling for potential confounders and the status of chemical use.

In addition to self-report data, observational data were obtained by monitoring the condition of coconut shells at residences at follow-up to examine the correlation between knowledge, self-reported actions and mosquito breeding at residences. Condition of discarded coconut shells and the presence of larvae in them in the backyards of villagers’ residences at follow-up were compared between the intervention and comparison villages using multiple logistic regression controlling for the potential confounder.

Finally, a series of analyses were conducted that illustrated a more comprehensive model of correlates of baseline and follow-up indices. These analyses added all 10 sociodemographic characteristics to the initial multiple linear regression models as well as all baseline measures for these analyses that focused on follow-up measures.

Data analysis was done using STATA version 8.2 (State Corporation, College Station, TX). Informed consent was obtained from all participants. The project protocol, consent forms, and survey questionnaires were reviewed and approved by the Human Subjects Committee at the Harvard School of Public Health (protocol no. 0211RICE).

**RESULTS**

**Participation rates.** Attendance at weekly participatory exercises was relatively high with two-thirds of the villagers in the education program attending two-thirds or more of the lessons. Additionally, make-up sessions (somewhat curtailed) were held later in the evenings for villagers who missed the day time exercises. Participation in the pre-educational and post-educational surveys was extremely high in both the intervention villages (only 8 of 150 lost to follow-up) and in the comparison villages (only 7 of 150 lost to follow-up).

**Sociodemographic characteristics of the study population.** A total of 285 villagers from four villages participated in both
One-tailed t-test
‡
arity regression by participation status in the education program, controll
The in-

The variety of actions taken for mosquito control (the availability of electricity

value comparing the intervention and comparison villages at follow-up on
Knowledge and action indices at follow-up were analyzed with multiple line
< 0.001), but not

< 0.0001), but with a much greater change in the intervention
Multiple linear regression controlling for baseline knowledge and actions and the potential confounder, showed that participation in the educational intervention still produced significantly higher levels of knowledge about mosquito ecology ($\beta = 4.218, P < 0.001$).

Impact of the education program on knowledge and actions. Changes in knowledge of mosquito ecology. The index of knowledge about mosquito ecology significantly increased in the intervention villages (from 1.697 to 5.958; $P < 0.0001$), but not in the comparison villages (from 1.832 to 1.727; $P = 0.843$) (Table 1). Multiple linear regression, controlling for age, final education grade, the number of family members, ratio of family members with and without a malaria history, sex, occupation, malaria history of the respondent, whether the respondent’s family received a government subsidy for low-income households, and materials of residence walls, was statistically the same between the intervention and comparison villages. However, significantly fewer villagers had electricity at their residences in the intervention villages than in the comparison villages ($P = 0.001$). Thus, availability of electricity was considered as a potential confounder and was controlled for in analyses that involved comparisons between the intervention and comparison villages.

Impact of the education program on knowledge and actions. Changes in knowledge of disease epidemiology. The increase in knowledge of disease epidemiology was significant both in the intervention villages (from 5.482 to 13.284; $P < 0.0001$) and comparison villages (from 4.711 to 5.775; $P = 0.0001$), but with a much greater change in the intervention villages. Multiple linear regression controlling for baseline knowledge and actions as well as the potential confounder showed that the participation in the educational intervention still produced significantly higher levels of knowledge about disease epidemiology ($\beta = 7.314, P < 0.001$).

Changes in the variety of actions for mosquito control and disease prevention. The variety of actions taken for mosquito control and disease prevention increased significantly in the intervention villages (from 2.028 to 3.641; $P < 0.0001$), but not in the comparison villages (from 2.406 to 2.392; $P = 0.537$). Participants in the educational intervention reported taking a significantly higher variety of actions for mosquito control and disease prevention ($\beta = 1.150, P < 0.001$).

A breakdown of these actions shows that the intervention villages increased in absolute percentages for the following actions: bed net use (59.2%), eliminating breeding sites (49.3%), applying oil or salt or fish to water bodies (23.9%), cleaning up surroundings (22.5%), and smoking and burning plants or trash (21.8%) (Table 3). Reductions in absolute percentages were seen for clearing jungle and removing shady places (-2.1%), residential insecticide spraying (-2.8%), and mosquito coil use (-9.9%). Results from the multiple logistic regression indicate that there were substantially higher probabilities of several actions being taken among respondents in the intervention villages than among respondents in the comparison villages. Controlling for actions at baseline and the potential confounder, bed net use was 4.1 times more likely among respondents in the intervention villages than those in the comparison villages (odds ratio [OR] = 4.08, 95% confidence interval [CI] = 2.13, 7.84). Likewise, elimination of breeding sites (OR = 11.1, 95% CI = 5.85, 21.08), applying oil or salt or fish into water bodies (OR = 39.54, 95% CI = 5.30, 294.81), cleaning up surroundings (OR = 4.01, 95%
CI = 2.40, 6.69), and smoking and burning plants or trash (OR = 2.01, 95% CI = 1.23, 3.31) were more likely to be carried out in the intervention villages. Furthermore, insecticide spraying was more likely to be done in the comparison villages than in the intervention villages (OR = 0.36, 95% CI = 0.19, 0.68). Removing shady places and mosquito coil use were not significant in this analysis.

**Conditions of coconut shells at residences.** Table 4 shows the results of the monitoring of coconut shells at the residences, which was conducted at the follow-up survey. The odds of households protecting coconut shells from rain water were much higher in the intervention villages than in the comparison villages (OR = 19.16, 95% CI = 7.16, 51.27). Mosquito larvae were found in coconut shells in five residences in the comparison villages (5 of 143 residences, house index = 3.5%), but in none in the intervention villages (P = 0.027).

**Changes in agricultural practices and chemical use among rice farmers.** A total of 118 respondents’ families in the intervention villages and 124 respondents’ families in the comparison villages cultivated rice from October 2003 to March 2004 when the educational intervention was carried out in the intervention villages (Table 5). Questions regarding their agricultural practices during that time period were asked at the follow-up survey retrospectively. In the comparison villages, most of rice farmers did not change their agricultural practices (92.7%), whereas most of the families in the intervention villages made one or more agricultural changes to control

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Selected sociodemographic characteristics of the study population in the intervention and comparison villages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention (n = 142)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Age, years</td>
<td>44.3</td>
</tr>
<tr>
<td>Education (final grade)</td>
<td>7.8</td>
</tr>
<tr>
<td>No. of family members</td>
<td>4.2</td>
</tr>
<tr>
<td>Malaria ratio in family</td>
<td>0.3</td>
</tr>
<tr>
<td>Sex</td>
<td>56</td>
</tr>
<tr>
<td>Male</td>
<td>86</td>
</tr>
<tr>
<td>Female</td>
<td>94</td>
</tr>
<tr>
<td>Occupation</td>
<td>48</td>
</tr>
<tr>
<td>Rice farmer</td>
<td>66</td>
</tr>
<tr>
<td>Other plus none</td>
<td>75</td>
</tr>
<tr>
<td>Malaria history</td>
<td>30</td>
</tr>
<tr>
<td>Yes</td>
<td>105</td>
</tr>
<tr>
<td>No</td>
<td>87</td>
</tr>
<tr>
<td>Economic status (Receive government subsidy)</td>
<td>55</td>
</tr>
<tr>
<td>Yes</td>
<td>123</td>
</tr>
<tr>
<td>No</td>
<td>19</td>
</tr>
<tr>
<td>Material of walls</td>
<td>4.9</td>
</tr>
<tr>
<td>Plaster and/or brick</td>
<td>33.1</td>
</tr>
<tr>
<td>Mud and/or cadjan</td>
<td>31.3</td>
</tr>
</tbody>
</table>

* Odds ratio (OR) controlling for each action at baseline and a potential confounder (the availability of electricity at home); CI = confidence interval.
† By chi-square test.

**Table 3** | Impact of the educational intervention on each individual type of action for mosquito control and mosquito-borne disease prevention |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Village</td>
<td>Baseline %</td>
<td>Follow-up %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed net use</td>
<td>Intervention (n = 142)</td>
<td>29.6</td>
<td>88.7</td>
</tr>
<tr>
<td></td>
<td>Comparison (n = 143)</td>
<td>40.6</td>
<td>67.8</td>
</tr>
<tr>
<td>Eliminate breeding sites</td>
<td>Intervention (n = 142)</td>
<td>38.7</td>
<td>88.0</td>
</tr>
<tr>
<td></td>
<td>Comparison (n = 143)</td>
<td>59.4</td>
<td>42.7</td>
</tr>
<tr>
<td>Clean surroundings</td>
<td>Intervention (n = 142)</td>
<td>0.7</td>
<td>24.7</td>
</tr>
<tr>
<td></td>
<td>Comparison (n = 143)</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Smoke/burn plants or trash</td>
<td>Intervention (n = 142)</td>
<td>25.4</td>
<td>47.2</td>
</tr>
<tr>
<td></td>
<td>Comparison (n = 143)</td>
<td>28.0</td>
<td>30.1</td>
</tr>
<tr>
<td>Insecticide spraying</td>
<td>Intervention (n = 142)</td>
<td>15.5</td>
<td>12.7</td>
</tr>
<tr>
<td></td>
<td>Comparison (n = 143)</td>
<td>21.7</td>
<td>28.0</td>
</tr>
<tr>
<td>Mosquito coil use</td>
<td>Intervention (n = 142)</td>
<td>33.1</td>
<td>23.2</td>
</tr>
</tbody>
</table>

* Odds ratio (OR) controlling for each action at baseline and a potential confounder (the availability of electricity at home); CI = confidence interval.
mosquitoes (94.1%). The difference in the number of changes in agricultural practices between the intervention and comparison villages was significant ($P < 0.001$ by chi-square test). The three major practices reported as new actions by respondents in the intervention villages were land leveling (78.8%), cleaning of irrigation canals (39.0%), and draining of paddies (24.6%).

All or most of rice farmers used herbicides in both the intervention (100.0%) and comparison villages (97.6%). The odds of rice farmers decreasing herbicides were 2.1 times higher in the intervention villages although this was of borderline significance ($OR = 2.08, 95\% CI = 0.98, 4.43$). The odds of rice farmers using no pesticides were 3.9 times higher in the intervention villages than in the comparison villages ($OR = 3.88, 95\% CI = 2.21, 6.83$). The odds of rice farmers decreasing or not using pesticide were 5.6 times higher in the intervention villages than in the comparison villages ($OR = 5.61, 95\% CI = 3.01, 10.46$).

### Table 4
Condition of discarded coconut shells and the presence of larvae in them in the backyard of villagers’ residences at follow-up

<table>
<thead>
<tr>
<th>Household Practices</th>
<th>Intervention (n = 142)</th>
<th>Comparison (n = 143)</th>
<th>Multiple logistic regression* OR and chi-square test $P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>coconut shells from rain water</td>
<td>96.5</td>
<td>61.5</td>
<td>$OR = 19.155 (7.156–51.271)$; $P &lt; 0.001$</td>
</tr>
<tr>
<td>Covered on the ground</td>
<td>47.9</td>
<td>32.9</td>
<td>$-\dagger$</td>
</tr>
<tr>
<td>Covered with cloth/sheet or collected in a bag</td>
<td>63.4</td>
<td>25.9</td>
<td>$-\dagger$</td>
</tr>
<tr>
<td>Burned</td>
<td>9.2</td>
<td>8.4</td>
<td>$-\dagger$</td>
</tr>
<tr>
<td>Sold</td>
<td>4.9</td>
<td>0.0</td>
<td>$-\dagger$</td>
</tr>
<tr>
<td>Presence of mosquito larvae (House index‡)</td>
<td>0.0</td>
<td>3.5§</td>
<td>$P = 0.027$</td>
</tr>
</tbody>
</table>

* Multiple logistic regression controlling for a potential confounder (availability of electricity). Value in parentheses is 95% confidence interval.
† Not performed.
‡ Percentage of inspected premises found to contain larvae.
§ Two households in the north and three households in the south.

### Table 5
Changes in chemical use among rice farmers due to the educational intervention

<table>
<thead>
<tr>
<th>Agricultural practice</th>
<th>Intervention villages (n = 118*)</th>
<th>Comparison villages (n = 124*)</th>
<th>Overall statistics†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of changes</td>
<td></td>
<td></td>
<td>Chi-square test $P$</td>
</tr>
<tr>
<td>0</td>
<td>5.9</td>
<td>92.7</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>1</td>
<td>50.8</td>
<td>5.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>2</td>
<td>38.1</td>
<td>1.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>3</td>
<td>5.1</td>
<td>0.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Kinds of practices</td>
<td></td>
<td></td>
<td>Multiple logistic regression OR and chi-square test $P$</td>
</tr>
<tr>
<td>Land leveling</td>
<td>78.8</td>
<td>4.8</td>
<td>$OR = 2.082 (0.978–4.434)$‡</td>
</tr>
<tr>
<td>Canal cleaning</td>
<td>39.0</td>
<td>3.2</td>
<td>$OR = 3.882 (2.208–6.827)$¶</td>
</tr>
<tr>
<td>Drainage</td>
<td>24.6</td>
<td>0.8</td>
<td>$OR = 5.614 (3.014–10.459)$§</td>
</tr>
</tbody>
</table>

Herbicide use

<table>
<thead>
<tr>
<th>Use</th>
<th>Intervention villages (n = 118*)</th>
<th>Comparison villages (n = 124*)</th>
<th>Overall statistics†</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>0.0</td>
<td>2.4</td>
<td>$P = 0.0891\dagger$</td>
</tr>
<tr>
<td>Yes/do not know</td>
<td>100.0</td>
<td>97.6</td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td></td>
<td></td>
<td>Multiple logistic regression OR</td>
</tr>
<tr>
<td>Decreased/no use</td>
<td>18.6</td>
<td>10.5</td>
<td>$OR = 3.882 (2.208–6.827)$¶</td>
</tr>
<tr>
<td>Increased/same/do not know</td>
<td>81.4</td>
<td>89.5</td>
<td>$P = 0.057$</td>
</tr>
</tbody>
</table>

Pesticide use

<table>
<thead>
<tr>
<th>Use</th>
<th>Intervention villages (n = 118*)</th>
<th>Comparison villages (n = 124*)</th>
<th>Overall statistics†</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>71.2</td>
<td>41.2</td>
<td>$OR = 3.882 (2.208–6.827)$¶</td>
</tr>
<tr>
<td>Yes/do not know</td>
<td>28.8</td>
<td>58.8</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td>Amount</td>
<td></td>
<td></td>
<td>Multiple logistic regression OR</td>
</tr>
<tr>
<td>Decreased/no use</td>
<td>82.2</td>
<td>48.5</td>
<td>$OR = 5.614 (3.014–10.459)$§</td>
</tr>
<tr>
<td>Increased/same/do not know</td>
<td>17.8</td>
<td>51.5</td>
<td>$P &lt; 0.001$</td>
</tr>
</tbody>
</table>

Reason for changes in chemical use

<table>
<thead>
<tr>
<th>Reason for changes</th>
<th>Intervention villages (n = 118*)</th>
<th>Comparison villages (n = 124*)</th>
<th>Overall statistics†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased/did not increase for predator conservation, mosquito control, or better environment and health</td>
<td>20.3</td>
<td>0.8</td>
<td>$OR = 31.404 (4.892–1301.424)$§</td>
</tr>
<tr>
<td>Other reasons(do not know)</td>
<td>79.7</td>
<td>99.2</td>
<td>$P &lt; 0.0001$</td>
</tr>
</tbody>
</table>
The reasons for changing the amount of chemicals used were classified into four categories based on respondents’ answers: decreased or maintained use to conserve natural enemies that control mosquitoes and pests or for better environment and health, decreased or maintained use due to less weed and pest problems, decreased due to cost only, and increased due to pest problems. Rice farmers in the intervention villages were 3.14 times more likely to mention decreasing or not increasing the amount of chemicals for mosquito control and environmental and health concerns than those in the comparison villages (OR = 31.40, 95% CI = 4.89, 1,301.42).

**Statistical model of determinants of knowledge and actions.** The results of several multiple linear regression analyses (backward elimination) regarding determinants of knowledge at baseline and at follow-up and actions at follow-up in all four villages were integrated and are shown in Figure 1. This overall representation of a model was created to clarify the role each sociodemographic and knowledge factor played in determining future knowledge and actions. Of the 10 sociodemographic characteristics modeled, two were significantly associated with baseline knowledge of mosquito ecology (final education grade \( \beta = 0.104, P < 0.001 \) and availability of electricity at the residence \( \beta = 0.355, P = 0.0173 \)), and four were significantly associated with baseline knowledge of disease epidemiology (sex \( \beta = -0.604, P = 0.045 \), number of family members \( \beta = 0.207, P = 0.041 \), ratio of family members with malaria history \( \beta = 1.052, P = 0.030 \), and final education grade \( \beta = 0.358, P < 0.001 \)). As a result, more school education was associated with higher levels of knowledge about both mosquito ecology and disease epidemiology. The availability of electricity was positively related to knowledge of mosquito ecology. Females and villagers with more family members and a higher ratio of family members with malaria history were also found to be more knowledgeable about disease epidemiology.

The final stage of the model focusing on actions at follow-up showed that significant determinants included knowledge of disease epidemiology at baseline \( \beta = 0.061, P = 0.014 \), actions at baseline \( \beta = 0.120, P = 0.019 \), knowledge of mosquito ecology at follow-up \( \beta = 0.120, P = 0.015 \), and knowledge of disease epidemiology at follow-up \( \beta = 0.072, P = 0.004 \), but none of the sociodemographic characteristics. Regardless of the differences in sociodemographic characteristics, those villagers who obtained higher levels of knowledge took a greater variety of actions to control mosquitoes and prevent diseases.

**DISCUSSION**

Two of the most important findings from this study were that the pilot community-based educational intervention kept high participation rates, and it had a significant positive impact on the knowledge and varieties of actions farmers took for mosquito control and mosquito-borne disease prevention. The educational program induced participants to gain substantial knowledge of mosquito ecology and disease epidemiology and to protect themselves against mosquito-borne infections by using environmentally sound measures for controlling mosquitoes and avoiding contact with mosquitoes. The success of the intervention could be attributed to four major characteristics of the education program: a community-based education that enhanced residents’ understanding of the mosquito-borne disease problems in their own community, a participatory approach that allowed participants to gain hands-on experiences with actions to be taken, using non-chemical measures that decreased environmental and health risks in residential areas and paddy fields, and an approach that required no cost or expensive instruments, all of which facilitated sustainability of participants’ activities.

Human action depends on decisions that balance motivating and deterring factors against a background of knowledge of the outcomes. Concern about malaria was a stronger motivation for those families that had more direct experience with the disease. High cost in labor or materials would act as a deterrent as would the discomfort caused by removing shade around the home. The intervention program made the knowledge of the relation between mosquitoes and mosquito-borne diseases stronger and offered low cost-interventions that did not increase and might even have reduced pest damage to rice crops. Therefore, the intervention helped to tip the balance in favor of action.

Participants in the educational intervention were shown to increase use of environmentally sound methods for mosquito control and disease prevention such as bed net use, breeding site elimination, and environmental cleanup, and decreased other methods that might have a negative influence on the environment, including insecticide spraying, mosquito coil use, and jungle clearing. To prevent mosquito breeding and reduce mosquito density, rice farmers initiated new agricultural practices, including land leveling, canal cleaning and draining, and decreased pesticide use. In addition, environmental awareness among rice farmers increased, especially about predator conservation for mosquito and pest control and ecosystem management through decreased chemical use.

**FIGURE 1.** Summary of determinants of knowledge and actions for mosquito control and disease prevention. Numbers shown are beta coefficients. All beta coefficients shown are significant at the 0.05 level. (1) Adjusted R2 for baseline knowledge of disease epidemiology: 0.219; (2) Adjusted R2 for baseline knowledge of mosquito ecology: 0.111; (3) Adjusted R2 for follow-up knowledge of disease epidemiology: 0.642; (4) Adjusted R2 for follow-up knowledge of mosquito ecology: 0.797; (5) Adjusted R2 for action at follow-up: 0.255.
To our knowledge, this is the first study to assess and report the impact of an ongoing education program on knowledge and actions for mosquito control and disease prevention in detail, and these favorable results should encourage the spread of this type of education program to other rice ecosystems in the world.

A correlation between knowledge, self-reported actions, and mosquito breeding at residences was demonstrated by monitoring the condition of coconut shells after the educational intervention. The community-based approach is considered to have played an important role in creating this link. In the intervention villages, significantly higher percentage of households protected coconut shells from rain water than in the comparison villages, and this led to lower observed mosquito larvae in the backyard of their residences. This correlation link between increased knowledge, more self-reported actions, and the absence of mosquito larvae at residences was not found in a previous study in Trinidad and Tobago, which used similar data collection methods combining a questionnaire and mosquito larval survey. This may be due to the lack of a community-based component in the mosquito control program. In their study sites, a vertically structured national program for mosquito control undertook periodic rounds of household inspections and insecticide application, but no community-based education was used at that time. A similar link, however, was seen in another study from Puerto Rico, which demonstrated that the exposure to an elementary school program, including dengue mosquito control activities at home, was associated with a significantly lower Aedes aegypti Breteau Indices (the mean number of containers found to contain larvae per premise, expressed as a percentage). The result of our monitoring together with the findings from these two previous studies indicate that education programs that are community-based and designed to increase practices for mosquito control and disease prevention could make enough difference in participants’ knowledge and actions to influence the presence and density of mosquito larvae in their living environments.

Statistical analysis regarding the impact of the education program on actual malaria incidence, however, was not feasible due to the limited number of cases. This study was conducted during a time when countrywide malaria incidence was low, and only a few malaria cases were found in the study sites. However, based on all the reported and observed behavior changes, it is reasonable to expect that self-protection from mosquito bites improved tremendously among participants, and thus the educational intervention likely would have a positive impact on mosquito-borne disease prevention.

This study also identified determinants of knowledge and actions for mosquito control and mosquito-borne disease prevention. Before the educational intervention, several sociodemographic characteristics (i.e. sex, the number of family members, the ratio of family members with malaria history, final education grade, and the availability of electricity at residence) were associated with knowledge levels. Women were more knowledgeable about disease epidemiology, probably because they are more likely to be care givers and decision makers for health care in households. Although there was no significant relationship between malaria history of the respondent and knowledge, the absolute number of family members and the ratio of family members that had malaria both had a significant positive impact on knowledge of mosquito-borne diseases. Observation of family members with malaria symptoms and experiences in taking care of them could increase knowledge of disease epidemiology. Level of school education was associated with knowledge of both mosquito ecology and disease epidemiology, whereas economic status, indicated by the government subsidy, was irrelevant to knowledge levels of either. The availability of electricity at home was positively related to knowledge of mosquito ecology, which could be partly explained by the availability of information from television at home and the fact that electric lights attract mosquitoes at night, which may increase villagers’ interest in mosquito ecology and mosquito-avoidance behaviors.

When the variety of actions was measured using the follow-up survey after the educational intervention, knowledge of disease epidemiology at baseline and knowledge of both mosquito ecology and disease epidemiology at follow-up were the only determinants of the changes in actions. Villagers with higher levels of knowledge of disease epidemiology at baseline were more likely to change actions possibly because the educational intervention reinforced their existing knowledge. In addition, villagers who had higher knowledge at the follow-up used their knowledge to take a wider variety of actions. The results also showed no associations between any of the sociodemographic characteristics and follow-up actions, and thus, indicate that anybody, regardless of their personal background, could benefit from the educational intervention. Therefore, there is no particular need to target subgroups of the population for future educational interventions. Only in the most limited resource settings should priority be given to subgroups with certain characteristics identified by our analysis related to lower knowledge, including men, those with fewer number of family members, those with a lower ratio of family members with malaria history, those with lower educational levels, and those without electricity at their residence.

This pilot education program, which promoted environmentally sound mosquito control measures, could be applicable to different regions of the world by making necessary adjustments taking into consideration the local context. If the program were to be conducted in countries with a low literacy rate, unlike Sri Lanka where the literacy rate is high even in rural rice-growing villages (92.1% in 2002), incorporating more materials and activities that do not require good reading skills such as pictures and role plays into the education program would enhance the understanding of the content among participants. Cultural and religious aspects should also be respected in developing region specific curricula, materials, and survey questionnaires as well as in choosing facilitators and interviewers. To incorporate the appropriate type of mosquito control measures into the education program, ecological characteristics of local vector mosquitoes should be carefully investigated. For example, in African countries, where the primary vector of malaria is Anopheles gambiae ss., which thrives in a household environment, the program should include more activities in and around residential areas. In addition, planning the timing of the intervention in relation to cultivation seasons and weather conditions that would influence farmer’s workload and possible outdoor activities should be taken into account. To make the impact of the education program sustainable, efforts should be made to incorporate information into the fabric of the community. For instance,
local schools could be involved in the project during and after the intervention. When this study was conducted, school children joined our education program and participated in skits to emphasize particular lessons for the villagers. Also, some of the activities were incorporated into the local school curriculum because of the interest of its principal. It would be ideal if the one-time intervention messages could be incorporated into a long-term routine educational curriculum in the future.

Educational intervention was effective in deepening accurate knowledge of mosquito ecology and mosquito-borne disease epidemiology and encouraging participants to take the initiative to implement environmentally sound measures to control mosquitoes at least for short periods after the educational intervention. The inferences made from the results observed that the intervention caused changes in knowledge and actions could have been strengthened if there were more data points available before baseline to identify pre-existing trends. Also, to find out how educated villagers could maintain their motivation and actions over a longer run, studies with a longer follow-up period will be important. Comparing the effectiveness of the education program in different cultivation seasons would also be helpful to determine the best timing of the intervention. In addition, follow-up educational programs and regular feedback on the impact of their mosquito control actions, including changes in local mosquito ecology and mosquito-borne disease incidence, could be useful information for villagers to help sustain motivation to continue their actions and to develop new strategies to prevent future outbreaks of mosquito-borne diseases.

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Authors’ addresses: Junko Yasuoka and Richard Levins, Department of Population and International Health, Harvard School of Public Health, 665 Huntington Avenue, Boston, MA 02115; Telephone: 617-432-1484, Fax: 617-566-0365, E-mails: jyasuoka@post.harvard.edu and humanece@hsph.harvard.edu. Thomas W. Mangione, Department of Biostatistics, Harvard School of Public Health, 655 Huntington Avenue, Boston, MA 02115, E-mail: tmangion@hsph.harvard.edu. Andrew Spielman, Department of Immunology and Infectious Diseases, Harvard School of Public Health, 665 Huntington Avenue, Boston, MA 02115, E-mail: aspielma@hsph.harvard.edu.

Reprint requests: Junko Yasuoka, Department of Population and International Health, Harvard School of Public Health, 665 Huntington Avenue, Boston, MA 02115.

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